

**** Per Governor's emergency [Proclamation 20-28](#) et seq., agencies are required to meet completely remotely without providing for a physical location.**

**** Per Section 3 of Anacortes [Resolution 2082](#) Ratifying Proclamation of Emergency and Providing Temporary Procedures to Respond to the COVID-19 Epidemic, adopted by the Anacortes City Council on March 16, 2020, and [Resolution 3025](#), adopted March 22, 2021, extending the duration of Resolution 2082 through June 30, 2021, all in-person Committee meetings of the City Council are cancelled. Council and committee meetings may be held telephonically regardless of whether the City has the capability of video recording meetings.**

- Meetings may be viewed on the [City of Anacortes website](#), on the City of Anacortes [YouTube](#) Channel, or on TV [Channel 10](#).
- The public may also watch, listen to, or participate in the meeting live by visiting <https://us02web.zoom.us/j/89255646791> or by telephoning 1-253-215-8782 and entering Meeting ID 892 5564 6791.
- The public is encouraged to comment via email to cityclerk@cityofanacortes.org or via written comment addressed to City Clerk, P.O. Box 547, Anacortes, WA 98221. Public comments received by the [City Clerk](#) prior to 3:00 p.m. the day of the meeting will become part of the record for the meeting, just as if presented in person.
- Complete guidelines for public participation in virtual Anacortes City Council meetings are available [here](#). View the quick video example for connecting to the meeting [here](#).



Anacortes City Council

Municipal Building Council Chambers

**** This meeting will be held electronically only ****

May 3, 2021
6:00 PM

PRELIMINARY AGENDA

[Packet Materials](#) / [Watch Meeting](#)

- 1. Call to Order**
- 2. Executive Session**
 - a. Potential Litigation or Litigation per [RCW 42.30.110\(1\)\(i\)](#) (15 minutes) (Discussion)
- 3. Announcements and Committee Reports**
 - a. COVID-19 Update (Discussion)
 - b. Finance Committee (Discussion)
 - c. Lodging Tax Advisory Committee (Discussion)
 - d. Public Works Committee (Discussion)
- 4. Public Comment**
- 5. Consent Agenda**
 - a. Minutes of April 26, 2021 (Action)
 - b. Approval of claims in the amount of \$122,614.68 (Action)
 - c. Resolution 3030: Waiving the State Competitive Bidding Requirements for the Purchase of Fairbanks Nijhuis (aka Fairbanks Morse) Pumps, Parts, and Service (Action)
 - d. Resolution 3031: Waiving the State Competitive Bidding Requirements for the Purchase of Foxboro Instrumentation (Action)
- 6. Public Hearings**

Per Resolution 2044, citizens wishing to comment on items not on the agenda may do so under the Public Comment portion of the agenda. Citizens wishing to comment on agenda items indicated with an asterisk (*) may do so as those items are considered by Council during the course of the meeting.

The City of Anacortes is committed to making public meetings available and accessible to all members of the community.
For assistance with special needs, please contact the City Clerk at 360-299-1960 in advance of the meeting.

- a. * Continued Public Hearing: Ordinance 3087: Vacating right-of-way of a portion of 11th Street adjacent to blocks 242 and 243, "Map of the City of Anacortes" together with the West 10 feet of B Avenue adjacent to Lot 1 of block 243 (Discussion/Action)
 - b. * Continued Public Hearing: Critical Area Regulations Draft 3 (Discussion)
7. **Other Business**
8. **Adjournment**

Per Resolution 2044, citizens wishing to comment on items not on the agenda may do so under the Public Comment portion of the agenda. Citizens wishing to comment on agenda items indicated with an asterisk () may do so as those items are considered by Council during the course of the meeting.*

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Anacortes City Council Minutes - April 26, 2021

Call to Order

Mayor Laurie Gere called to order the Anacortes City Council meeting of April 26, 2021 at 6:00 p.m. Councilmembers Jeremy Carter, Ryan Walters, Christine Cleland-McGrath, Carolyn Moulton, Bruce McDougall and Matt Miller all participated in the meeting in absentia via video conference. Councilmember Anthony Young was absent.

Mr. McDougall moved, seconded by Ms. Cleland-McGrath, to excuse the absence of Mr. Young. The motion carried unanimously by voice vote.

Announcements and Committee Reports

COVID-19 Update: Mayor Gere reported on current case statistics and vaccination progress for Anacortes, Skagit County, Washington State, and the nation. The mayor noted the significant increase in cases in Skagit County and said Skagit County was at risk of moving back to Phase 2 if that trend continued.

Fiber Committee: Mr. McDougall reported from the committee meeting held the previous week, deferring to the staff report later on the agenda.

Housing Affordability and Community Services Committee: Ms. Moulton reported from the committee meeting held the previous week. The topics discussed included preparation for an upcoming outreach meeting with stakeholders regarding the community services strategic plan, federal assistance for renters and small businesses, and means of assisting those in the community most in need of housing assistance.

Planning Committee: Ms. Moulton reported from the committee meeting held earlier in the evening. The topics discussed included a staff report on booming building permit activity, the resulting need for an additional temporary building inspector, pending legislation in Olympia, and the Sharpes corner property owned by the city.

Public Comment

No one present wished to address the Council on any topic not already on the agenda.

Consent Agenda

Mr. Carter removed Item 4a, Minutes of April 19, 2021, from the Consent Agenda. Mr. Miller moved, seconded by Mr. Carter, to approve the following Consent Agenda items. The motion carried unanimously by voice vote.

- a. Approval of claims in the amount of \$391,030.87
The following vouchers/checks were approved for payment:
EFT numbers: 99901 through 99945, total \$220,845.09
Check numbers: 99946 through 99958, total \$32,827.03
Wire transfer numbers: 283246 through 283426, total \$468.30
- b. Contract Modification: Commercial Ave Corridor Plan Phase 1 - 11TH ST to 13TH St Design #19-095-TRN-001

Minutes of April 19, 2021

Mr. Carter asked that the minutes of April 19, 2021 be corrected to reflect that he had not been able to attend the special meeting at 5:00 that evening. Mr. Carter moved, seconded by Mr. Miller, to approve the minutes as corrected. The motion carried unanimously by voice vote.

Anacortes City Council Minutes - April 26, 2021

PUBLIC HEARINGS

CDBG 2021 Annual Action Plan

Planning Director Don Measamer introduced the CDBG 2021 Annual Action Plan for public comment, referring to the packet materials for this agenda item. He noted that the public comment period would end May 5 and said no comments had been received thus far. He said the Action Plan would come back to City Council on May 10 for approval to forward the plan to HUD.

Mayor Gere invited members of the audience to comment on this agenda item. No one present wished to address the Council. The mayor left the public hearing open until May 10, 2021.

OTHER BUSINESS

Ordinance 3089: Amending the 2021 Budget

Parks & Recreation Director Jonn Lunsford presented Ordinance 3089 which would amend the 2021 budget to add one Parks Maintenance FTE to the existing 2021 budget. He reported that the City Council Personnel Committee had reviewed the proposed addition. Mr. Lunsford explained the need for the position. Members of the Personnel Committee said the committee recommended approval.

CHRISTINE CLELAND-MCGRATH moved, seconded by RYAN WALTERS, to adopt Ordinance 3089 amending the 2021 budget. Vote: Ayes - JEREMY CARTER, RYAN WALTERS, CHRISTINE CLELAND-MCGRATH, CAROLYN MOULTON, BRUCE MCDOUGALL, MATT MILLER. Nays - None. Result: Passed

Resolution 3029: Authorizing the Hiring of 1 ASAC Administrator and 2 Parks Maintenance Workers

Mr. Lunsford presented Resolution 3029 which would authorize the hiring of an Anacortes Senior Activity Center Administrator and two Parks Maintenance workers.

CAROLYN MOULTON moved, seconded by RYAN WALTERS, to adopt Resolution 3029 authorizing the Mayor to hire 3 positions in the Parks and Recreation department. Vote: Ayes - JEREMY CARTER, RYAN WALTERS, CHRISTINE CLELAND-MCGRATH, CAROLYN MOULTON, BRUCE MCDOUGALL, MATT MILLER. Nays - None. Result: Passed

Access Anacortes Fiber Internet Update

Administrative Services Director Emily Schuh provided the regular monthly update on Access Anacortes Fiber Internet. Ms. Schuh's slides were added to the packet materials for the meeting. Ms. Schuh reported on customers in service, pending orders and revenue received, celebrating 698 customers in service. She noted the take rate by district, which was exceeding a 35% take rate in the current service areas. Ms. Schuh shared financial reports for the fiber project. She also reported network expansion projections for 2021, 2022 and 2023. The report concluded with a summary of special projects underway.

Contract Award: Municipal Broadband Network – 2021 Westside Backbone Expansion #21-094-FBR-001

Ms. Schuh requested City Council consent to award a contract in the amount of \$5,055,304.09 to Robinson Brothers Construction, Inc. (RBC) to deploy backbone infrastructure for the City's Fiber To The Home project in areas west of Anacopper Mine Road. She responded to councilmember questions about the unit costs in this rocky terrain. Mr. Miller noted that a budget amendment may be required to accommodate the contract before year end.

RYAN WALTERS moved, seconded by MATT MILLER, to authorize the Mayor to sign a contract 21-094-
Anacortes City Council Minutes - April 26, 2021

FBR-001 with RBC in the amount of \$5,055,304.09 to perform the construction of Municipal Broadband Network – 2021 Westside Backbone Expansion. Vote: Ayes - JEREMY CARTER, RYAN WALTERS, CHRISTINE CLELAND-MCGRATH, CAROLYN MOULTON, BRUCE MCDOUGALL, MATT MILLER. Nays - None. Result: Passed

Adjournment

There being no further business, at approximately 7:00 p.m. the Anacortes City Council meeting of April 26, 2021 was adjourned.

The following claims against the City of Anacortes have been preaudited and certified by the Clerk-Treasurer as ready for City Council approval at the May 3, 2021 City Council meeting:
[Download this file in OpenDocument spreadsheet format.](#)

Invoice Doc #	Transaction Date	Invoice #	Vendor Full Name	Description	Total Amount	Approval Queue
283490	9/1/2020	2770	SKAGIT LAND TRUST	ACFL CONSERVATION EASEMENT PROGRAM CONSULT	\$ 2,982.00	parks1
283685	10/1/2020	2784	SKAGIT LAND TRUST	CONSERVATION EASEMENT PROGRAM CONSULT	\$ 994.00	parks1
283686	11/2/2020	2817	SKAGIT LAND TRUST	CONSERVATION EASEMENT PROGRAM CONSULT	\$ 1,455.50	parks1
283674	12/30/2020	WAANA130746	FASTENAL COMPANY	MAINTENANCE SUPPLIES	\$ 48.60	dwwtp
283420	2/1/2021	20.79-01	NORTHLINE SURVEYING, INC.	LAKESIDE QUARRY AERIAL SURVEY	\$ 5,060.00	parks1
283695	2/12/2021	GIS-02122021-01	SKAGIT COUNTY GOVERNMENT	DIGITAL AERIAL PHOTOS	\$ 5,531.00	pw1
280646	3/9/2021	INV/GUS/2021/0078	GUTERMANN	GUTERMANN LEAK DETECTION EQUIPMENT	\$ 35,254.00	wdist
283666	3/15/2021	22320	APSCO, INC	SLUDGE PUMP STATOR	\$ 3,647.66	dwwtp
283679	3/23/2021	331 0567209	UNIFIRST CORPORATION	FIBER UNIFORM LAUNDRY	\$ 33.94	fiber
283687	4/1/2021	2959	SKAGIT LAND TRUST	CONSERVATION EASEMENT PROGRAM CONSULT	\$ 390.50	parks1
283662	4/1/2021	386000156	US BANK NA - CUSTODY TREAS DIV	INVESTMENT FEES 3/1-3/31/21	\$ 42.00	finance
283412	4/8/2021	10536-03-21F	BERK CONSULTING, INC.	PARK IMPACT FEE UPDATE MARCH 2021	\$ 57.50	parks1
283481	4/10/2021	2125	ECCOS DESIGN, LLC	PHASE 2 CEMETERY EXPANSION CONSULTATION	\$ 1,942.50	parks1
283615	4/10/2021	2128	ECCOS DESIGN, LLC	SITE DESIGN	\$ 1,207.50	pw1
283462	4/10/2021	ContractGood	GOOD, PAMELA	PAYMENT TO TANGO INSTRUCTOR 1/7-2/4/20	\$ 139.00	pkrec
283410	4/13/2021	935	SKAGIT COUNTY PUBLIC HEALTH	COMMUNITY SERVICES @ SENIOR ACTIVITY CENTER: JAN. FEB. MARCH 2021	\$ 9,550.00	parks1
283460	4/14/2021	1221078	SKAGIT PUBLISHING LLC	PUBLISH AA-2046687 AA-2046995	\$ 424.66	finance
283669	4/16/2021	WAANA133203	FASTENAL COMPANY	MAINTENANCE SUPPLIES	\$ 233.25	dwwtp
283479	4/17/2021	156912	LAKESIDE INDUSTRIES, INC.	WA CLASS G ASPHALT	\$ 556.39	dshop
283480	4/17/2021	157161	LAKESIDE INDUSTRIES, INC.	DUMP FEES	\$ 417.10	dshop
283670	4/19/2021	9874587463	GRAINGER	MAINTENANCE SUPPLIES	\$ 12.69	dwwtp
283486	4/19/2021	8790	NORTH FORK NURSERY	CEDAR TREE FOR EARTH DAY. PICKED UP 8.7%	\$ 65.22	parks1
283474	4/19/2021	0267793-IN	REISNER DISTRIBUTOR INC	AFT/DEF FLUID- SHOP	\$ 1,521.52	dshop
283613	4/19/2021	1150756	SKAGIT COUNTY SOLID WASTE FUND	WTP DUMP RUN 0.4 TN	\$ 41.03	dwwtp
283484	4/20/2021	27616	AEON MFG CO INC	VASES FOR MARKERS	\$ 252.54	parks1
283454	4/20/2021	299528A	BAY CITY SUPPLY	FACILITY SUPPLIES	\$ 636.82	pwfac
283456	4/20/2021	299749	BAY CITY SUPPLY	COVID-19 PPE TOUCHLESS PAPER TOWEL DISPENSER	\$ 105.47	pwfac

Invoice Doc #	Transaction Date	Invoice #	Vendor Full Name	Description	Total Amount	Approval Queue
283461	4/20/2021	795 700 0000 4	CASCADE NATURAL GAS CORP.	CITY HALL 3/19-4/19/21	\$ 894.80	finance
283475	4/20/2021	710 300 0000 5	CASCADE NATURAL GAS CORP.	OPS: 03/19- 04/19/21	\$ 809.48	dshop
283489	4/20/2021	538 000 0000 1	CASCADE NATURAL GAS CORP.	411 HILLCREST DR. 03/19-04/19/21	\$ 49.33	parks1
283491	4/20/2021	260 037 3822 1	CASCADE NATURAL GAS CORP.	611 R AVENUE 03/19-04/19/21	\$ 246.57	parks1
283568	4/20/2021	038 200 0000 2	CASCADE NATURAL GAS CORP.	APD 3/19-4/19/21	\$ 752.91	apd
283570	4/20/2021	199 800 0000 4	CASCADE NATURAL GAS CORP.	703 R AVENUE 3/19-4/19/21	\$ 92.39	museum
283571	4/20/2021	912 800 0000 0	CASCADE NATURAL GAS CORP.	MUSEUM 1305 8TH STREET 3/19-4/19/21	\$ 256.45	museum
283606	4/20/2021	674 400 0000 7	CASCADE NATURAL GAS CORP.	STA 1: 3/19 - 4/19/21	\$ 152.38	medic
283607	4/20/2021	169 400 0000 9	CASCADE NATURAL GAS CORP.	STA 2: 3/19 - 4/19/21	\$ 151.52	medic
283667	4/20/2021	989 800 00008	CASCADE NATURAL GAS CORP.	WWTP 3/19-4/19/21	\$ 105.06	dwwtp
283688	4/20/2021	154 700 0000 9	CASCADE NATURAL GAS CORP.	LIBRARY 3/19-4/19/21	\$ 723.34	publib
283458	4/20/2021	216637	NAPA	OIL FILTER STRAP	\$ 45.69	dshop
283459	4/20/2021	216726	NAPA	OIL FILTER #018	\$ 4.62	dshop
283476	4/20/2021	216751	NAPA	OIL FILTER #403	\$ 12.45	dshop
283477	4/20/2021	216652	NAPA	STARTER #128	\$ 219.33	dshop
283558	4/20/2021	S6-6275559	SEATTLE AUTOMOTIVE DIST INC	VALVE #018	\$ 34.69	dshop
283680	4/20/2021	331 0571631	UNIFIRST CORPORATION	FIBER UNIFORM LAUNDRY	\$ 91.99	fiber
283602	4/21/2021	6348838	CARDINAL HEALTH 110, INC.	PHARMACEUTICALS	\$ 65.64	medic
283559	4/21/2021	812-16360	GCR TIRES & SERVICES	FLAT TIRE REPAIR #425	\$ 67.00	dshop
283560	4/21/2021	812-16361	GCR TIRES & SERVICES	TRUCK #514 SERVICE TIRES	\$ 131.21	dshop
283561	4/21/2021	812-16362	GCR TIRES & SERVICES	SERVICE TIRE ON #511	\$ 86.25	dshop
283610	4/21/2021	9321097080	GRAYBAR ELECTRIC COMPANY, INC	OPTICAL SPLITTERS	\$ 4,458.47	fiber
283563	4/21/2021	12419532	HACH COMPANY	VALVE CONNECTOR, PUMP TUBING	\$ 501.87	dwwtp
283601	4/21/2021	INV-21290	IMAGE360	4 VINYL MISSION STATEMENT	\$ 145.49	medic
283684	4/21/2021	106231	JWC ENVIRONMENTAL, INC	MAINTENANCE SUPPLIES	\$ 2,212.80	dwwtp
283478	4/21/2021	216919	NAPA	PLATINUM FILTER KIT	\$ 32.73	dshop
283671	4/21/2021	0267963-IN	REISNER DISTRIBUTOR INC	INCINERATOR FUEL	\$ 1,489.55	dwwtp
283487	4/21/2021	5061859708	RICOH USA, INC	S/N C86112175 3RD FL COPIER 1/21-4/20/21	\$ 743.44	finance
283612	4/21/2021	331 0571772	UNIFIRST CORPORATION	WTP LAUNDRY SERVICE	\$ 97.13	dwwtp
283488	4/22/2021	638 000 0000 0	CASCADE NATURAL GAS CORP.	411 HILLCREST DR. #B, 3/19-04/19/21	\$ 128.72	parks1
283608	4/22/2021	AN 805007	CENTRAL WELDING SUPPLY CO, INC	OXYGEN FOR AMBULANCE	\$ 58.61	medic
283611	4/22/2021	93105623	CHEMTRADE CHEMICALS US LLC	ALUMINUM SULFATE	\$ 4,609.71	dwwtp
283682	4/22/2021	51008	KRIEG CONSTRUCTION, INC	3/8" HMA- STREET DEPT	\$ 8,607.67	dshop
283557	4/22/2021	MV252988	MOTOR TRUCKS, INC	DRAIN VALVE W/HTR #512	\$ 397.65	dshop
283554	4/22/2021	217059	NAPA	LAMP- #403	\$ 18.67	dshop
283598	4/22/2021	217049	NAPA	NAPA OIL FILTER #406	\$ 12.45	dshop
283677	4/22/2021	217163	NAPA	EXACT FIT BLADE- #403	\$ 10.37	dshop
283678	4/22/2021	217061	NAPA	AIR FILTER- #403	\$ 15.49	dshop
283556	4/22/2021	113563	WALTON BEVERAGE COMPANY, INC	CITY HALL BREAK ROOM SUPPLIES	\$ 210.00	finance

Invoice Doc #	Transaction Date	Invoice #	Vendor Full Name	Description	Total Amount	Approval Queue
283565	4/22/2021	113565	WALTON BEVERAGE COMPANY, INC	WTP BREAKROOM SUPPLIES	\$ 140.00	dwtpt
283698	4/23/2021	ReimbBuffum	BUFFUM, JESSE	PER DEIM FOR TRAINING; BUFFUM - PATROL RIFLE INSTRUCTOR COURSE	\$ 130.00	apd
283665	4/23/2021	04/23/2021	FIDALGO CLEANING	CARNEGIE CLEANING	\$ 200.00	museum
283609	4/23/2021	12422711	HACH COMPANY	SYRINGE TUBING X 2	\$ 98.84	dwtpt
283675	4/23/2021	21-31937-1	MILLENNIUM	FIBER OPTIC DROP CABLE	\$ 2,450.94	fiber
283663	4/23/2021	217181	NAPA	MISC FILTERS- SHOP STOCK	\$ 243.69	dshop
283614	4/23/2021	1152471	SKAGIT COUNTY SOLID WASTE FUND	WTP DUMP RUN 0.45 TN	\$ 46.15	dwtpt
282498	4/26/2021	15668	ARCHIVESOCIAL, INC.	ARCHIVING PLATFORM FOR SOCIAL MEDIA SITES	\$ 4,788.00	infosys
283672	4/26/2021	04/26/2021	FIDALGO CLEANING	APD CLEANING & SUPPLIES	\$ 800.00	apd
283600	4/26/2021	2785445	FOSTER GARVEY PC	WTP DEMO (AUG.2020) MATTER NO. 96	\$ 11,597.33	legal
283676	4/26/2021	217389	NAPA	LAMP- #195	\$ 11.26	dshop
283689	4/27/2021	6362688	CARDINAL HEALTH 110, INC.	PHARMACEUTICALS	\$ 546.79	medic
283690	4/27/2021	217548	NAPA	BATTERY & CORE #029	\$ 215.37	dshop

Total **\$122,614.68**



City Council Contract Agenda Bill

Meeting Date: 5/3/2021 **Agenda Item:** 5c

Subject: Resolution 3030 – Waiving the State Competitive Bidding Requirements for the Purchase of Fairbanks Nijhuis (aka Fairbanks Morse) pumps, parts, and service for use at the City's Sewage Pump Stations

Staff Contact: Fred Buckenmeyer

Approved for Submittal to Council by: Darcy Swetnam, City Attorney
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Action Type: Resolution

Summary Statement: City staff seeks City Council approval of Resolution 3030 to waive the bidding requirements for the purchase of Fairbanks Nijhuis (aka Fairbanks Morse) pumps, parts, and service for use at the City's sewage pump stations.

Background:

- RCW 39.04.280 provides that the City, by resolution, may waive competitive bidding requirements when a purchase is clearly and legitimately limited to a single source of supply, or when the purchase involves special facilities or market conditions.
- The City currently has Fairbanks Nijhuis (also known as Fairbanks Morse) pumps installed at four sewage pump stations in the collection system. The Fairbanks Morse pumps are specifically selected to meet the hydraulic dynamics unique to each station to efficiently meet the pumping demands.
- The current discharge plumbing, controls, and hydraulic performance at the pump stations are specific to the Fairbanks Nijhuis brand of pump.
- Installing a different brand would require a full modification of the entire pumping system at each sewage pump station.
- Fairbanks Nijhuis (formally Fairbanks Morse), has designated Granich Engineered Products, Inc. as the sole vendor and sole authorized service professionals of Fairbanks Nijhuis pumps in Washington, Oregon and the panhandle of Idaho.

Previous Council/Committee Action: N/A

Competing Viewpoints Considered: N/A

Recommended Motion: I move that Resolution 3030 be approved to waive the competitive bidding requirements due to a single source of supply for the purchase of Fairbanks Nijhuis pumps, parts, and service for use at the City's sewage pump stations, and authorizes sole source purchasing from Granich Engineered Products, Inc.

Alternative Actions: N/A

Attachments: Resolution 3030, Granich Engineered Products, Inc. sole source letter

RESOLUTION 3030

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF ANACORTES, WASHINGTON, authorizing the purchase of Fairbanks Nijhuis (aka Fairbanks Morse) pumps, parts, and service for use at the City's sewage pump stations, and waiving the competitive bidding requirement due to a single source of supply, pursuant to RCW 39.04.280.

WHEREAS, RCW 39.04.280 provides that the City, by resolution, may waive competitive bidding requirements when a purchase is clearly and legitimately limited to a single source of supply, or when the purchase involves special facilities or market conditions.

WHEREAS, the City currently has Fairbanks Nijhuis (also known as Fairbanks Morse) pumps installed at four sewage pump stations in the collection system. The Fairbanks Morse pumps are specifically selected to meet the hydraulic dynamics unique to each station to efficiently meet the pumping demands; and

WHEREAS, the current discharge plumbing, controls, and hydraulic performance at the pump stations are specific to the Fairbanks Nijhuis brand of pump; and

WHEREAS, installing a different brand would require a full modification of the entire pumping system at each sewage pump station; and

WHEREAS, Fairbanks Nijhuis (formally Fairbanks Morse), has designated Granich Engineered Products, Inc. as the sole vendor and sole authorized service professionals of Fairbanks Nijhuis pumps in Washington, Oregon and the panhandle of Idaho; and

NOW, THEREFORE, BE IT RESOLVED by the City Council of the City of Anacortes, Washington, as follows:

Section 1. The City Council of the City of Anacortes finds that purchasing the Fairbanks Nijhuis pumps, parts, and service that meet the City's current sewage pump station requirements, clearly limits the City of Anacortes to a single source of supply from Granich Engineered Products, Inc., justifying the waiver of competitive bidding requirements.

Section 2. The City Council of the City of Anacortes hereby waives the bidding requirements for the purchase of Fairbanks Nijhuis pumps, parts, and service for use at the City's sewage pump stations, and authorizes sole source purchasing from Granich Engineered Products, Inc.

Section 3. Any actions of the City or its officers prior to the date hereof and consistent with the terms of this Resolution are ratified and confirmed.

Section 4. This Resolution shall be in full force and effect after its adoption and approval.

The foregoing resolution was ADOPTED by the City Council of the City of Anacortes, Washington, at a regular, open public meeting thereof this 3rd day of May 2021.

Laurie Gere, Mayor

ATTEST:

Steven D. Hoglund, City Clerk/Treasurer

APPROVED AS TO FORM:

Darcy Swetnam, City Attorney



January 01, 2021

To: All Municipal Pump Users and Agencies

Western Regional Office
3601 Fairbanks Ave
Kansas City, KS 66106

Phone: 626-437-4215

Re: Fairbanks Morse Municipal Sales and Service Distribution
Washington and Oregon

To whom it may concern,

Granich Engineered Products is Fairbanks Nijhuis (formally Fairbanks Morse) exclusive distributor for municipal pumps, pump parts and is the authorized service and repair center in Washington, Oregon and the panhandle of Idaho. Granich is authorized to provide service and repair to maintain factory warranties. Please feel free to contact me directly if you have any additional questions regarding Fairbanks Morse sales. Please see the below contact information:

Granich Engineered Products, Inc
1313 S 96th Street
Seattle, WA 98108

Contact: Ken Hogan
Cell: 206-953-1409
Em: kenh@granich.com
Website: www.granich.com

Sincerely,

Sincerely,
James Slocum

James Slocum
Western Regional Manager- Municipal



City Council Contract Agenda Bill

Meeting Date: 5/3/2021 **Agenda Item:** 5d

Subject: Resolution 3031 – Waiving the State Competitive Bidding Requirements for the Purchase of Foxboro instrumentation for use at the Anacortes Wastewater Treatment Plant and Pump Stations

Staff Contact: Fred Buckenmeyer

Approved for Submittal to Council by: Darcy Swetnam, City Attorney
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Action Type: Resolution

Summary Statement: City staff seeks City Council approval of Resolution 3031 to waive the bidding requirements for the purchase of Foxboro instrumentation for use at the Anacortes Wastewater Treatment Plant.

Background:

- RCW 39.04.280 provides that the City, by resolution, may waive competitive bidding requirements when a purchase is clearly and legitimately limited to a single source of supply, or when the purchase involves special facilities or market conditions.
- The City currently has several Foxboro flowmeters and instrument transmitters throughout the Wastewater Treatment Plant and pump stations. They are designed to measure flow in a variety of process application and report flow information to the plants SCADA system.
- Components of flow measuring devices and transmitters are only designed to work with their manufacturers system. For instance, a flow tube from one manufacture would not work with a transmitter from another.
- Installing a different brand would require a full modification of the entire flow metering and instrument transmitter components throughout the plant and pump stations.
- Engineered Process Controls, LLC is the only Authorized Manufacturers Representative for the Foxboro branded Schneider-Electric Process Instrumentation and SCADA & Telemetry products in Washington and Oregon.

Previous Council/Committee Action: N/A

Competing Viewpoints Considered: N/A

Recommended Motion: I move that Resolution 3031 be approved to waive the competitive bidding requirements due to a single source of supply for the purchase of Foxboro instrumentation for use at the Anacortes Wastewater Treatment Plant and pump stations, and authorizes sole source purchasing from Engineered Process Controls, LLC.

Alternative Actions: N/A

Attachments: Resolution 3031, Engineered Process Controls, LLC sole source letter

RESOLUTION 3031

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF ANACORTES, WASHINGTON, authorizing the purchase of Foxboro instrumentation for use at the Anacortes Wastewater Treatment Plant and pump stations, and waiving the competitive bidding requirement due to a single source of supply, pursuant to RCW 39.04.280.

WHEREAS, RCW 39.04.280 provides that the City, by resolution, may waive competitive bidding requirements when a purchase is clearly and legitimately limited to a single source of supply, or when the purchase involves special facilities or market conditions.

WHEREAS, the City currently has several Foxboro flowmeters and instrument transmitters throughout the Wastewater Treatment Plant and pump stations. They are designed to measure flow in a variety of process application and report flow information to the plants SCADA system; and

WHEREAS, components of flow measuring devices and transmitters are only designed to work with their manufacturers system. For instance, a flow tube from one manufacture would not work with a transmitter from another; and

WHEREAS, installing a different brand would require a full modification of the entire flow metering and instrument transmitter components throughout the plant and pump stations; and

WHEREAS, Engineered Process Controls, LLC is the only Authorized Manufacturers Representative for the Foxboro branded Schneider-Electric Process Instrumentation and SCADA & Telemetry products in Washington and Oregon; and

NOW, THEREFORE, BE IT RESOLVED by the City Council of the City of Anacortes, Washington, as follows:

Section 1. The City Council of the City of Anacortes finds that purchasing the Foxboro instrumentation that meet the City's current flowmeter and instrument transmitter requirements and installed components at the Wastewater Treatment Plant and pump stations, clearly limits the City of Anacortes to a single source of supply from Engineered Process Controls, LLC, justifying the waiver of competitive bidding requirements.

Section 2. The City Council of the City of Anacortes hereby waives the bidding requirements for the purchase of Foxboro instrumentation for use at the City's Wastewater Treatment Plant and pump stations, and authorizes sole source purchasing from Engineered Process Controls, LLC.

Section 3. Any actions of the City or its officers prior to the date hereof and consistent with the terms of this Resolution are ratified and confirmed.

Section 4. This Resolution shall be in full force and effect after its adoption and approval.

The foregoing resolution was ADOPTED by the City Council of the City of Anacortes, Washington, at a regular, open public meeting thereof this 3rd day of May 2021.

Laurie Gere, Mayor

ATTEST:

Steven D. Hoglund, City Clerk/Treasurer

APPROVED AS TO FORM:

Darcy Swetnam, City Attorney

Schneider Electric
10900 Equity Dr
Houston, TX 77041
(713) 329-1600

March 18, 2021

Dear Valued Customer:

Engineered Process Controls, LLC is the only Authorized Manufacturers Representative for branded Schneider-Electric Process Instrumentation and SCADA & Telemetry products in the following assigned markets and territories:

Industrial and Municipal Water & Wastewater Markets in the states of

- Washington: all counties
- Oregon: all counties

If you have any questions about our products or services, please do not hesitate to contact **Engineered Process Controls, LLC**. If you have any questions regarding our representative relationship, please feel free to contact me or **Engineered Process Controls, LLC** directly.

Very truly yours,



Darryl Churchill
District Sales Manager, Western US Region
Process Instrumentation and SCADA & Telemetry
Schneider Electric
(303) 249-2041

Engineered Process Controls, LLC
PO Box 890
Woodinville, WA 98072
(425) 844-8901

Schneider Electric
10900 Equity Dr
Houston, TX 77041
(713) 329-1600



City Council Agenda Bill

Meeting Date: May 3, 2021

Agenda Item: 6.a.

Agenda Item Title: Continued Public Hearing: Ordinance 3087: Vacating right-of-way of a portion of 11th Street adjacent to blocks 242 and 243, "Map of the City of Anacortes" together with the West 10 feet of B Avenue adjacent to Lot 1 of block 243

Staff Contact(s): DARCY SWETNAM

Approved for Submittal to Council by **Action Type**

DARCY SWETNAM

Ordinance

STEVE HOGLUND

Item Summary: Ordinance 3087 proposes the vacation of right-of-way of a portion of 11th Street adjacent to blocks 242 and 243, "Map of the City of Anacortes" together with the West 10 feet of B Avenue adjacent to Lot 1 of block 243. The vacation is provided for in a Property Agreement between the City, the Wynn Family Trust, and the Ortman Family LLCs, which provides that the City will vacate certain areas of right-of-way and the Wynn Family Trust will grant the City an easement across their property for the Guemes Channel Trail.

Budget Impact:

N/A

Previous Action: The City Council passed [Resolution 3017](#) at the [March 1, 2021](#) City Council meeting. This set a public hearing to be heard on the proposed vacation on April 5, 2021. On [April 5, 2021](#) the public hearing was continued to April 19, 2021. On [April 19, 2021](#) City Council conducted a site visit and then received public comment at the public hearing during the regular meeting. The public hearing was continued to May 3, 2021.

Recommended Motion: Adopt Ordinance 3087 vacating right-of-way of a portion of 11th Street adjacent to blocks 242 and 243, "Map of the City of Anacortes" together with the West 10 feet of B Avenue adjacent to Lot 1 of block 243.

Alternative Actions: Propose alternative language, decline to take action.

Attachments (listed in order presented):

1. Ordinance 3087
2. City Attorney memo on public questions
3. Map
4. Ordinance 2824 Ortman 11th Street vacation and easement
5. Property Agreement for Easements
6. A Avenue Agreement Slide Presentation 12/14/2020
7. Neighbors Petition A Avenue
8. Noronha Comments
9. Flanagan Comments
10. Glaeser Comments
11. Guzik Comment
12. Harvey Comments
13. Ivie Comments
14. Ivie Email with Photos
15. Munsterman Comments
16. Roush Comments
17. Steen Comments
18. Wynn Comments
19. Public Comments Received after packet publication

RETURN TO:

City of Anacortes
P.O. Box 547
Anacortes, WA 98221

ORDINANCE NO. 3087

**AN ORDINANCE VACATING RIGHT-OF-WAY OF A PTN. OF 11TH STREET
ADJACENT TO BLOCKS 242 AND 243, "MAP OF THE CITY OF ANACORTES"
TOGETHER WITH THE WEST 10 FEET OF B AVENUE ADJACENT TO LOT 1 OF
BLOCK 243**

**THE CITY COUNCIL OF THE CITY OF ANACORTES DOES HEREBY ORDAIN AS
FOLLOWS:**

WHEREAS, per AMC Chapter 12.50 Street and Alley Vacation the City Council, a hearing on the petition or proposal held before the City Council shall be upon the day fixed by resolution or at the time to which a hearing may be adjourned; and

WHEREAS, at the March 1, 2021, City Council meeting a resolution was passed to set a hearing date for April 5, 2021, to consider a petition to vacate right-of-way on 10th Street; and

WHEREAS, the City Council opened the public hearing on said proposal on April 5, 2021 fixed by Resolution 3017 and continued the public hearing to April 19, 2021, and agreed to approve the proposal as set-forth below; and

WHEREAS, the City and property owners have entered into a certain Property Agreement, dated December 21, 2020, which provides that, in exchange for the vacation of certain portions of unopened City right-of-way, the City will obtain easements for a public trail along the Guemes Channel waterfront; and

WHEREAS, the City hereby finds that a vacation of the area in question will provide a significant benefit to the public in the form of increased access to trail easements for the future Guemes Channel Trail; and

WHEREAS, the City hereby finds the street or alley is neither currently required for public use or public access nor anticipated to be needed for public use or access in the future; and

WHEREAS, the City hereby concludes that the substitution of a new and different public way would be more useful to the public; and

WHEREAS, the City hereby finds no possible future public uses which may require this right-of-way; and;

WHEREAS, the City has considered all objections to the proposed vacation; and

WHEREAS, the City hereby finds the vacation of the entire width is not possible and that the requested partial vacation adequately addresses all factors in AMC 12.50.060; and

WHEREAS, the City hereby finds that the proposed compensation meets the requirements of AMC Chapter 12.50; now, therefore

THE CITY COUNCIL OF THE CITY OF ANACORTES, DOES HEREBY ORDAIN AS FOLLOWS:

SECTION 1. Findings of Fact and Conclusions of Law.

All of the recitals are hereby adopted as findings and conclusions.

SECTION 2. Vacations.

The street and alley right-of-way areas within the City of Anacortes described in Exhibit A should be and are hereby vacated.

SECTION 2. Compensation.

Compensation for the vacation shall be provided by alternative compensation pursuant to AMC Section 12.50.130 and shall be in the form of easements for trail purposes. The easement area to be conveyed to the City as compensation are described in Exhibit B.

SECTION 4. Effective Date: This ordinance shall take effect 5 (five) days after execution and recording of the easements described in Section 2 above and publication as required by law.

PASSED AND APPROVED this 19th day of April 2021.

CITY OF ANACORTES:

BY: _____
Laurie Gere, Mayor

ATTEST:

Steven D. Hoglund, City Clerk Treasurer

APPROVED AS TO FORM:

Darcy J. Swetnam, WSBA #40530
City Attorney

Exhibit A: Vacated Areas

LEGAL DESCRIPTION VACATION #2

TO P56379 WYNN FAMILY TRUST

That portion of Government Lot 5, Section 13, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

The North $\frac{1}{2}$ of 11th Street lying southerly of the SEATTLE & NORTHERN RAILWAY COMPANY'S STATION GROUND and Block 242, Plat of "MAP OF THE CITY OF ANACORTES", per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington and Easterly of a line projected South that is Southwest of the Southwest corner of said Block 242, said line being 1.01 feet southwest on a curve to the right with the center point of a radius bearing North 24°53'07" West, 7789.44 feet and a central angle of 0°00'27", and Westerly of a line beginning in the Southeast corner of vacated "B" Avenue according to Vacation Ordinance 684; thence South 0°33'28" East, 6.00 feet; thence South 41°59'48" West, 45.35 feet to the center line of 11th Street.

LEGAL DESCRIPTION VACATION #3 & #4

TO P56380 ANACORTES 3 LLC

That portion of Section 24, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

That portion of the South $\frac{1}{2}$ of 11th Street adjacent to and lying north of Lots 1 & 2 and the East $\frac{1}{2}$ of Lot 3, Block 243, Plat of "MAP OF THE CITY OF ANACORTES", per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington and the West 10 feet of "B" Avenue within the 11th Street right-of-way.

ALSO, the West 10 feet of "B" Avenue adjacent to and abutting the north 70 feet of Lot 1 of said Block 243.

LEGAL DESCRIPTION VACATION #5

TO P56382 Ortman Family LLC

That portion of Section 24, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

West 10 feet of the South 30 feet of "B" Avenue adjacent to and abutting Lot 1 of, Block 243, Plat of "MAP OF THE CITY OF ANACORTES", per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington.

Exhibit B: Compensation

That portion of the Burlington Northern Railroad designated as reserve right-of-way for the Seattle and Northern Railroad as shown on the "MAP OF THE CITY OF ANACORTES, SKAGIT COUNTY, WASHINGTON", as per plat recorded in Volume 2 of Plats, page 4, records of Skagit County, Washington.

TOGETHER WITH a portion of Tract 14 of Plate No. 8 of the tide and shoreline of Section 13, Township 35 North, Range 1 East, W.M., Anacortes Harbor, all being more particularly described as follows:

Beginning at the intersection of 11th Street and "B" Avenue of said Plat; thence North 0°33'35" East along the Northerly projection of the centerline of "B" Avenue, a distance of 217.06 feet to the true point of beginning being an intersection with a curve having a radius point bearing North 20°46'49" West, a radial distance of 985.37 feet; thence Southwesterly along the arc of said curve to the right through a central angle of 2°58'54", an arc distance of 51.28 feet; thence South 72°12'05" West, a distance of 13.20 feet to the beginning of a curve to the left having a radius of 925.36 feet; thence along the arc of said curve through a central angle of 5° an arc distance of 81.88 feet; thence North 8°56'58" West, a distance of 70.47 feet; thence North 62°14'00" East, a distance of 169.11 feet to the intersection with the Northerly projection of the centerline of "B" Avenue; thence South 0°33'35" West, a distance of 98.99 feet to the true point of beginning.

EXCEPT the South 10 feet thereof.



To: Public

From: Darcy Swetnam, City Attorney

cc: City Council

Date: April 12, 2021

Re: 11th Street and B Avenue Vacations

Staff have received a number of questions regarding the City-initiated proposal to vacate portions of 11th Street and B Avenue. It is our goal to provide the best information to the public to respond to questions and concerns so that Council can obtain the best feedback possible from the public at the public hearing on April 19, 2021. I have attempted to group the questions we received by topic and provide as much information as possible. Please don't hesitate to reach out with additional questions.

Please be aware that you may provide comments until the date of the meeting. If I receive your comments by **noon on Wednesday, April 14**, they will be published in the packet. However, any comments received prior to the public hearing on **Monday, April 19** will be distributed to Council (even if they're after the packet deadline) and they will be added to the packet later.

Map

1. Several members of the public have requested a map of the property and areas to be vacated.

Answer: I have attached a map that shows the four separate areas to be vacated by the present ordinance. Please note that the vacation identified in the Property Agreement as vacation #1 was previously vacated to the Ortman's in a previous process. Therefore, the areas proposed to be vacated in the present proposal are numbers 2-5. They are individually labeled as such on the map.

2010 Ortman Vacation

2. On 08/02/2010, an easement for trail purposes, across the north portion of the Ortman property, was granted. What were the conditions of that transaction?

Answer: I have attached the ordinance that vacated the right of way in 2010.

Payment for the Vacation

3. Why now, with no exchange, are the Ortman's receiving vacated area?

Answer: The consideration for the vacation is in the Property Agreement signed in 2020, which I've attached for reference. Under the proposed vacation, the consideration to be provided by the Ortman's is that they will support the vacation and the City's receipt of an easement across the Wynn property. They have previously given an easement to the City for the trail purposes.

This proposal has been discussed between the parties for over 10 years. The City worked with several property owners in the area to negotiate an agreement where several parcels of right-of-way would be vacated in exchange for several pieces of easement along the planned location of the Guemes Channel Trail. Two of the property owners to that proposed agreement withdrew, leaving only the City, the Wynns, and the Ortman's. This was a discussion that was led by the City with the sole purpose of obtaining easements along the waterfront, while addressing the concerns of the property owners granting the easements and keeping all parties whole. This was not a negotiation led or initiated by the Ortman's.

Please note that, in AMC 12.50.020, a City-initiated vacation petition like the present petition can be prohibited if 50% of the abutting property owners (owners who property touches the area proposed to be vacated) file an objection. Therefore, if the Ortman's opposed the vacation, the City would be prohibited from moving forward with the vacation, meaning the Wynns would not provide the easement for Trail purposes.

The City has received considerable feedback from the public in support of efforts to develop the Trail from the ferry to downtown. The vast majority of this property is held in private ownership, leaving the City in the position of needing to negotiate easements with each individual property owner or obtain interest through condemnation actions. The City has always tried to be respectful of property owners and attempt to create opportunities for all involved to have their

concerns addressed. The Property Agreement that prescribed the process for vacating the area in this proposal received unanimous support from the City Council and City leadership and there was no public opposition when it was approved.

Trail Easement

4. Does it make sense to negotiate for a trail segment that goes from and to nowhere?

Answer: The path to acquiring the easements necessary to construct the Guemes Channel Trail has to start somewhere. The City is obviously not going to build a trail that goes to and from nowhere, but all properties along the proposed trail area are in private ownership and the City is working on securing easements along the Channel. It would be improper for the City to comment on the status of other properties in private ownership at this point.

Value of property in the vacation petition

5. What is the dollar value of the land proposed to be vacated?

Answer: There are four areas separately described in the vacation petition that are covered by this vacation. City Engineer Eric Shjarback, as the designee of the Director of Public Works, has provided a rough estimate of value of the four areas to be vacated based on comps from the Skagit County Assessor. (Please note that AMC 12.50.120 authorizes the Director of Public Works to identify values of vacations totaling less than 5,000 square feet based on assessed values of land from properties in the immediate vicinity.) He provided the following values, which correlate to the vacation numbers of the map provided with this packet:

1. Vacation #2: the North half of 11th Street: To be vacated to the Wynns: 4547 square feet: \$227,350.
2. Vacation #3: the south half of 11th Street: To be vacated to the Ortman's: 3395 square feet: \$169,750
3. Vacation #4: The westernmost 10' strip of B Avenue fronting 2401 B Avenue: To be vacated to the Ortman's: 700 square feet: \$35,000
4. Vacation #5: The Westernmost 10' strip of B Avenue along 1114 B Avenue: To be vacated to the Ortman's: 300 square feet: \$15,000

6. What is the dollar value of the easement area?

Answer: The estimated square footage of the easement area is 4000 square feet, which would make the estimated value of the area based on the City Engineer's estimated price per square foot to be approximately \$200,000 for the land.

Notice

7. Did the City provide notice of the public hearing on the proposal?

Answer: AMC Section 12.50.040 provides the requirements for posting a notice of a public hearing on a vacation. It requires that the City publish notice in the official paper, post a placard in a conspicuous place at each end of the street or alley to be vacated, post notice in three public places in the City, and mail written notice at least 15 days before the hearing to all owners within 300 feet of the proposed vacation. The placards posted at the property have to be highly visible, at least 11 by 14 inches, include a map, contain a statement indicating that a vacation petition has been initiated, and identify the place and time for the meeting. City provided the required notice under the Code, as well as the required notice for the public meetings where Council scheduled the public hearing and approved the contract.

Criteria for Granting the Vacation

8. AMC 12.50.060 lists the factors to be considered in vacation determinations. Please address how this proposal speaks to each:

Answer: Below is an evaluation of each of the factors listed in the code. Please note that AMC 12.50.060 clarifies that vacations are made within Council's sole and absolute discretion. A particular proposal does not necessarily have to meet each of the following factors, but Council must adopt findings that indicate whether the proposal does or does not meet them prior to granting a vacation petition.

A. Whether a change of use or vacation of the street or alley will provide a significant benefit to the public.

Answer: The benefit to the public of the proposed vacation is the acquisition of an easement that can be used in the future for the construction and location of the Guemes Channel Trail. The City has worked with the property owners to the Agreement for many years to adequately address their concerns and get to the point

where an easement is a reality. The City will have to obtain easements to move forward with construction of a trail.

- B. Whether the street or alley is neither currently required for public use or public access nor anticipated to be needed for public use or access in the future.

Answer: First, both the end of 11th Street and the strip of land along B Avenue are currently unopened and not required for public access, ingress, or egress. The street grid in the area is and has been developed for many years, and there are no plans to expand the street to require use of the area in question. According to the Planning Director, even if the vacation is granted, there would still be room for the placement of curb, gutter, and sidewalk in the City's right-of-way along the west edge B Avenue adjacent to the proposed vacation areas 4 and 5.

There are currently no plans to develop these sections of unopened right of way in any long-term plans of the City. Additionally, the City does not intend to provide or support parking in the neighborhood in question. Any future plans for the trail in that area would discourage parking and relocate it to a designated parking area in another part of town that would support parking and higher density traffic. Further, the City does not intend there to be public access points to the trail in this neighborhood, making it an unlikely parking spot for individuals wanting to use the Trail.

- C. Whether the substitution of a new and different public way would be more useful to the public;

Answer: There is no current plan to relocate public right of way from the proposed vacation areas. However, the development of the Guemes Channel Trail would provide an alternative public way for pedestrian and bike traffic by the public.

- D. Whether possible future public uses may require the right-of-way

Answer: City staff have indicated that it is unlikely that future public uses will require the right-of-way in the proposed vacation.

- E. Whether objections to the proposed vacation are made.

Answer: The City has received multiple letters from surrounding neighbors objecting to the vacation, which are attached for reference.

Land Use Options if Vacation is Granted

9. If the Ortman or any other owner removes the building at 2401 B Avenue, what is the height limit in that zoning district and how close can a structure be located along B Avenue if lots #4 and #5 are vacated?

Answer: The maximum building height in that area is 35 feet, which is the same as most other residential zones in town. If the vacation petition is granted, the property at 2401 11th Street (owned by Ortman on the south side of 11th Street) would have its front yard moved to B Avenue, which has a 20' setback requirement rather than the 10' side yard setback from B Avenue that currently applies to building on that property. If the vacation of the 10' strip along B Avenue is granted, any house on that lot will not be able to be located any closer to B Avenue than 20'.

10. Have any discussions been held by the City with the Ortman for demolition or new construction on their parcels?

Answer: There have been no discussions between the City and the Ortman on demolition or new construction on their property.

Mechanics of the Property Agreement

11. AMC 12.50.110 establishes a method of providing a credit for the dedication of alternate property for "street purposes" however despite staff's presentation of the proposal as an exchange, I see no obligation on the part of the property owners to grant the easement under the terms of the Property Agreement. The presentation slides attached to the Property Agreement in December suggest that the property owners would initiate the grant of the easement within 10 days of the ordinance approving the proposed vacation, however there is no corresponding language in the Property Agreement. A suggested remedy would be to delay the effective date of the vacation ordinance to when the trail easement is granted by the property owners.

Answer: The Property Agreement at Section III(A) requires the Wynns to execute the trail easement to the City within 10 days of approval of the vacation. Therefore, the City would have a breach of contract action if that did not occur. Secondly, the proposed Ordinance granting the vacation says at Section Four:

“This ordinance shall take effect five days after execution and recording of the easements described in Section 2 above and publication as required by law.”
So, the City had already built the commenter’s remedy into the ordinance, as we do for all vacation ordinances.

Miscellaneous Questions

12. There is a fire hydrant that appears to be in the vacated portion of B and 11th. If it needs to be moved, at who’s expense will that happen?

Answer: The City would ask the new property owner to cover all costs associated with any movement of fire hydrants.

13. There also appears to be a ‘deck’ near the shore on the Ortman’s property. What will be the consequences of this agreement on that structure?

Answer: The proposed vacation will not have any impact on any existing decks.

14. Have the owners been educated about shoreline vegetation management?

Answer: I don’t believe there has been any discussion of shoreline vegetation management in connection with this vacation proposal.

15. Section 12.050.070 of the newly adopted code section established a new city policy against vacation of portions of ROWs. Under the new code section there is an opportunity to grant an exception under some broad criteria which include consideration of public benefit. How can the City justify this?

Answer: Section 12.50.070 AMC requires vacations to be for the entire width of the right-of-way unless Council finds an exception. Under subsection (B), Council may establish an exception if it adopts findings that the vacation of the entire width is not possible and that the partial vacation addresses the factors discussed above and laid out in AMC 12.50.060. In this case, there is paved street over the majority of the B Avenue right-of-way, making vacation of the entire width not possible with current City street needs. Council would have to adopt this analysis in its findings supporting the vacation to proceed with vacating a strip of B Avenue.

Attachments:

1. Map of the proposed vacated area

2. 2010 Ordinance vacating Right-of-way
3. Property Agreement
4. Public Comments



City of Anacortes

Wynn Vacation

Guemes Channel

P31538

P31489

P56379

#2 Wynn

#3 Ortman

#4 Ortman

#5 Ortman

11TH ST

BAVE

12TH ST

2419

2413

1200

2319

2315

2309

1202





201008020105

Skagit County Auditor

8/2/2010 Page 1 of 10 3:31PM

RETURN TO:

City of Anacortes
P.O. Box 547
Anacortes, WA 98221

CHICAGO TITLE 620011435 **ORDINANCE NO. 2824**

AN ORDINANCE VACATING A RIGHT-OF-WAY OF CERTAIN PORTIONS OF

11th Street, Block 243 MAP OF ANACORTES
RECORDS OF SKAGIT COUNTY WASHINGTON

THE CITY COUNCIL OF THE CITY OF ANACORTES DOES HEREBY ORDAIN AS FOLLOWS:

WHEREAS, the requisite number of owners of property abutting certain streets and alleys located within the City of Anacortes have petitioned for an alteration of the plats in which those streets are contained, and have requested vacation a portion of the streets therein; and

WHEREAS, the City Council held a public hearing on said proposal on June 7, 2010 following a recommendation from the Board of Adjustment based on a hearing held on November 5, 2009 and agreed to approve the proposal as set-forth below; now, therefore,

THE CITY COUNCIL OF THE CITY OF ANACORTES, DOES HEREBY ORDAIN AS FOLLOWS:

SECTION 1. The following described right-of-way on streets and alleys located in the City of Anacortes should be and are hereby vacated:

That portion of Government Lot 5, Section 13, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

All that portion of 11th street lying southeasterly of the Great Northern Railway Company right of way and westerly of the Northerly extension of the east line of Lot 4, Block 243; ALSO, that portion of the south ½ of 11th Street adjacent to and abutting upon the west ½ of Lot 3, Block 243, all as shown on the plat of "Map of The City of Anacortes", as per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington.

SECTION 2. This Ordinance shall be recorded with Attachment A, an Easement for the future Guemes Channel Trail, which shall represent compensation for the vacated right of way as described above. The vacation shall not be effective until such full recordation.

SECTION 3. Effective Date: This ordinance shall take effect from and after 5 (five) days after its passage and publication as required by law.

PASSED AND APPROVED this 7 day of June, 2010.

CITY OF ANACORTES:

BY: H. Dean Maxwell
H. Dean Maxwell, Mayor

ATTEST:

Steve D. Hoglund
Steve D. Hoglund, City Clerk Treasurer

APPROVED AS TO FORM:

Bradford Furlong
Bradford Furlong, City Attorney WSBA #12924

Chicago Title has placed this
document for recording as a
customer courtesy and accepts no
liability for its accuracy or validity



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Skagit County Auditor

8/2/2010 Page

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10 3:31PM



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Skagit County Auditor

7/23/2010 Page 1 of 8 3:44PM

AFTER RECORDING, RETURN TO:

CITY OF ANACORTES

Attn: Carol Yates

P.O. Box 547

Anacortes, Washington 98221

SKAGIT COUNTY WASHINGTON
REAL ESTATE EXCISE TAX

JUL 23 2010

Reference numbers of assigned or released documents: None

Amount Paid \$
Skagit Co. Treasurer
By *Mmm* Deputy

Partial Legal Description: Ptn Parcel "B" of Survey Recorded AF#200502170146

Assessor's Tax I.D./Parcel Number(s): 350113-0-012-0009; P31488

LAND TITLE OF SKAGIT COUNTY

136892-SA

TRAIL EASEMENT

The undersigned, Anacortes 1, LLC ("Grantor"), a Washington limited liability company, as a gift and for no other consideration, hereby conveys and quit claims a perpetual nonexclusive easement ("Easement") to the City of Anacortes, a Washington municipal corporation ("Grantee"), over, and across the following property located in Skagit County, Washington ("Grantor's Property"), legally described as set forth in Exhibit A.

1. **Purpose.** The purpose of the Easement is for the construction, operation, maintenance and repair of a non-motorized, public, handicapped accessible, recreational trail ("Trail"). The easement is up to twenty-two feet (22') wide and Trail may be no wider than fourteen feet (14') including shoulders, and will traverse Grantor's Property beginning at Grantor's eastern boundary and cross to Grantor's western boundary along a route ("Easement Area") legally described in Exhibit B and depicted in Exhibit C.

Grantor and Grantee may agree in writing to relocate the Trail as necessary and convenient over time to preserve the accessibility or contiguity of the Trail. Such agreement shall be effective when a changed legal description is recorded as an amendment hereto.

Additionally, this Easement conveys the right, and Grantee accepts the duty, to conduct shoreline stabilization work on all land between the north side of the Trail and the Ordinary High Water Mark ("OHM") of the Guemes channel or Grantors' northerly property line, whichever is closer to the Trail; *provided*, that the duty to conduct such shoreline stabilization work shall arise only to the extent such work is necessary due to the installation



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Skagit County Auditor

8/2/2010 Page 3 of 10 3:31PM

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and/or maintenance of the Trail by Grantee. All other shoreline stabilization work which may be necessary or desirable shall be conducted by Grantor.

This Easement conveys the right, privilege and authority, to Grantee and Grantee's contractors, to enter Grantor's Property with materials, workers, volunteers or agents, to construct, maintain, replace and reconstruct the Trail and to perform shoreline stabilization work, together with the right of ingress and egress over and across the Easement Area at any and all times for the purposes of doing anything reasonably necessary or useful or convenient for the enjoyment of the Easement hereby granted; and the right to grade and re-grade land, spread gravel or apply pavement or concrete, place foundations and cut and remove any vegetation and other obstructions which may endanger the safety or interfere with the use of said Trail. Grantee may install gates, fences and other reasonable structures to control usage of the Easement Area. Grantee will conduct all activities permitted herein so as to reasonably minimize any adverse impacts to Grantor's Property.

2. **Use of Easement.** The Easement granted herein shall be for the construction, operation, maintenance and repair of a public non-motorized recreational Trail and by Grantee at Grantee's sole cost and expense. This Easement should not be construed to: (a) permit access to any other portion of Grantor's Property for any purpose; and (b) permit mechanized or motorized equipment or vehicles of any nature on the Trail, without the express permission of Grantor, except for trail work by Grantee and its agents or in emergency circumstances; and (c) the use of personal battery operated scooters for disabled or infirmed citizens.

3. **Duties Conditional.** Grantee is under no obligation to install the Trail authorized herein and reserves unto itself the absolute right to determine the timing, configuration and specifications of the Trail and whether the appropriate amount of funds are on hand to allow design and/or construction of the Trail.

4. **Indemnification.** To the extent permitted by law, Grantee shall indemnify and hold Grantor harmless from any and all claims, actions, damages or liability occasioned wholly or in part by any negligent or intentional act or omission by Grantee its agents or invitees, relating to the use, construction, maintenance, operation or repair of the Trail or conduct of shoreline stabilization work located within the Easement Area, except to the extent attributable to the acts or omissions of any third person or entity or Grantor, its agents or invitees.

5. **Reservation to Grantor.** Grantor shall have the right to use the Easement Area for any purpose not inconsistent with the full use and enjoyment by Grantee, its successors and assigns, of the rights and privilege herein granted. Grantee is responsible for constructing, operating and maintaining the above-described improvements. Grantor shall not place any buildings or fencing on the Easement Area or impair the public's or Grantee's access to the Easement Area; *provided*, the Grantor shall not be required to remove any existing structure on the Easement Area until the Grantee is ready to commence trail construction and then only after sixty (60) day written notice to the Grantor.

**TRAIL EASEMENT
ANACORTES 1, LLC, GRANTOR
CITY OF ANACORTES, GRANTEE**

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6. **Restrictions on Public Use.** Grantee shall have the right to require that public use is conducted in a manner that does not unreasonably disturb plant or wildlife habitat or the quiet use and enjoyment of nearby private property not subject to the Easement; and Grantee may limit, restrict or prohibit public use of all or any part of the Trail temporarily assure safety or for maintenance purposes and indefinitely as necessary or appropriate to preserve the Trail.

7. **No Third-Party Rights.** The parties agree and acknowledge that this Easement is solely for the benefit of Grantee and that it confers no rights on any third person or entity or the public in general.

8. **Foliage.** After the Trail is constructed, the Grantee shall ensure that all foliage in the Easement Area shall be maintained at a height no higher than ten feet (10').

9. **Fencing.** When the Trail is constructed the Grantee shall construct and maintain a fence that will restrict public access south of the fence, and which shall not be more than five feet (5'), measured horizontally, south of the Trail's paved edge nor in any event be constructed within three and one-half feet (3.5') north of the south easement line. The fence shall be a split rail style, and shall have posted signs indicating that the property to the south of the fence is private. The fence shall include a lockable gate to provide access to the Trail by Grantor. Nothing in this Easement shall restrict Grantor's right to construct a fence south of the Grantee's fence.

10. **Shoreline Stabilization.** Nothing in this Easement shall be construed to require or prevent Grantor or Grantee from conducting shoreline stabilization work on Grantor's property, either before or after the trail is constructed.

TO HAVE AND TO HOLD unto Grantee, its successors, and assigns forever.

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**TRAIL EASEMENT
ANACORTES 1, LLC, GRANTOR
CITY OF ANACORTES, GRANTEE**



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Skagit County Auditor

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IN WITNESS WHEREOF, the undersigned Grantor has executed this instrument on this 19 day of July 2010.

GRANTOR
Anacortes 1, LLC

By: Mark E. Ortman

Member

MARK E. ORTMAN

Printed Name

STATE OF WASHINGTON }

} ss

COUNTY OF SKAGIT }

I hereby certify that I know or have satisfactory evidence that Mark E. Ortman is the person who personally appeared before me, and said person acknowledged that he signed this instrument, on oath stated that he was authorized to execute the instrument and acknowledged it as the Managing Member of Anacortes 1, LLC., to be the free and voluntary act of such party for the uses and purposes mentioned in this instrument.

Dated this 19 day of July 2010.

C. T. Moser

Notary Public in and for the State of Washington,
residing

at Mount Vernon

My appointment expires 6-1-12



TRAIL EASEMENT
ANACORTES 1, LLC, GRANTOR
CITY OF ANACORTES, GRANTEE



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Skagit County Auditor

ACCEPTED on the above terms and conditions by Grantee, this 19th day of July 2010.

GRANTEE:
CITY OF ANACORTES

By: H. Dean Maxwell

H. Dean Maxwell

Its: Mayor

Approved as to form:

Attest:

BCF

Bradford E. Furlong, WSBA #12924
City Attorney

Steven Hoglund, Finance Director

STATE OF WASHINGTON)

) ss.

COUNTY OF SKAGIT)

On this 19th day of July 2010, before me, the undersigned, a Notary Public in and for the state of Washington, duly commissioned and sworn, personally appeared H. Dean Maxwell, to me known to be the individual described in and who executed the within and foregoing instrument, and acknowledged it, as the Mayor of the City of Anacortes, to be the free and voluntary act of such entity for the uses and purposes mentioned in this instrument.

Witness my hand and official seal hereto affixed the day and year first above written.



Bradford E. Furlong
Notary Public in and for the state of
Washington, residing at mt Vernon
My commission expires: 11/01/12
Printed Name: Bradford E. Furlong

TRAIL EASEMENT
ANACORTES 1, LLC, GRANTOR
CITY OF ANACORTES, GRANTEE

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EXHIBIT A

That portion of those certain strips, parcels or tracts of land in Section 24 and Government Lot 5 of Section 13, Township 35 North, Range 1 East, W.M., shown and designated on the original "PLAT OF THE CITY OF ANACORTES", as "SEATTLE AND NORTHERN RAILWAY COMPANY'S STATION GROUND", and as Reserved right-of-way for Company's right-of-way for the Seattle and Northern Railway, according to a certain paper in writing in escrow with John P. Hoyt, dated May 28, 1889, described as follows:

Beginning at the intersection of the centerline of "B" Avenue and Eleventh Street;
thence North $0^{\circ}37'11''$ East 40.00 feet along the centerline of "B" Avenue, to the South line of Block 242, extended Easterly;
thence North $0^{\circ}37'11''$ East 177.32 feet to a point on curve which lies 30 feet Southerly (and radially) from the centerline of the railroad, as now located and constructed the radius point of said curve being North $20^{\circ}49'23''$ West 985.37 feet from the above described "point on curve";
thence Westerly on a curve to the right, through a central angle of $3^{\circ}01'28''$ an arc distance of 52.01 feet;
thence South $72^{\circ}12'05''$ West parallel with the 30 feet distant (Southeasterly) from the center of said railroad, a distance of 13.19 feet to the beginning of a curve to the left having a radius of 925.37 feet;
thence along said curve to the left through a central angle of $5^{\circ}04'10''$ an arc distance of 81.88 feet, said point being 30 feet Southerly, (as measured radially) from the centerline of the railroad, said point also being the true point of beginning;
thence South $9^{\circ}13'41''$ East 128.45 feet to the point on curve on the original Railroad right-of-way, said curve having a radius of 7,789.44 feet, the radius point of said curve being North $24^{\circ}48'57''$ West 7,789.44 feet from the above described "point on curve";
thence Southwesterly along said curve to the right having a radius of 7,789.44 feet, through a central angle of $1^{\circ}48'44''$ an arc distance of 246.37 feet to the Northwestern corner of Lot 10, Block 243, "CITY OF ANACORTES", as per plat recorded in Volume 2 of Plats, page 4, records of Skagit County, Washington, and the Easterly margin of "A" Avenue, according to said plat;
thence North $0^{\circ}37'11''$ East along the Northerly extension of said Easterly margin of "A" Avenue, 115.00 feet to a point on a line that is parallel with and 30 feet distant Southeasterly from the centerline of said Railroad (as measured at right angles);
thence North $58^{\circ}41'30''$ East along said parallel line, 98.29 feet to a point of curvature in said parallel line;
thence along the arc of said curve to the right having a radius of 925.37 feet, through a central angle of $8^{\circ}16'25''$ an arc distance of 133.63 feet to the true point of beginning.

Situate in the County of Skagit, State of Washington.



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EXHIBIT B

TRAIL EASEMENT

That portion of the Burlington Northern Railroad designated as reserve right-of-way for the Seattle and Northern Railroad as shown on the Plat "Map of the City of Anacortes, Skagit County, Washington", as per plat recorded in Volume 2 of Plats, page 4, records of Skagit County, Washington;

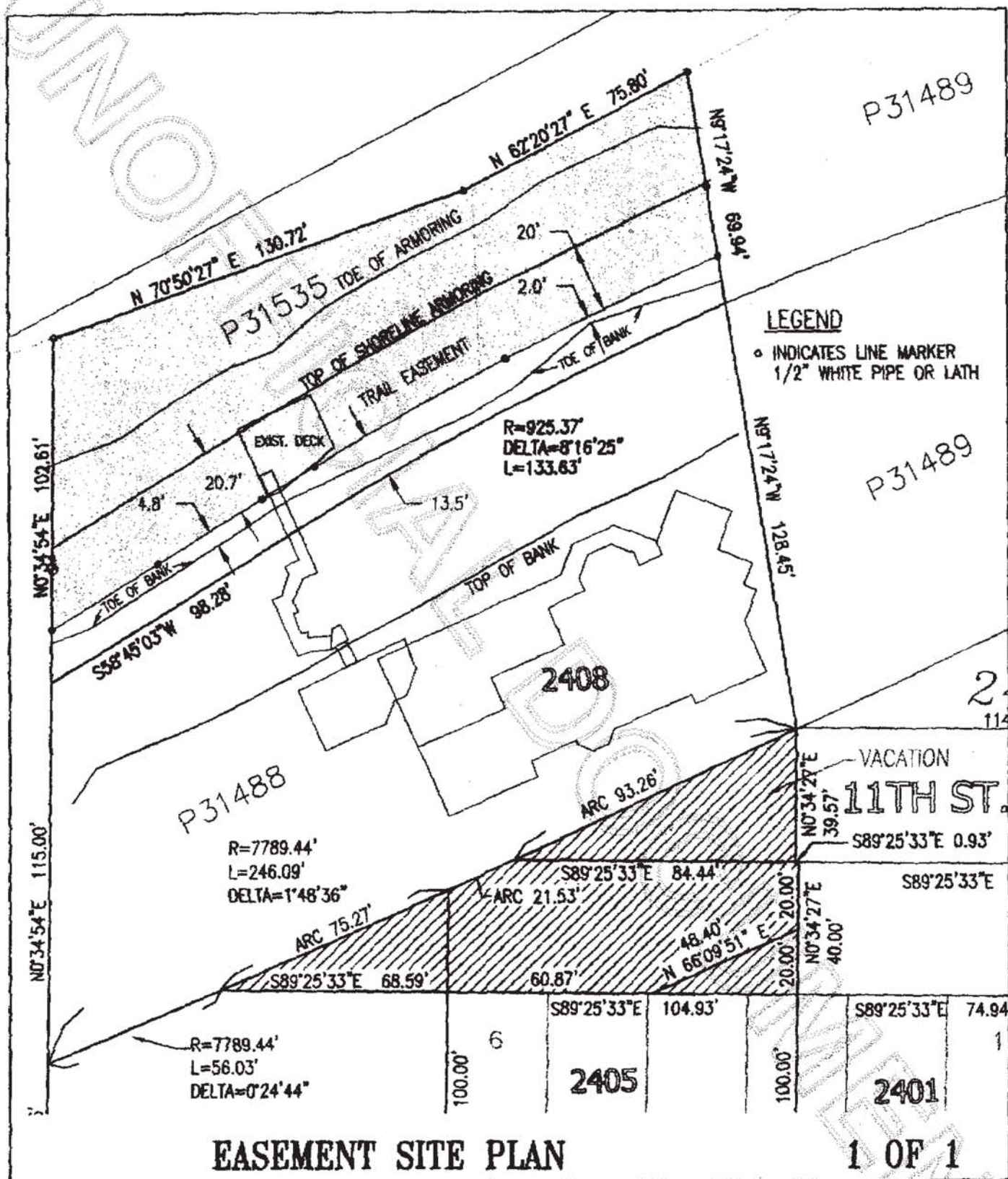
TOGETHER WITH a portion of Tract 14 of Plate No.8 of the Tide and Shorelands of Section 13, Township 35 North, Range 1 East, W.M., Anacortes Harbor, all being more particularly described as follows:

Beginning at the Southwest corner of Block 243 of said Plat; thence North 0 degrees 33'46" East along a projection of the West edge of said Block, a distance of 308.10 feet to the true point of beginning; thence North 0 degrees 33'46" East, a distance of 102.32 feet; thence North 70 degrees 44'00" East, a distance of 130.63 feet; thence North 62 degrees 14'00" East, a distance of 77.28 feet; thence South 8 degrees 56'58" East, a distance of 70.47 feet to an intersection with a curve having a radius point bearing South. 22 degrees 52'05" East, a radial distance of 925.36 feet; thence Westerly along the arc of said curve to the left through a central angle of 8 degrees 16'25", an arc distance of 133.62 feet; thence South 58 degrees 51'30" West a distance of 98.98 feet to the true point of beginning.

EXCEPT the South 13.5' thereof.



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**Property Agreement
between the
City of Anacortes
and
Property Owners.**

This Property Agreement ("Agreement") is entered into effective as of the last signature date by the undersigned parties below, by and between the City of Anacortes ("City"), a Washington municipal corporation, and Property Owners ("Wynn Family Trust, Ortman Family LLC, Anacortes 1 LLC, Anacortes 2 LLC, and Anacortes 3 LLC).

RECITALS

- A. The City is in the process of constructing a paved public trail along the Guemes Channel waterfront ("Trail") with a goal of connecting downtown Anacortes to Washington Park.
- B. The City desires to construct the Trail within the legally described boundaries of the Wynn and Ortman Properties described below. The City would like to obtain easements for the Trail.
- C. The Ortman Family, through Anacortes 1, LLC conveyed to the City of Anacortes an easement across the Ortman Properties, recorded on August 2, 2010, under Skagit County Auditor's File Number 201007230112 as a gift and for the construction, operation, maintenance, and repair of the Trail, which is legally described in Exhibit C, which is hereby incorporated by reference. .
- D. The City possesses certain portions of dedicated public right-of-way which are currently not used for streets, including B Avenue and 11th Street.
- E. The Ortman Family desires to add a portion of currently unvacated 11th Street and a portion of unvacated B Avenue to their properties at 1116 B Avenue, 2405 11th Street, 2401 11th Street, and 1114 B Avenue, all in Anacortes, Washington.
- F. The Wynn Family Trust desires to add a portion of currently unvacated 11th Street to its property at 2402 11th Street, Anacortes, Washington.
- G. The Properties that are the subject of this Agreement are as follows:
 - a. Ortman Properties:
 - i. Anacortes 1 LLC owns Skagit County Parcel P31488, legally described in Exhibit A, which is hereby incorporated by reference, hereinafter referred to as "Anacortes 1 Property".
 - ii. Anacortes 2 LLC owns Skagit County Parcel P56381, legally described in Exhibit A, hereinafter referred to as "Anacortes 2 Property".

- iii. Anacortes 3 LLC owns Skagit County Parcel P56380, legally described in Exhibit A, hereinafter referred to as "Anacortes 3 Property".
 - iv. Ortman Family LLC owns Skagit County Parcels P56382, P131777, and P31535, legally described in Exhibit A, hereinafter referred to as "Ortman Family LLC Properties".
 - v. The six parcels referenced above are hereby collectively referred to as "Ortman Property".
 - b. Wynn Property: The Wynn Family Trust owns Skagit County Parcels P31489, P 31538, and P56379, legally described in Exhibit A, hereinafter referred to as "Wynn Property".
- H. The Parties wish to work cooperatively to transfer ownership of various pieces of real property to keep the Parties whole and allow construction of the Trail.

AGREEMENTS

NOW, THEREFORE, for good, valuable, and fair consideration, the adequacy and receipt of which are hereby acknowledged, the parties hereby Agree as follows.

- I. Purpose: The purpose of this Property Agreement is to allow the Parties to transfer certain interests in real property so that each Party achieves a desired adjustment to their real property interests and boundaries while allowing the City to proceed with construction of the Guemes Channel Trail.
- II. City Obligations
 - A. Vacation. Within ten (10) days following execution of this Agreement, the City will initiate and begin processing a Petition to vacate 5 separate portions of City right-of-way, legally described and depicted in Exhibit B, which is hereby incorporated by reference. Said vacation petition(s) must comply with all requirements of the Revised Code of Washington, the Anacortes Municipal Code, and the Anacortes Public Works and Planning Departments. The City cannot guarantee the outcome of vacation proceedings.
 - B. Insurance. The City will ensure any City property interest conveyed via easement to the City, including the Trail, during and after construction, is covered by the City's general liability coverage through Washington Cities Insurance Authority.

III. Wynn Obligations

- A. Easement. In exchange for approximately 4,125 square feet of vacated right-of-way, within ten (10) days of City approval of the vacation, the Trustee of the Wynn Family Trust will convey on a form substantially similar to Exhibit D or by format approved by the City Attorney, an express easement over and across their property for construction and maintenance of the Guemes Channel Trail. The easement area to be conveyed is legally described on attached Exhibit C.

IV. Ortman Obligations

- A. Easement. In exchange for approximately 4,906 square feet of vacated right-of-way, the Ortman Family has conveyed to the City of Anacortes an easement for the construction, operation, maintenance, and repair of the Trail. The easement area is legally described on attached Exhibit C.
- B. Vacation. The Ortman Family hereby agrees not to oppose any future Petitions to vacate the portion of 11th Street described as Vacation #2 in favor of the Wynn Family Trust.

VII. Additional Terms

- A. Indemnification. The City agrees to indemnify, defend, and hold harmless the other Parties, their officers, agents, and employees from and against any and all claims, losses, actions or judgments for damages or injury to persons or property arising out of or in connection with the acts and/or performances or activities of the City, its agents, employees, representatives, or agents pursuant to this Agreements, except to the extent caused by the negligence of the other Party.
- B. Cooperation. The Parties will reasonably cooperate with each other to implement the terms of this Agreement, including but not limited to, executing documents and taking other action reasonably necessary to implement the terms of this Agreement.
- C. Captions or Interpretations. Paragraph titles or captions are inserted as a matter of convenience and for reference, and in no way define, limit, extend, or describe the scope of this Agreement or any provision.
- D. Modification or Amendment. This Agreement may not be changed, altered, or modified, except in writing and signed by the Parties.
- E. Severability. In the event any term or condition of this Agreement or application thereof to any person or circumstance is held invalid, such

invalidity shall not affect other terms, conditions or applications of this Agreement which can be given effect without the invalid term, condition or application. To this end, the terms and conditions of this Agreement are declared severable.

- F. Entire Agreement. This Agreement constitutes the entire agreement between the Parties relating to the transactions contemplated hereby. The Parties acknowledge they have not relied on any promise, representation or warranty, whether express or implied, not contained in this Agreement.
- G. No Partnership or Joint Venture. No partnership and/or joint venture exists between the Parties, and no partnership and/or joint venture is created by and between the Parties by virtue of this Agreement. No agent, employee, contractor, subcontractor, consultant, volunteer, or other representative of the parties shall be deemed an agent, employee, contractor, subcontractor, consultant, volunteer, or other representative of the other party.
- H. Choice of Law/ Venue. Any dispute under this Agreement or related to this Agreement shall be decided in accordance with the laws of the State of Washington. Venue for any court proceeding arising under or related to this Agreement shall be in Skagit County Superior Court.
- I. Binding Effect; No Assignments. This Agreement will be binding upon and inure to the benefit of the Parties and their respective heirs, trustees, executors, administrators, and successors. The Parties represent, covenant, and warrant they have not directly or indirectly assigned, transferred, encumbered, or purported to assign, transfer, or encumber to any person or entity any portion of any liability, claim, demand, action, cause of action, or rights herein released and discharged in this Agreement.
- J. Counterparts. This Agreement may be executed in counterparts, and when each party has signed and delivered at least one such counterpart, each counterpart shall be deemed an original, and, when taken together with other signed counterparts, shall constitute one Agreement, which shall be binding upon and effective as to all Parties.

V. Signatures

The Parties hereto have executed this Property Agreement on the dates shown below.

Laurie Gere, Mayor
City of Anacortes

Date

Hugh Thomas Wynn
Hugh Thomas Wynn, Trustee
Wynn Family Trust

Nov 7, 2020
Date

Sylvia Wynn
Sylvia Wynn, Trustee
Wynn Family Trust

Nov 7, 2020
Date

M.E.L.
Name, Title
Ortman Family LLC

Nov. 13, 2020
Date

M.E.L.
Name, Title
Anacortes 1 LLC

Nov. 13, 2020
Date

M.E.L.
Name, Title
Anacortes 2 LLC

Nov. 13, 2020
Date

M.E.L.
Name, Title
Anacortes 3 LLC

Nov. 13, 2020
Date

EXHIBIT A
Property Descriptions:

Wynn Family Trust Property:

That portion of the Burlington Northern Railroad designated as reserve right-of-way for the Seattle and Northern Railroad as shown on the plat "MAP OF THE CITY OF ANACORTES, SKAGIT COUNTY, WASHINGTON", as per plat recorded in Volume 2 of Plats, page 4, records of Skagit county, Washington.

TOGETHER WITH a portion of Tract 14 of Plate No. 8 of the tide and shorelands of Section 13, Township 35 North, Range 1 East, W.M., Anacortes Harbor, all being more particularly described as follows:

Beginning at the intersection of 11th Street and "B" Avenue of said plat:
Thence North 0°33'35" East along the Northerly projection of the centerline of "B" Avenue, a distance of 217.06 feet to the true point of beginning being an intersection with a curve having a radius point bearing North 20°46'49" West, a radial distance of 985.37 feet;
Thence Southwesterly along the arc of said curve to the right through a central angle of 2°58'54", an arc distance of 51.28 feet; thence South 72°12'05" West, a distance of 13.20 feet to the beginning of a curve to the left having a radius of 925.36 feet; thence along the arc of said curve through a central angle of 5°04'10", an arc distance of 81.88 feet; thence North 8°56'58" West, a distance of 70.47 feet; thence North 62°14'00" East, a distance of 169.11 feet to the interaction with the Northerly projection of the centerline of "B" Avenue;
Thence South 0°33'35" West, a distance of 98.99 feet to the true point of beginning.

Situate in the County of Skagit, State of Washington.

All of Block 242, "MAP OF THE CITY OF ANACORTES", as per plat recorded in Volume 2 of Plats, page 4, records of Skagit County, Washington, TOGETHER WITH that portion of the West Half of vacated "B" Avenue lying between the North line of Eleventh Street and the Northwestern boundary of said Block 242 extended Northeasterly, TOGETHER WITH portions of those certain strips, parcels, or tracts of land in Government Lot 5 of Section 13, Township 35 North, Range 1 East, W.M., shown and designated on the said map of the City of Anacortes as "SEATTLE AND NORTHERN RAILWAY COMPANY'S STATION GROUND", and as "RESERVED RIGHT OF WAY FOR THE SEATTLE AND NORTHERN RAILWAY, according to a certain paper in writing in escrow with John P. Hoyt, dated May 28, 1889", described as follows:

Beginning at the intersection of the centerline of "B" Avenue and Eleventh Street as shown on said Plat; thence North 0°27'11" East along the centerline of "B" Avenue a distance of 40.00 feet to the South line of said Block 242 extended Easterly, and the true point of beginning; thence North 0°37'11" East a distance of 177.32 feet to a point

on curve which lies 30 feet Southerly (and radially) from the centerline of the railroad, as now located and constructed, the radius point of said curve being North 20°49'23" West a distance of 985.37 feet from the above described "point on curve"; thence Westerly, on a curve to the right, through a central angle of 3°01'23", an arc distance of 52.01 feet; thence South 72°12'05" West, parallel with and 30 feet distance (southeastern) from the center of said railroad a distance of 13.19 feet to the beginning of a curve to the left having a radius of 925.37 feet; thence along said curve to the left through a central angle of 5°04'10", an arc distance of 81.88 feet, said point being 30 feet southerly (as measured radially) from the centerline of the railroad; thence South 9°13'41" East a distance of 128.45 feet to the point on curve on the original railroad right of way line, said curve having a radius of 7,789.44 feet the radius point of said curve being North 24°48'57" West a distance of 7,789.44 feet from the above described "point on curve"; thence Northeasterly on said curve to the left, through a central angle of 0°00'22", an arc distance of 0.82 feet, to the westerly corner of Block 242; thence South 89°24'09" East along the South line of Block 242 and said South line extended, a distance of 115.13 feet to the true point of beginning;

SUBJECT TO easement for underground truck and/or lateral sewers in favor of the City of Anacortes, a municipal corporation, recorded November 15, 1961, under Auditor's No. 614521, affecting the East eight feet (8') of the West Half of B Avenue produced northerly from the North line of 11th Street to Great Northern Railroad right of way.

Ortman Properties

Ortman Family LLC, is the owner of real property legally described as:

Lots 7 through 10, Block 243, MAP OF THE CIYT OF ANACORTES, according to the Plat thereof recorded in Volume 2 of Plats, pages 4 through 7, records of Skagit County, Washington.

Together with that portion of vacated 11th Street which would attached by operation of law in accordance with City of Anacortes Ordinance No 2824.

Anacortes 1, LLC is the owner of real property legally described as follows:

That portion of those certain strips, parcels or tracts of land in Section 24 and Government Lot 5 of Section 13, Township 35 North, Range 1 East of the Willamette meridian, shown and designated on the original Plat of the City of Anacortes as "Seattle and Northern Railway Company's Station Ground," and as "Reserved right-of-way for company's right-of-way for the Seattle and Northern Railway, according to a certain paper in writing in escrow with John P. Hoyt, dated May 28, 1889," described as follows:

Commencing at the intersection of the centerline of "B" Avenue and Eleventh Street; thence North 0°37'11" East along the centerline of "B" Avenue a distance of 40.00 feet to the South line of Block 242 extended Easterly;

Thence North $0^{\circ}37'11''$ East a distance of 177.32 feet to a point on a curve which lies 30 feet Southerly (and radially) from the centerline of the railroad, as now located and constructed, the radius point of said curve being North $20^{\circ}49'23''$ West a distance of 985.37 feet from the above described "point on curve";

Thence Westerly, on a curve to the right, through a central angle of $3^{\circ}01'28''$, an arc distance of 52.01 feet;

Thence South $72^{\circ}12'05''$ West, parallel with the 30 feet distant (Southeasterly) from the center of said Railroad a distance of 13.19 feet at the beginning of a curve to the left having a radius of 925.37 feet;

Thence along said curve to the left through a central angle of $5^{\circ}04'10''$, an arc distance of 81.88 feet, said point being 30 feet Southerly (as measured radially) from the centerline of the railroad, said point also being the true point of beginning;

Thence South $9^{\circ}13'41''$ East a distance of 128.45 feet to the point on curve on the original Railroad right-of-way line, said curve having a radius of 7,789.44 feet, the radius point of said curve being North $24^{\circ}48'57''$ West a distance of 7,789.44 feet from the above described "point on curve";

Thence Southwesterly along said curve to the right having a radius of 7,789.44 feet, through a central angle of $1^{\circ}48'44''$, an arc distance of 246.37 feet to the Northwestern corner of Lot 10, Block 243, City of Anacortes, according to plat thereof recorded in Volume 2 of Plats, page 4, records of Skagit county, Washington, and the Easterly margin of "A" Avenue, according to said plat;

Thence North $0^{\circ}37'11''$ East, along the Northerly extension of said Easterly margin of "A" Avenue, 115.00 feet to a point on a line that is parallel with and 30 feet distant Southeasterly from the centerline of said Railroad (as measured at right angles);

Thence North $58^{\circ}51'30''$ East, along said parallel line 98.64 feet to a point of curvature in said parallel line;

Thence along the arc of said curve to the right having a radius of 925.37 feet, through a central angle of $8^{\circ}16'25''$ an arc distance of 133.63 feet to the true point of beginning.

Together with that portion of vacated 11th Street, which would attach by operation of law in accordance with City of Anacortes Ordinance No. 2824.

Anacortes 2, LLC, is the owner of real property legally described as follows:

The West half of Lot 3 and all of Lots 4, 5, and 6, Block 243, City of Anacortes, according to the Plat recorded in Volume 2 of Plats, pages 4 through 7, records of Skagit County, Washington.

Together with that portion of vacated 11th Street which would attach by operation of law in accordance with City of Anacortes Ordinance No. 2824.

Anacortes 3, LLC, is the owner of real property legally described as follows:

Lots 1 and 2 and the East half of Lot 3, Block 243, City of Anacortes, according to the Plat recorded in Volume 2 of Plats, pages 4 through 7, records of Skagit County, Washington.

EXHIBIT B
Vacation Descriptions:

LEGAL DESCRIPTION VACATION #1
TO P31488 ANACORTES 1 LLC

That portion of Government Lot 5, Section 13, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

The West 14.05 feet of the North 1/2 of 11th lying southerly of the SEATTLE & NORTHERN RAILWAY COMPANY'S STATION GROUND and Westerly of a line projected South that is Southwest of the Southwest corner of Block 242, Plat of "MAP OF THE CITY OF ANACORTES", per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington, said line being 1.01 feet southwest on a curve to the right with the center point of a radius bearing North 24°53'07" West, 7789.44 feet and a central angle of 0°00'27".

LEGAL DESCRIPTION VACATION #2
TO P56379 WYNN FAMILY TRUST

That portion of Government Lot 5, Section 13, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

The North 1/2 of 11th Street lying southerly of the SEATTLE & NORTHERN RAILWAY COMPANY'S STATION GROUND and Block 242, Plat of "MAP OF THE CITY OF ANACORTES", per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington and Easterly of a line projected South that is Southwest of the Southwest corner of said Block 242, said line being 1.01 feet southwest on a curve to the right with the center point of a radius bearing North 24°53'07" West, 7789.44 feet and a central angle of 0°00'27", and Westerly of a line beginning in the Southeast corner of vacated "B" Avenue according to Vacation Ordinance 684; thence South 0°33'28" East, 6.00 feet; thence South 41°59'48" West, 45.35 feet to the center line of 11th Street.

LEGAL DESCRIPTION VACATION #3 & #4
TO P56380 ANACORTES 3 LLC

That portion of Section 24, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

That portion of the South ½ of 11th Street adjacent to and lying north of Lots 1 & 2 and the East ½ of Lot 3, Block 243, Plat of "MAP OF THE CITY OF ANACORTES", per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington and the West 10 feet of "B" Avenue within the 11th Street right-of-way.

ALSO the West 10 feet of "B" Avenue adjacent to and abutting the north 70 feet of Lot 1 of said Block 243.

LEGAL DESCRIPTION VACATION #5

TO P56382 Ortman Family LLC

That portion of Section 24, Township 35 North, Range 01 East of the Willamette Meridian, described as follows:

West 10 feet of the South 30 feet of "B" Avenue adjacent to and abutting Lot 1 of, Block 243, Plat of "MAP OF THE CITY OF ANACORTES", per plat recorded in Volume 2 of Plats, pages 4 through 7, inclusive, records of Skagit County, Washington .

EXHIBIT C
Easement Descriptions:

Ortman Easement

That portion of the Burlington Northern Railroad designated as reserve right-of-way for the Seattle and Northern Railroad as shown on the Plat "Map of the City of Anacortes, Skagit County, Washington", as per plat recorded in Volume 2 of Plats, page 4, records of Skagit County Washington;

TOGETHER WITH a portion of Tract 14 of Plate No.8 of the Tide and Shorelands of Section 13, Township 35 North, Range 1 East, W.M., Anacortes Harbor, all being more particularly described as follows:

Beginning at the Southwest corner of Block 243 of said Plat; then North 0 degrees 33'46" east along a projection of the West edge of said Block, a distance of 308.10 feet to the true point of beginning; thence North 0 degrees 33'46" East, a distance of 102.32 feet; thence North 70 degrees 44'00" East, a distance of 130.63 feet; thence North 62 degrees 14'00" East, a distance of 77.28 feet; thence South 8 degrees 56'58" East, a distance of 70.47 feet to an intersection with a curve having a radius point bearing South 22 degrees 52'05" East, a radian distance of 925.36 feet; thence Westerly along the arc of said curve to the left through a central angle of 8 degrees 16'25", an arc distance of 133.62 feet; thence South 58 degrees 51'30" West a distance of 98.98 feet to the true point of beginning.

EXCEPT the South 13.5' thereof.

Wynn Easement:

PORTION OF PARCEL P56379:

That portion of the Burlington Northern Railroad designated as reserve right-of-way for the Seattle and Northern Railroad as shown on the "MAP OF THE CITY OF ANACORTES, SKAGIT COUNTY, WASHINGTON", as per plat recorded in Volume 2 of Plats, page 4, records of Skagit County, Washington.

TOGETHER WITH a portion of Tract 14 of Plate No. 8 of the tide and shoreline of Section 13, Township 35 North, Range 1 East, W.M., Anacortes Harbor, all being more particularly described as follows:

Beginning at the intersection of 11th Street and "B" Avenue of said Plat:

Thence north $0^{\circ}33'35''$ East along the Northerly projection of the centerline of "B" Avenue, a distance of 217.06 feet to the true point of beginning being an intersection with a curve having a radius point bearing North $20^{\circ}46'49''$ West, a radial distance of 985.37 feet:

Thence Southwesterly along the arc of said curve to the right through a central angle of $2^{\circ}58'54''$, an arc distance of 51.28 feet;

Thence South $72^{\circ}12'05''$ West, a distance of 13.20 feet to the beginning of a curve to the left having a radius of 925.36 feet;

Thence along the arc of said curve through a central angle of 5° an arc distance of 81.88 feet;

Thence North $8^{\circ}56'58''$ West, a distance of 70.47 feet;

Thence North $62^{\circ}14'00''$ East, a distance of 169.11 feet to the intersection with the Northerly projection of the centerline of "B" Avenue;

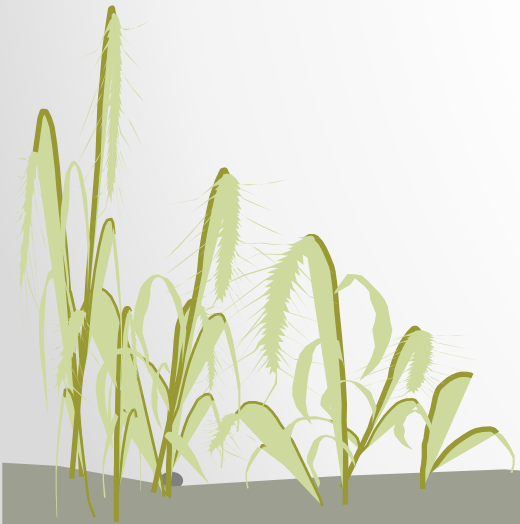
Thence South $0^{\circ}33'35''$ West, a distance of 98.99 feet to the true point of beginning.

EXCEPT the South 10 feet there of.

Situate in the County of Skagit, State of Washington.

Property Agreement for Trail Easements

December 14, 2020



Terms of the Agreement

- Parties

- City of Anacortes
- Wynn Family Trust by Trustees Tom and Sylvia Wynn
- Ortman Family LLCs

- Consideration

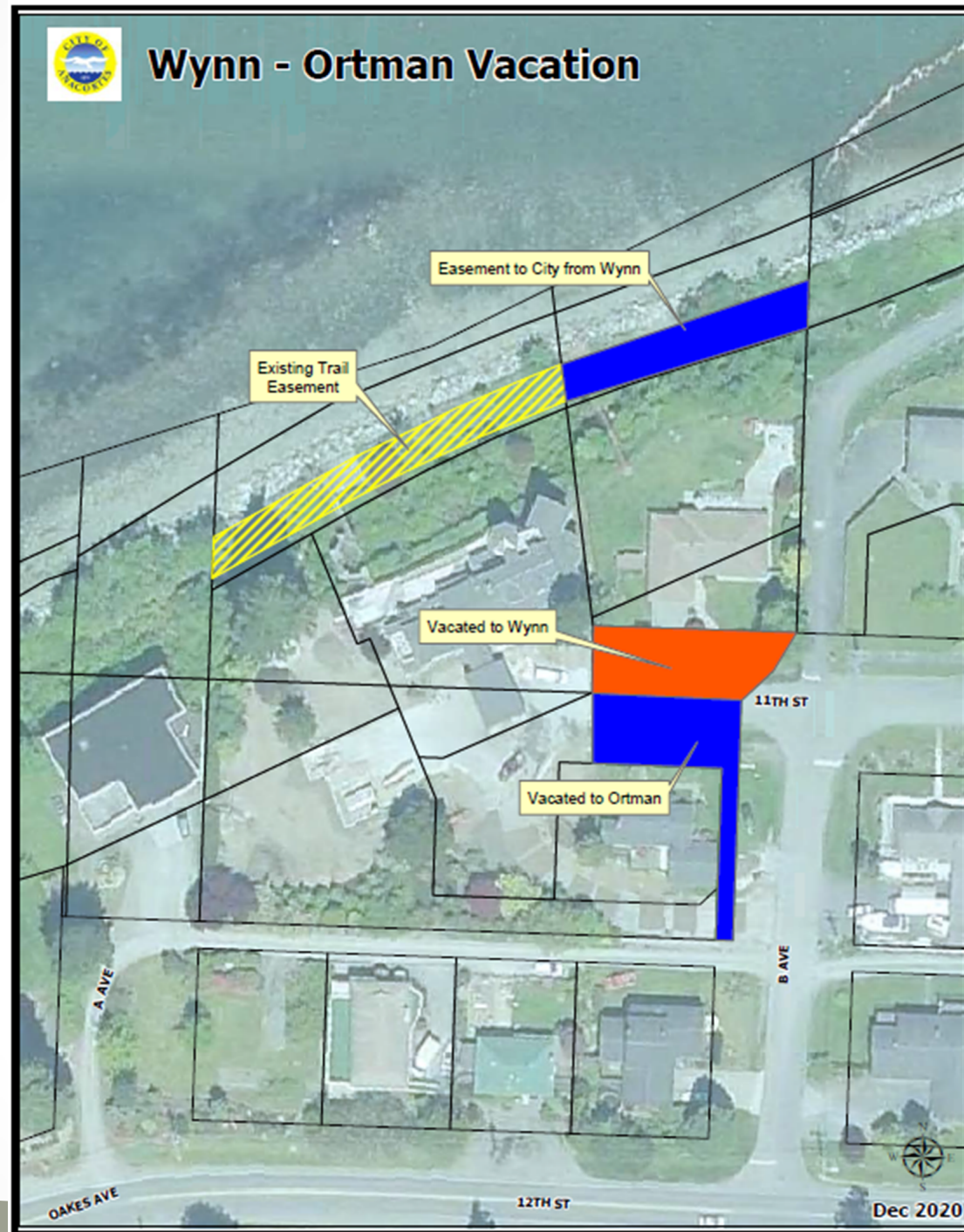
- The City will initiate a process to vacate portions of 11th Street and B Avenue
- If approved, the Wynn family will convey an easement to the City along the Guemes Channel for trail purposes
- The Ortman family has already vacated an easement along the Guemes Channel for the trail

- Additional Info

- The City has been discussing concerns and process with the Parties for over 2 years
- City is not bound to grant vacation, but will not secure easement unless vacation is granted



Wynn - Ortman Vacation



Steps to Carry Out Agreement

- Contract Approval (12/14?)
- City initiates vacation w/in 10 days of execution of Agreement
- City processes vacation petition
- If City grants vacation, Wynn Family Trust executes Easement to the City w/in 10 days of vacation



Hans Glaeser

March 31, 2021

To
City Attorney's Office

Anacortes, WA 98221

We submit enclosed petition.

Sincerely,

A handwritten signature in dark ink, appearing to read 'Hans Glaeser', written in a cursive style.

3-30-2021

PROPOSED VACATION OF 11TH STREET AND B AVENUE PETITION

Insofar as the undersigned are desirous of learning more about the proposed extension of the Guemes Channel trail, we ask City Council to provide more time to understand the full impact of vacating portions of 11th Street and B Avenue. It is unclear why portions of B Avenue will be vacated and requests for additional information were not returned by the City Attorney. It is also unclear what can be developed on the vacated portions of 11th Street. Can the existing compound at the end of 11th Street become ever larger and more incompatible with our neighborhood?

We ask that you please allow more time to adequately understand the proposal to vacate 11th Street and B Avenue.

Name

Address

1	Ken Flores	2319 11th Street
2	Mary Flores	"
3	Dinda B. Schaff	1100A
4	Theresa S. Schaff	1100A
5	Klozer	2504 Oakes Ave
6	John Narden	2514 OAKES AVE
7	Peggy Narden	2514 Oakes Ave.
8	Sam King	2412 12TH ST
9	Betty J. King	2412 12TH ST
10	Sharon Harvey	1118 B Ave (Bx 2055)
11	My B. Moulton	2602 OAKES AVE
12	Karen Thompson	2520 Oakes Ave

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We ask that you please allow more time to adequately understand the proposal to vacate 11th Street and B Avenue.

Name

Address

13 Norman E. Thompson 2520 Odessa Ave.
14 [Signature] 2308 12th St
15 [Signature] 2308 12th St (Sam Gork)
16 Willo Jean Holt 2306 12th St.
17 Cynthia Morton 1009 C AVE.
18 [Signature] DON MORTON 1009 C AVE
19 James E. Anderson 1006 C AVENUE
20 Jim Anderson 1006 C Avenue
21 Clarice Way 2203 10th St. Anacortes
22 [Signature] 2203 10th Anacortes
23 [Signature] 2207 10th ANACORTES
24 [Signature] 1014 C AVE Scott Betts
25 [Signature] 2219 10th St.

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We ask that you please allow more time to adequately understand the proposal to vacate 11th Street and B Avenue.

Name

Address

Fwd: vacation application for 11th St and B Ave

From: Arne Glaeser arne.glaeser@comcast.net

To: Hans Glaeser HKGLAESER@HOTMAIL.COM

Date: Sunday, March 21, 2:38 PM

----- Forwarded Message -----

Subject:vacation application for 11th St and B Ave

Date:Sun, 21 Mar 2021 17:37:10 -0400

From:Arne Glaeser [<arne.glaeser@comcast.net>](mailto:arne.glaeser@comcast.net)

To:darcys@cityofanacortes.org

Mr. Swetnam,

Good afternoon. A public notice is posted at 11th Street and B Avenue for the proposed vacation of 4 parcels. The notice does not provide an application number and I could not find information quickly for this City initiated proposal on the City's website. I hope to gather information about the proposed vacation if you don't mind prior to the deadline to submit comments.

What is the purpose of the City proposed vacations particularly for the proposed vacation of lots #4 and #5 along B Avenue? The extra 10 feet of right of way is more than other parcels along B Avenue and I am particularly curious why the City proposes to vacate that 10 foot strip to the Ortman's. Was a request made by the Ortman's for this 10 additional feet of City property? If the Ortman's or any other owner removes the building at 2401 B Avenue, what is the height limit in that zoning district and how close can a structure be located along B Avenue if lots #4 and #5 are vacated. Additionally does the B Avenue frontage for 2401 B Avenue become the front yard for that parcel if that parcel no longer has frontage along 11th Street if parcels #2 and #3 are vacated? The front of that house is oriented to 11th Street and I wonder if the front yard will be along B Avenue if the two parcels of 11th Street are vacated. Are utilities located in parcels #4 and #5 that are proposed to be vacated? Finally, have any discussions been held by the City with the Ortman's for demolition or new construction on their parcels?

Madam Mayor, City Council,

My name is Sean Noronha and I am the owner of the property at 1117 B Ave. I would like this written statement to be considered for the petition by the Ortman and Wynn families to vacate 11th Street and B Ave. As a concerned citizen, I am writing to urge you to block the vacation request. **I do not believe that it is in the best interest of the city to pursue vacation as it would be detrimental to the adjacent community, as well the long-term effects that would hinder the Anacortes community at large.**

Anacortes has had a long history of accessibility to people across a wide range of socioeconomic statuses. This equity has enabled the growth that allowed folks to contribute, in ways outside of their income, to the benefit of the community writ large. What Anacortes is not, is an exclusive community that caters to the whims of individuals (or families) that utilize their vast funds to put up walls, both fences and of trees, and continue to pursue additional resources that only serve themselves. In 1962 when Anacortes became an “All American City”, the recognition was meant to showcase the integral work of the whole community as it pertains to “address critical issues and create stronger connections among residents...” which in this case, would bring a sense of irony given the current situation facing the neighborhood.

If the city were to continue with this request, it would lend credence to the optic that city entities are seemingly appeasing an individual(s) whose primary goal is to acquire more property and subsequently eliminate views, within our community, even more so than has happened in the past, from the previous street end vacation. To add insult to injury, these individuals do not even call Anacortes their home part-time, much less full-time. **Our neighborhood must live with the effects year-round.** We must also be cognizant of the slippery slope this vacation could start; down a path where other individuals could potentially pursue street end vacations throughout Anacortes, not just in Old Town, costing the Anacortes community dearly for generations to come.

The process for this vacation also proved to be shockingly inequitable and unjust, leaving respondents with no clear notice, and a highly compressed timeframe to respond. While not specifically pointing fingers at any one entity, the lack of overall material and the continued lack of transparency results in an appearance of complicity in an effort to focus on a singular goal (Guemes Channel Trail).

I urge you to vote “No” on this vacation for the greater good of all Anacortes residents.

Thank you for your consideration. I can be contacted at sean.j.noronha@gmail.com for any questions, and would be happy to elaborate for further questions.

Sincerely,
Sean Noronha

March 23, 2021

Included are questions related to the proposed vacation of property on 11th and B in Anacortes (maps below). Please consider them as decisions are made related to the proposal.

1. On 08/02/2010, an easement for trail purposes, across the north portion of the Ortman property, was granted. What were the conditions of that transaction?
2. Why now, with no exchange, are the Ortman's being gifted 4,906 square feet. (The Wynn's are gaining 4,125 square feet in exchange for their easement.)
3. What is the dollar value of the land now being gifted?
4. While one can read the legal descriptions, to the untrained reader they are difficult to understand. Per the property agreements signed in 2020 on 11/7 and 11/13, five separate properties are being vacated. No flagging distinguishes the properties. Are they somehow 'merged' on the map?
5. There is a fire hydrant that appears to be in the vacated portion of B and 11th. If it needs to be moved, at who's expense will that happen? There also appears to be a 'deck' near the shore on the Ortman's property. What will be the consequences of this agreement on that structure?
6. Have the owners been educated about shoreline vegetation management?
7. AMC 12.50.060 lists the factors to be considered in vacation determinations, and 'B' is one of these: "Whether the street or alley is neither currently required for public use or public access nor anticipated to be needed for public use or access in the future." This raises the question: are there possible public uses for the vacated property? The City clearly has some long-term plans for the pier east of the referenced property. What will be the access and the parking capabilities?
8. Does it make sense to negotiate for a trail segment that goes from and to nowhere? On the west end, Lovrics has publicly stated hesitancy at having the GCT go through their property; on the east end, the land is privately owned and there is limited room for a trail. The shoreline is susceptible to winter storms and sea level rise. Will this be a repeat of the problems associated with Phases 1 and 7 of the current GCT (inadequate and unsuccessful mitigation, slope destabilization, repeated trail damage)? Additionally, there is no public access. And, finally, the state's Puget Sound recovery efforts are aimed at **removal** of shoreline armoring; this plan will likely **add** armoring.

Hopefully some of these issues can be addressed at the April 5 public hearing. Thank you.

The first photo below is taken from Google maps, the second is a screenshot of a presentation from the 12/14/20 City Council Meeting.



Swetnam, Darcy

From: Karin Glaeser <hkglaeser@hotmail.com>
Sent: Monday, April 12, 2021 11:46 AM
To: Swetnam, Darcy
Cc: Walters, Ryan (Anacortes City Council)
Subject: Vacation application for 11th Street and B Avenue

Mrs. Swetnam,

We are opposed to the proposed vacation of B Ave. It is in conflict with 12.50.070 because the B Avenue portion requested to be abandoned could be needed for public use, such as a new side walk or even bike lane.

Also, it would be of interest to know why B Ave portions are requested to be vacated and who requested them to be vacated.

Mr. Ortman gave already easement for Guemes Trail at an earlier time. Why is he getting in addition part of 11th Street and B Avenue?

Our concerns about setbacks and hight limits etc. for possible construction on the Ortman property after acquiring part of B Ave. and 11th Street in our letters March 21st and April 8th were never addressed.

Sincerely,

Hans and Karin Glaeser, 2319 11th Street April 12th 2021

Swetnam, Darcy

From: Jessica Guzik <jessica.swapp@gmail.com>
Sent: Monday, April 12, 2021 9:48 AM
To: Swetnam, Darcy
Subject: 11th and B Ave

Hello Darcy,

I would like to submit my concerns about the city's plan to vacate land on 11th ST and B Ave. I support the Guemes Channel Trail project, but I'm worried that the planned land exchange will open the door to people building even larger houses.

From what I've heard, the owners of the gigantic house on the shoreline (The Ortmanns?) could use this as an opportunity to build up even higher. It seems like that's why they would want the tiny strip of land up B Ave; to get a higher point on their property so they can build two stories up from the highest point. What other reason would that owning that strip along B Ave serve? This would block the rest of the neighborhood from enjoying our properties. They could also buy the Wynn's property and do the same thing, building another huge house that doesn't fit the neighborhood.

I urge the city not to make this exchange, and to look out for the interests of the bulk of the neighborhood.

Thank you,
Jessica Guzik
2308 12th ST, Anacortes
971-801-0138

Dear Att. Sweetnam,

4/13/21



My computer is not working so please excuse my hand-written letter of concern.

#1

YES

I live at 1118 B Ave. The Ortman and Wynns request for "vacating" 11th street I fully agree to! This request makes complete and logical sense!

But to the 2nd request on B

Ave ... NO, I do not agree to this request. The Ortman are very-very Rarely at this Anacortes

LOCATION. This B Ave request makes

NO Sense (other than the RICH People getting MORE-MORE-MORE) (the Haves vs the HAVE-NOTS) yet again? The Ortman

#2



NO

↑A↑

ridiculous Request.



have full time caretakers who live at
the property full time BUT OTHERWISE
are at 1114 B Ave basically NEVER!
(98% of the time they are not there nearly
EVER)

So please leave B Ave. remaining
as is and give them 11th Street, -YES.

Sincerely
Thank you,

Sharon Elizabeth
Harvey (HARVEY)

1118 B. Ave
Anacortes, WA. 98221

ph. 360-293-9283

Rebecca J. Ivie
2309 11th St
Anacortes, WA 98221

April 13, 2021

City of Anacortes
Anacortes City Council

I am writing to ask you Not to approve the Wynn Ortman Vacation.

I have lived on 11th St. since 1994. The City already vacated a portion of 11th St. to the Ortman family in 2009/10. The Ortman family built a fence across 11th. It was too tall for the code. Neighbors complained and the city required the fence be removed. Next the Ortman family put up a 42" fence and planted fast growing evergreens which blocked the water views of multiple property owners.

Based on this track record, neighbors are concerned about what will happen next at the end of 11th St. I think my neighbors and I are all trying to visualize what our street will look like in the future, because we didn't envision how the previous 11th St. vacation would radically change the look and feel of the neighborhood.

If the Wynn family does end up to selling to the Ortman family at some point, I feel it's likely that these city streets, a strip of B Ave and the end of 11th St., will be absorbed into the Ortman compound. More building will happen and more neighbors will lose views.

Our view to the west is already ruined. I would hate to see other neighbors lose their views as well. It's unfortunate that this proposal was brought to the City Council, by the City of Anacortes staff, as a package deal with both property owners involved. I don't think most neighbors would oppose the Wynns getting ½ of the end of 11th in exchange for their waterfront property. If they put up a "private property" sign to discourage people from parking there, that would be fine with me. I do oppose giving more city land to the Ortman family.

It is also unfortunate that this street vacation, which the Ortman family have been trying to get for many years, is also being combined with the Guemes Channel Trail concept (GCT). I think most reasonable people would agree that vacating streets is a bad idea for Old Town Anacortes. If these same people are pro GCT, I fear they will have a hard time deciding which is more important.

In the Anacortes American, there was a statement about the Wynn and Ortman families wanting the city to "turn over ownership of the street end to them so they can protect access to their properties." Just to be clear, there is currently no lack of access to either property. The Ortman family have a private road off B Ave. with a large gate. The Wynns have no problem accessing their property from 11th St.

There are other concerns and complicating issues such as; The Ortman caretaker house garage being in the setback, the fire hydrant (what happens to that?), the ongoing sewer problems at 11th and B Ave., the conflict with AMC 12.50.100 B, as well as the precedent that would be set.

Currently, the GCT is a long way away. There are 14+ property owners, between Lovric's shipyard and the Ortman land, who are not in favor of giving up their waterfront for the project. I am in favor of delaying this Wynn Ortman vacation proposal until such a time when the GCT plans are more evolved and the trail is more likely to become a reality.

Thank you so much for your time and interest in this proposal and for listening to the people who make up this neighborhood.

Rebecca Ivie
360-20-6286

Swetnam, Darcy

From: Beck Ivie <becksteriv@icloud.com>
Sent: Tuesday, April 13, 2021 7:51 AM
To: Swetnam, Darcy
Subject: 3 photos and a Word Doc related to Wynn Ortman Vacation for April 19 City Council Meeting
Attachments: City Council 1.docx



Swetnam, Darcy

From: Walters, Ryan (Anacortes City Council)
Sent: Thursday, April 1, 2021 9:18 AM
To: Swetnam, Darcy
Subject: Fw: 11th Street/B Ave. Vacation; Resolution 3017
Attachments: Bave_11th_Vac_LD.pdf; BAVE_11th_Vac_SketchMap.pdf

See this email as well.

Ryan Walters

Anacortes City Councilmember, Ward 1
mobile 360-610-7770

From: Gary E Munsterman <gmunsterman@sbcglobal.net>
Sent: Friday, February 26, 2021 3:10 PM
To: Walters, Ryan (Anacortes City Council) <ryanw@cityofanacortes.org>
Cc: Marlene Finley <marlenefinley17@gmail.com>
Subject: 11th Street/B Ave. Vacation; Resolution 3017

Councilmember Walters – The Anacortes American alerted me to the subject pending action before the City Council on 1 March 2021. Inasmuch as our residential property, is bounded on two sides by undeveloped public city right-of-way (ROW), I reviewed and provided comments on the 2020 ordinance amending vacation criteria and procedures in Municipal Code Chapter 12.50 and am similarly interested in it's application. I also frequently use B Avenue as a walking route to and from my residence on Kellogg Place. Since both the project site and our residence are located within your district, I am alerting you to several concerns regarding the pending City Council action.

My most significant concern is the difficulty in obtaining readily available public information on the proposal through the Council's 1 March meeting packet. In order to obtain the attached sketch map of the proposal, I was required to refer back to the 14 Dec 2020 meeting packet, Exhibit B to a Property Agreement between the City and property owners. I also find a deficiency in the resolution in that nothing in the agenda item describes property proposed to be vacated. Section 2 and Exhibit B of the resolution describe effected parcel numbers, but neither describe the areas to be vacated. I suggest that the attached legal description inserted as a resolution exhibit.

In my reading of the Property Agreement approved by the Council in December, the Council has agreed to initiate the vacation pursuant to AMC 12.50.020 (B), as opposed to a petition prescribed in 12.50.020 (A). This is significant in that a council initiated petition effectively waives compensation requirements pursuant to AMC 12.50.100 (B). AMC 12.50.110 establishes a method of providing a credit for the dedication of alternate property for "street purposes" however despite staff's presentation of the proposal as an exchange, I see no obligation on the part of the property owners to grant the easement under the terms of the Property Agreement. The presentation slides attached to the Property Agreement in December suggest that the property owners would initiate the grant of the easement within 10 days of the ordinance approving the proposed vacation, however there is no corresponding language in the Property Agreement. A suggested remedy would be to delay the effective date of the vacation ordinance to when the trail easement is granted by the property owners.

I would like for you to consider proposing the council direct staff to obtain either an appraisal or an opinion of value for both the proposed vacation area, which I estimate to contain over 9,000 sf of buildable lands, as well as the area of the proposed trail easement. The waterfront easement most assuredly has monetary value. With the City's vacation compensation policy in AMC 12.50.100, I believe the public has a right to know if the valuations have equivalency. Such

a determination would also inform the feasibility of acquiring trail easements from other property owners between the project area and the existing completed section of the Guemes Channel Trail.

As indicated on the attached sketch map and legal descriptions, the proposal also includes the vacation of a 10 foot strip of the B Street RoW. Section 12.050.070 of the newly adopted code section established a new city policy against vacation of portions of RoWs. Under the new code section there is an opportunity to grant an exception under some broad criteria which include consideration of public benefit. Absent a remedy for the lack of a legal obligation for the property owners to dedicate the trail easement under the terms of the Property Agreement, I see no benefit. If the city council grants an exception under this policy for one of the first vacations requests under the new ordinance, the city has effectively by precedent nullified the policy and should strike AMC 12.50.070. I believe the policy is sound and the City should not allow petitions to piecemeal shave sections of RoW for vacation.

I am supportive of city acquisition of the proposed trail easement to adjoin with the prior segment granted 11 years ago if the City would commit to pursue a use and trail easement for the privately owned B Street extension from the owner of Assessor Parcel # 56375 proceeding towards the Channel and providing access to the existing cannery. I do not believe it is a prudent use of staff resources to pursue trail easements which do not have near term public utility or are a part of an approved and funded city project.

The City is endowed with generous RoWs, many of which remain undeveloped which greatly contribute to wildlife habitat, open space, stormwater management and the overall quality of life. I would be interested in further exploring some ideas on how these assets can be better address a broader range of community needs. If you have any questions concerning the above comments or to more further discuss other RoW management options please reply or call.

Gary Munsterman
1410 Kellogg Pl
415-272-3911

Sent from [Mail](#) for Windows 10



Virus-free. www.avast.com

Dear Anacortes City Council,

My name is Angela Roush, I live and own the home at 2316 12th street, and I am writing to urge you to block the petition by the Ortman and Wynn families to vacate 11th Street and B Ave.

This vacation sets a detrimental precedence for all of Anacortes. Additionally, it has been poorly explained to the community. I have heard from neighbors that this vacation was a) initiated by the city and b) for the trail, two details that I can only presume because I have not received or seen any additional information at the time of my sending this letter / petition to indicate if this is actually true.

I do sympathize with the desire to build the trail. But there will be unintended consequences if the Ortman family gains more land for the community. You would be giving more land to a family that has purposefully shut out the entire rest of the community that surrounds it with their two-story tall row of evergreens. If you haven't already, I recommend you stand at the end of 11th street and note the tall row of evergreens that the Ortman family has planted. I believe they would plant even more trees to isolate themselves from the rest of the community if given the chance with this vacation. The worst part of all of this is that the Ortman family only lives in Anacortes for the summer months, usually starting around the 4th of July, and ending when the Arizona temperatures become tolerable again.

I believe that without the vacation, we the surrounding community have some leverage to have the giant hedge reduced in size, but if the Ortman family gains this portion of 11th street in the vacation, well, that might place the rest of us at a disadvantage. Because I am not an expert at reading Municipal Code, I would like for this issue to be addressed prior to a decision by the city council. Specifically, how is it that the Ortman family was required by the city (and I presume the Municipal code) to lower the portion of their fence that crosses the end of 11th street (you can see a very clear height difference), yet they have been allowed to keep and maintain a thick evergreen hedge right next to the fence that reaches roughly 10 times the fence height, is that to code now, and would it be to code if they gain the land in the vacation?

In summary, I ask city council to please deny this vacation. Please keep Anacortes as a thriving community first and foremost, not a scenic plot of land for the wealthiest to monopolize, one vacation at a time. Thank you for your consideration.

I can be contacted at aroush16@gmail.com for any questions, and would be happy to elaborate on what I have written.

Swetnam, Darcy

From: June Steen <steen.june@gmail.com>
Sent: Sunday, April 11, 2021 9:10 PM
To: Swetnam, Darcy
Subject: 11th St vacation.

Mr. Swetnam,

I am June Steen, 2410 12th St, Anacortes, WA 98221. My property is across the alley from the Ortman property.

I am in favor of continuing the Guemes Channel trail. I approve vacating the end of 11th St in order for this to happen. However, I am concerned with what might happen with the Winn property. I hope that no construction will be allowed so near the high bank and the shore. When the Ortman's bought their property, they "remodeled" and "built on" the small house until it was the present mansion. The construction went on for years. My understanding is that this was done to get around the prohibitions against building so near the bank and shoreline. I hope this will not happen again.

I am not in favor of vacating the 10 feet of B Ave. I would like to see curbs and sidewalks on B Ave someday as well as in the surrounding neighborhood. Also, when the Guemes Channel trail is completed, this 10 feet of B Avenue might be used as parking for access to the trail at the end of B Ave.

Please put my comments into the record.
Thank you.

June Steen

Swetnam, Darcy

From: Vaux, Bob
Sent: Monday, April 12, 2021 8:46 AM
To: Swetnam, Darcy
Subject: FW: From the Wynn Family re. the Guemes Channel Trail

Good Morning... forwarding as promised. bv

From: Laura Wynn <lwhuntite@gmail.com>
Sent: Sunday, April 11, 2021 8:34 PM
To: Vaux, Bob <Bobv@cityofanacortes.org>; Sylvia Wynn <swynn36@frontier.com>
Subject: Fwd: From the Wynn Family re. the Guemes Channel Trail

Hi Bob:

Should Darsy see this letter, I do not have her email

Thanks

Laura

----- Forwarded message -----

From: Laura Wynn <lwhuntite@gmail.com>
Date: Mon, Apr 12, 2021 at 6:31 AM
Subject: From the Wynn Family re. the Guemes Channel Trail
To: <laurieg@cityofanacortes.org>, <christinec@cityofanacortes.org>, <jeremyc@cityofanacortes.org>, <mattm@cityofanacortes.org>, <brucem@cityofanacortes.org>, <carolynm@cityofanacortes.org>, <anthony@cityofanacortes.org>, <ryanw@cityofanacortes.org>

Dear Mayor Gere and Anacortes City Council Members:

This letter is to help clarify the information regarding Resolution 3017 scheduled for April 19th 2021.

After negotiations with the city/council the Wynn Family agreed to grant an easement to the city which is located at the water's edge of our property. This easement will enable the city to continue the construction of the Guemes Channel Trail and when finished will be a valuable asset for all the residents of Anacortes to use and enjoy. In return, the city/council is willing to vacate to the Wynn Family the north half of a small, dead end section of 11th St. that abuts our property. This agreement also allows the Ortman Family this same section of the south half of 11th Street which abuts their property.

The continuation of the Guemes Channel Trail from Lovic's going east has been in the works for a very long time and we believe this exchange between the Wynn family and the city/council is a positive step forward to ensure the Guemes Channel Trail will become a reality that will benefit all the

citizens of Anacortes.

Yours Sincerely,

Sylvia Wynn and the Wynn Family

Hunt, Marcia

From: Jane Brandt <vjbrandt@hotmail.com>
Sent: Monday, April 19, 2021 8:53 AM
To: CityClerk
Subject: Ordinance 3087 6b. Critical Area Regulations draft 3
Attachments: Ordinance 3087.docx

Comment for Mayor and City Council
Regarding tonight's agenda
Thank you
Jane Brandt

Sent from [Mail](#) for Windows 10

Ordinance 3087

6b. Critical Area Regulations Draft 3

Anacortes City Mayor and City Council Members

I am contacting you to express concern that the proposed 6b. Critical Areas Draft 3 does not offer important protection for areas such as SHIP. I am grateful that the March Point Heronry and the AFCL have increased protection but areas such as SHIP have diminished protection. SHIP is designated a Habitat of Local Importance and the language in Draft 3 is weakened from Draft 2. The Washington Department of Ecology gave SHIP a score of 8 for habitat which is the second highest rating. This area is important to the nesting bird population and to other forms of wildlife. As natural areas disappear in the city, areas such as SHIP will become even more important to sustaining the bird and other wildlife populations. This year a new nesting colony of great blue herons has been established at SHIP and the Ospreys have nested there for years, telling us that this is an important area to be protected. I am not a great birder but those who are, have noted 30 to 40 species in this area.

I am very concerned about the loss of critical habitat for flora and fauna in this city. I hope that you will think of the future and protect areas that have contributed to Anacortes being special. I urge you to take seriously and support Evergreen Islands recommendations to the Anacortes CAO, Draft 3. Please think of the future of Anacortes and do not decrease protection for critical areas of importance to the natural environment which supports the bird and other wildlife populations in the city.

Respectfully submitted

Jane Brandt

3936 W. 12th Street

Anacortes, WA 98221

Hunt, Marcia

From: wlfarmer <wlfarmer@earthlink.net>
Sent: Friday, April 16, 2021 5:30 PM
To: CityClerk
Subject: Letter in Support of City Vacation/Easement for Guemes Trail
Attachments: Letter Supporting 11th St. Easement 2021-04-16.jpg

See attached. Please circulate copies to Mayor Gere and City Councilmembers in advance of hearing April 19, 2021.

Walt Farmer



Virus-free. www.avast.com

Walter L. Farmer
1518 10th St.
Anacortes, WA 98221
(909) 635-5889 (cell)

April 16, 2021

Hon. Laurie Gere, Mayor
Anacortes City Councilmembers

Via Email and
regular mail
to Anacortes City Clerk

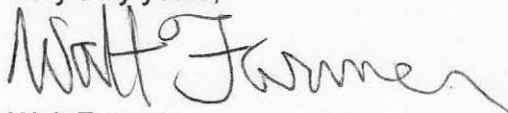
Dear Mayor Gere and Councilmembers,

I'm writing in support of the proposed agreement between City of Anacortes and property owners to vacate City street at 11th and B in return for an easement on the owners' land, for use as part of the proposed Guemes Channel Trail.

Anacortes' reputation as a seaside bedroom community, as a Port serving the San Juan Islands, and tourism center of Skagit County will be enhanced by connecting the Tommy Thompson Trail with the Guemes Channel Trail. The right to use this easement is another step toward completion of a unified non-motorized connection across the entire City of Anacortes.

Regional, state and federal policies are consistent with the public's preference for clean, healthy transportation improvements. This step will advance a distinctive project that will improve the quality of life for all, residents and visitors alike, and it is the right thing to do.

Very truly yours,



Walt Farmer
WLF/wf

Hunt, Marcia

From: Hunt, Marcia
Sent: Monday, April 19, 2021 2:31 PM
To: Hunt, Marcia
Subject: RE: Additional Document for 19 Apr Meeting

From: Sean Noronha <sean.j.noronha@gmail.com>
Sent: Friday, April 16, 2021 2:31 PM
To: Swetnam, Darcy <darcys@cityofanacortes.org>; Holden, Alexandra <alexandrah@cityofanacortes.org>
Subject: Additional Document for 19 Apr Meeting

Darcy/Alexandra,

I don't know if your system can take emails with 20MB files so I've attached it to my Google Drive.
<https://drive.google.com/file/d/11mqeT40Os-YhMwV1E43UZg0c2fNDYiC3/view?usp=sharing>

Please let me know if you do not receive it.

Best,
Sean

GOOGLE EARTH IMAGERY FROM 2006 TO PRESENT

SEAN NORONHA

1117 B AVE

2006

Street end of 11th pre-vacation

Residents with views unaffected by northern property (Felitsa Demopoulos. Previous owner of land/homes)



Image © 2021 Maxar Technologies

Google Earth

2009

Street end of 11th vacated
(construction in progress)

Residents with views affected by
northern property (Ortman)



2011

Residents with views affected by northern property (Ortman). Tall trees and fence erected along the entire length of alleyway

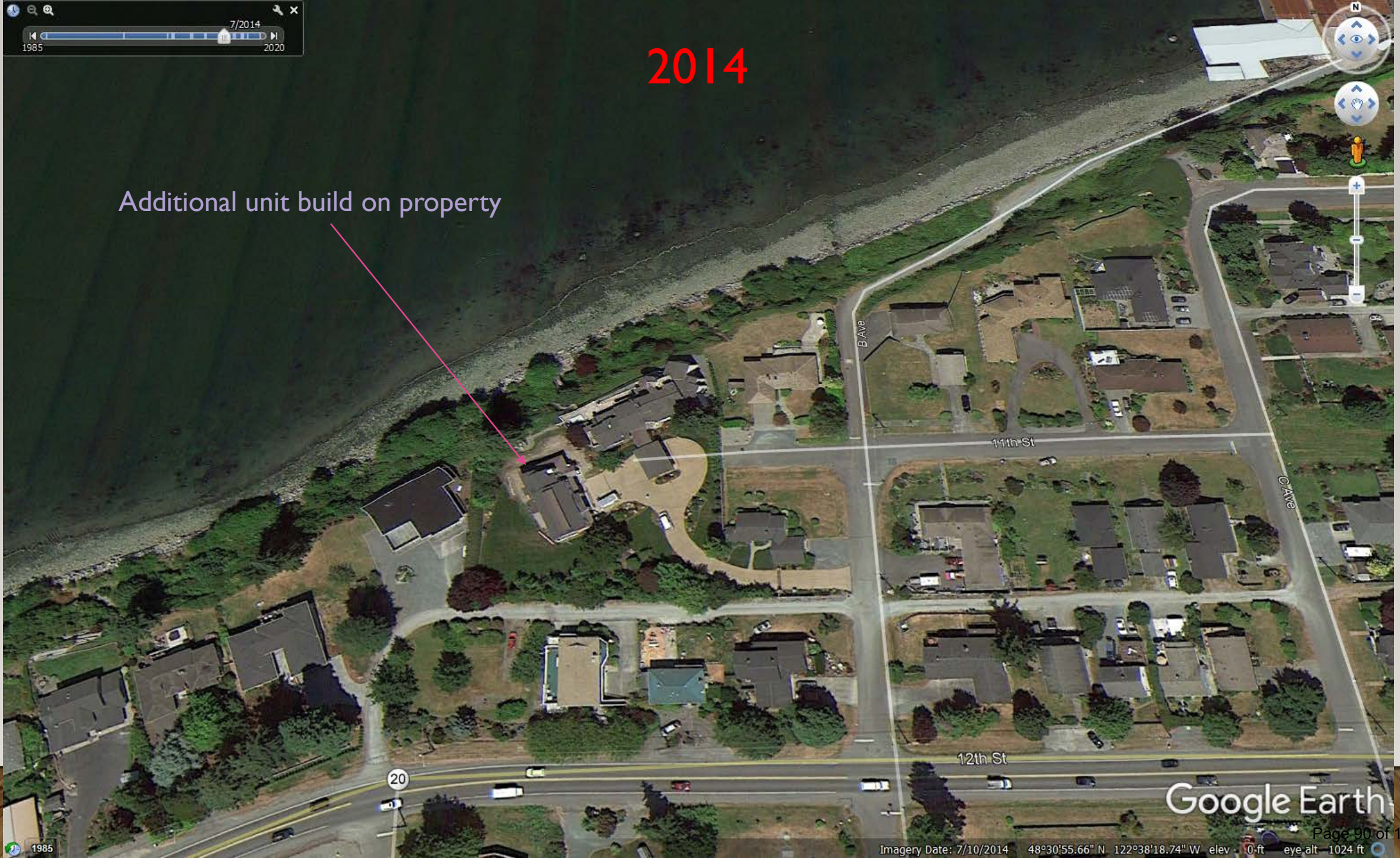
Street end of 11th vacated, and tall fence erected. Unsure of when city forced Ortman Family to comply with setback height restriction of fence



Google Earth

2014

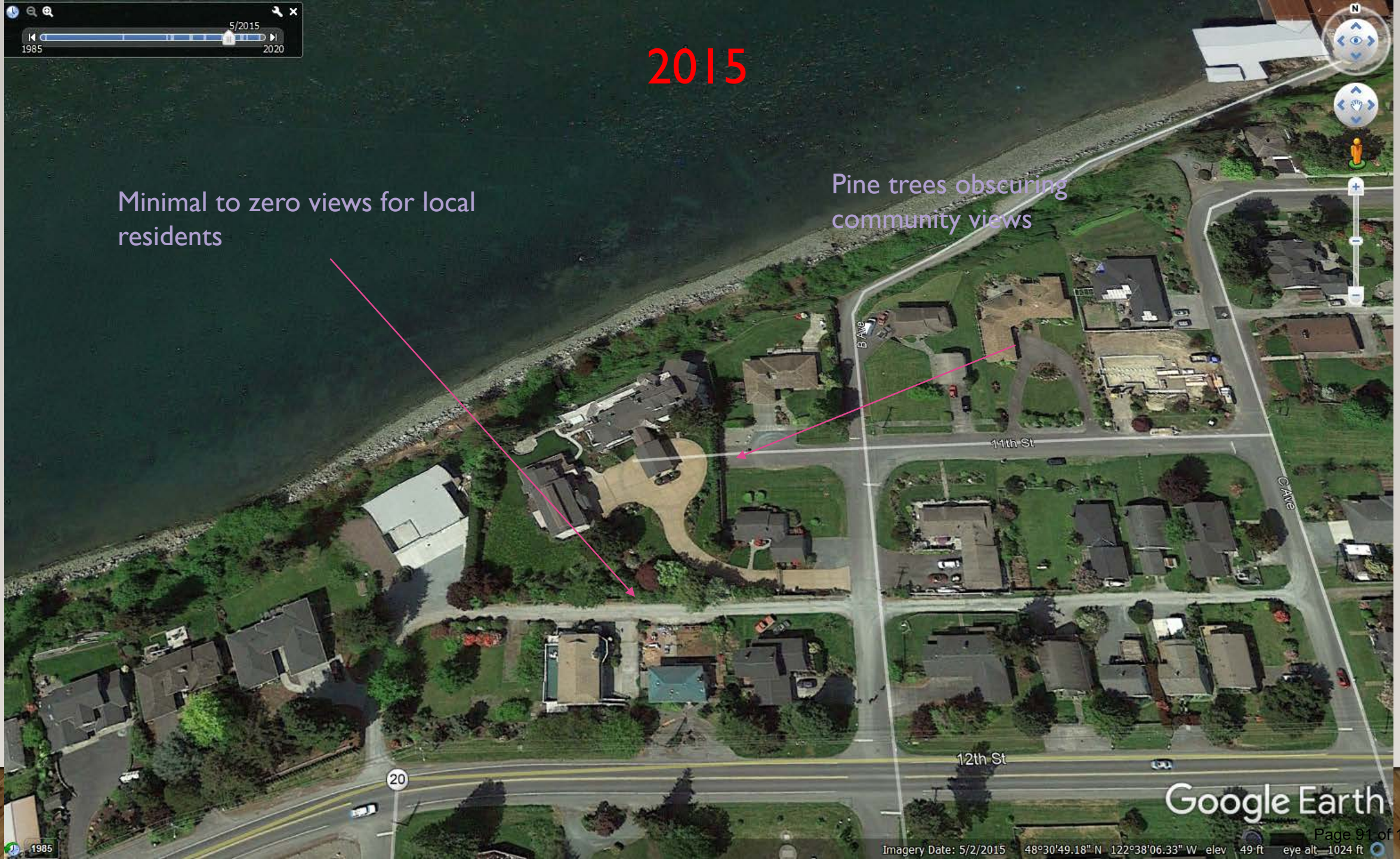
Additional unit build on property



2015

Minimal to zero views for local residents

Pine trees obscuring community views



Google Earth

2020

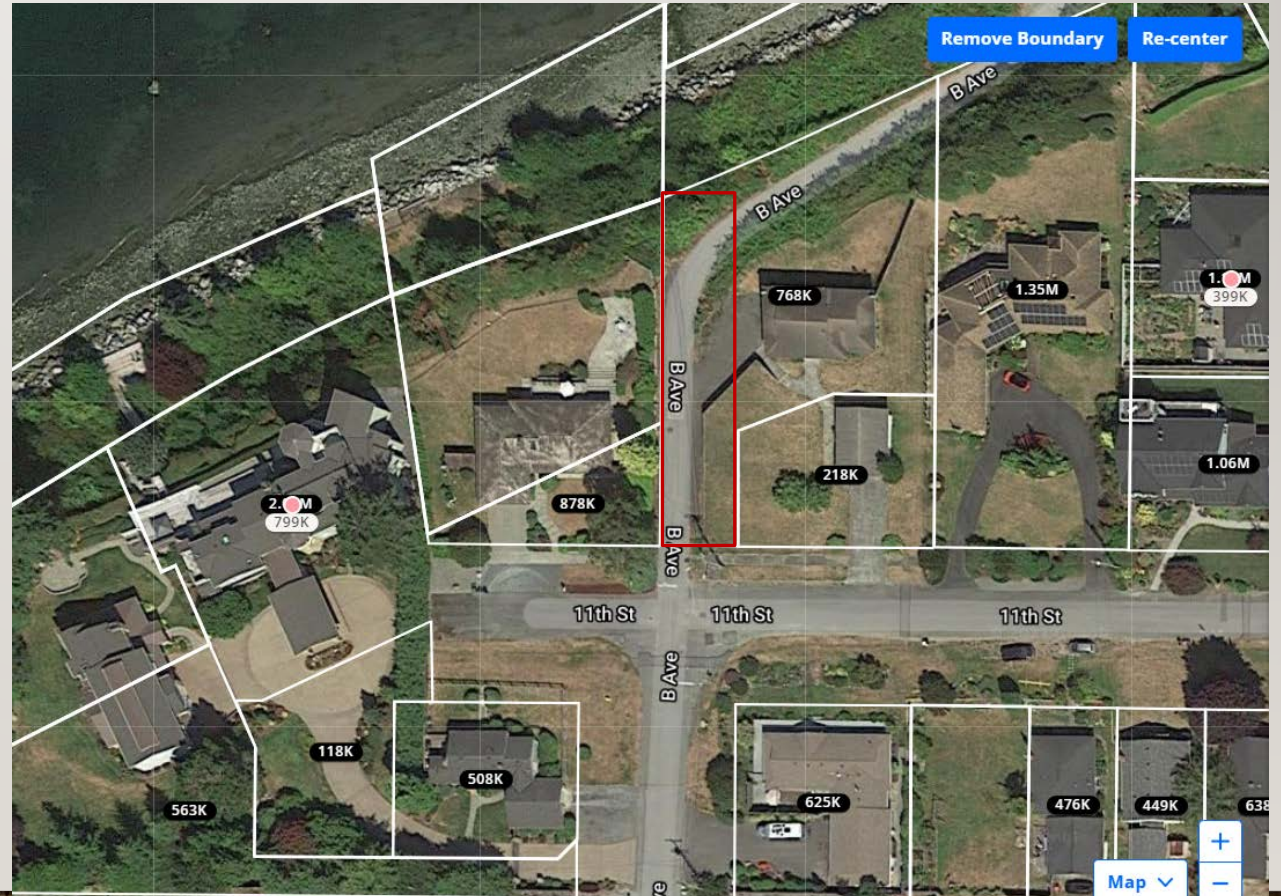
Neighborhood assumption that the entire property would be cordoned off, with tall fences, tress, etc (future?)



Google Earth

MUDDY WATERS...

- Additional questions to address:
 - City vacation of B Ave land to P56375 (2322 11th)
 - If the GCT were to be built, how does the surrounding community access from what *used* to be public access to the waterfront and now is private land? 2007 vacation of Lots 1 & 2 of AN SP 93-004?



SOME HISTORY

- Anacortes American
10 June 1998 —
Washington Digital
Newspapers

- Vacation was denied for the previous owner, but given to owner with monetary means?

**WS**
Office of the Secretary of State
Washington State Library

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🏠 / Anacortes American / 10 June 1998

Anacortes American, Volume 109, Number 12, 10 June 1998

Issue Article ▾

Street vacation denied
Anacortes American (Anacortes, WA), 10 June 1998, B4.
<https://washingtondigitalnewspapers.org/?a=d&d=ANACAMER19980610.2.47>

Text

Why may this text contain mistakes?
Correct this text 🛠️

Street vacation denied

A street vacation in the city's oldest neighborhood, one that offers a striking view of the Guemes Channel, was denied by city councilors because it had the potential for too great an impact on neighbors. Felitsa Demopoulos, who lives at 2408 11th St., petitioned the city for a street vacation there. She wants to buy a 900-square-foot wedge that would, subsequently, allow more developable channel frontage. But some city councilors said they were puzzled, that Demopoulos probably already has

Keeping track of the weather planners

Company's predictions right on first try, but let's see how they do in June



WEATHER OR NOT VINCE STREATO

It's been a month since the weather planners' predictions were first published. They were pretty good, but let's see how they do in June.

At first, I was skeptical. I mean, I had heard that the weather planners were good, but I didn't know how good. So I decided to test them. I took a walk around the city and saw how many of the predictions were correct. I was surprised to find that they were pretty good. I mean, I had heard that the weather planners were good, but I didn't know how good. So I decided to test them. I took a walk around the city and saw how many of the predictions were correct. I was surprised to find that they were pretty good.

Ok, maybe Weather Planners got lucky with my first forecast. So I decided on a second test, one we can all monitor.

At first, I was skeptical. I mean, I had heard that the weather planners were good, but I didn't know how good. So I decided to test them. I took a walk around the city and saw how many of the predictions were correct. I was surprised to find that they were pretty good. I mean, I had heard that the weather planners were good, but I didn't know how good. So I decided to test them. I took a walk around the city and saw how many of the predictions were correct. I was surprised to find that they were pretty good.

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A street vacation in the city's oldest neighborhood, one that offers a striking view of the Guemes Channel, was denied by city councilors because it had the potential for too great an impact on neighbors. Felitsa Demopoulos, who lives at 2408 11th St., petitioned the city for a street vacation there. She wants to buy a 900-square-foot wedge that would, subsequently, allow more developable channel frontage. But some city councilors said they were puzzled, that Demopoulos probably already has

CONCLUSION

- An example of what could potentially spread throughout the city if a new precedent were set
 - There are a LOT of street ends, especially in Old Town
- Singular focus on GCT while not addressing long-term trail considerations (Wildlife habitat, upkeep, stormwater management, etc)
 - Future acquisitions from other property owners for trail construction. Are you really going to get everyone to give up their shoreline property for GCT? **If no one gives up their land, then what?**

Hunt, Marcia

From: Brian Wetcher <brwetcher@gmail.com>
Sent: Saturday, April 17, 2021 1:22 AM
To: CityClerk
Subject: Ordinance 3087 " B" Ave vacation

Ordinance 3087 " B" Ave vacation

Saturday, April 17, 2021
1:17 AM

Subject	Ordinance 3087 " B" Ave vacation
From	Brian Wetcher
To	citycouncil@city of anacortes .org
Cc	'Marlene Finley'; tom.glade@comcast.net; 'Kathleen Flanagan'; 'Wim'; 'Rich Bergner (EvergreenIslands)'; 'Jan Heald Robinson'; 'Andrea Doll'; 'Kyle Loring (LoringAdvising)'; 'Brenda Lavender'
Sent	Saturday, April 17, 2021 12:47 AM

Mayor

Gere,Councilmembers:

I would like to preface my comments on this vacation with some pertinent history of the concept of the Guemas Channel Trail. In the early 1980s Burlington Northern Railroad,as a part of the developing “rails to trails” movement offered to sell the entire railroad right of way to the city for well under \$200’000,a bargain even in 1980s dollars.Tommy Thompson,founder and builder of the Anacortes Railway advocated quite strongly for this acquisition,initially as an extention route for his railway ,but also as public access to the shore line and a nonmotorized pathway from central Anacortes to the west end. Tommy, as a founding member of Evergreen Islands , serving as a member of the Board of Directors at that time, gained the enthusiastic support of the membership for this acquisition. Several Board members including myself made public comment in support of this acquisition of the shoreline for the public.The City Council ,in their wisdom , declined the offer.

Property owners adjacent to the railroad right of way became alarmed at the prospect of public access next to their property. Subsequently they formed a consolidated purchasing group and bought the entire right of way adjoining their properties from Burlington Northern and distributed the parcels to the participating property owners.

City Councils change ,staff change and community attitudes change. The concept of the Guemas Channel Trail has been embraced by the community for many years now . The City Council and staff have spent much time effort and capital to bring forth the reality of the trail as it exists today, including acquiring access easements ,some of which should have been in the possession of the city already.

Consistent with my public comment at that City Council meeting so many years ago I continue to support acquisition of public trail easements on the Guemas Channel by the city. I do however, question the efficacy of this particular vacation process as procedure and policy inconsistent with city statutes and public access goals of city policy.

This vacation is presented as one vacation of 9000 square feet. City statutes require vacations over 5000 square feet to be professionally appraised;this has not been done for this vacation. The allocation of the vacation sections apportioned equally to each of the property owners would be less than the 5000 square foot threshold if presented as separate vacations. What statutory empowerment does the city assert to consolidate what should be two separate vacations requests into one of 9000 square feet without requiring a professional appraisal? Either the 5000 square foot threshold applies or this is two separate vacation requests and should be submitted separately.

The existing right of way being exchanged for the trail easement allows for public access to the Guemas Channel shoreline area similarly to the right of ways further east from which the street end parks and access to the Guemas Channel trail have been created . The concept of the Guemas Channel Trail has always included local neighborhood access to the trail from existing right of ways . Approving this vacation as presented effectively eliminates any such access in this neighborhood . The closest access is quite a ways east. Accordingly ,I propose a compromise between a street end park and extinguishing public access by reducing the existing right of way to 12 feet in width to afford a maintained pedestrian access to the trail corridor for this neighborhood,vacating the rest of the right of way to the adjoining property owners.The city should not be eliminating access for an entire neighborhood ,a right of way already owned by the city,to the benefit of exclusivity for the property owners

The easement acquired by this vacation is only one of many necessary to complete this section of the Guemas Trail right of way. This process will set a precedent applicable to all such future easements in this section of the trail as well as others where private property easements are necessary to complete the trail. The ambiguities represented by the consolidation of this vacation request represent a lack of clarity within the process best remedied by the separation of the easements into two separate requests. The precedent of eliminating localized public shoreline access in exchange for the trail easement defeats the purpose of neighborhood connections to the trail, best remedied by retaining a pedestrian right of way as I indicated earlier. Precedents in land use decisions need to be based on clear procedures and standards as well as public benefit. Council members need to consider whether the process of this vacation request/easement acquisition meets that standard and should be used as a template for similar actions in the future.

I would therefor respectfully request that councilmembers remand this request back to city staff to improve the clarity of the process and the public access value of the vacation request, or deny the the vacation request outright as presented.

consideration of my comments, Brian R.
Wetcher

Thank you for your

Hunt, Marcia

From: Brian Wetcher <brwetcher@gmail.com>
Sent: Saturday, April 17, 2021 1:09 PM
To: CityClerk
Cc: tom.glade@comcast.net; 'Marlene Finley'
Subject: FW: Ordinance 3087 " B" Ave vacation, Rev. A

April

17, 2021

To: Mayor Gere and Anacortes City Councilmembers

cc: Marlene Finley; Tom Glade; Kathleen Flanagan; Wim Houppermans; Rich Bergner,

Jan Heald Robinson; Andrea Doll, Brenda Lavender, Kyle Loring (LoringAdvising)

Re: Ordinance 3087 " B" Ave vacation – Rev. A

Mayor Gere, Councilmembers:

I am prefacing my comments on this vacation with some pertinent history of the concept of the Guemes Channel Trail. In the early 1980s Burlington Northern Railroad, as a part of the developing “rails to trails” movement, offered to sell the entire railroad right of way to the city for well under \$200,000, a bargain even in 1980s dollars.

Tommy Thompson, founder and builder of the Anacortes Railway, advocated quite strongly for this acquisition – initially as an extension route for his railway ,but also as public access to the shore line and a nonmotorized pathway from central Anacortes to the west end. Tommy, as a founding member of Evergreen Islands. Serving as a member of the Board of Directors at that time, gained the enthusiastic support of the membership for this acquisition. Several Board members including myself made public comment in support of this acquisition of the shoreline for the public. The City Council ,however, declined the offer.

Property owners adjacent to the railroad right of way became alarmed at the prospect of public access next to their property. Subsequently they formed a consolidated purchasing group and bought the entire right of way adjoining their properties from Burlington Northern. The group distributed the parcels to the participating property owners.

City Councils change ,staff change, and community attitudes change. The concept of the Guemes Channel Trail (the Trail) has been embraced by the community for many years now . The City Council and staff have spent much time effort and capital to bring forth the reality of the trail as it exists today (including acquiring access easements ,some of which should have been in the possession of the city already). The current trail is consistent with my public comment at that City Council meeting so many years ago

I continue to support the City’s acquisition of public trail easements on the Guemes Channel. I do however, question the efficacy of this particular vacation process as

procedure and policy inconsistent with city statutes and public access goals of city policy. This vacation is presented as one vacation of 9000 square feet. City statutes require vacations over 5000 square feet to be professionally appraised; this has not been done for this vacation. The allocation of the vacation sections apportioned equally to each of the property owners would be less than the 5000 square foot threshold if presented as separate vacations.

What statutory empowerment does the city assert to consolidate what should be two separate vacations requests into one of 9000 square feet without requiring a professional appraisal? Either the 5000 square foot threshold applies or this is two separate vacation requests and should be submitted separately.

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Approving this vacation as presented, effectively eliminates any such access in this neighborhood . The closest access is quite a ways east. Accordingly ,I propose a compromise between a street end park and extinguishing public access by reducing the existing right of way to 12 feet in width to afford a maintained pedestrian access to the trail corridor for this neighborhood, vacating the rest of the right of way to the adjoining property owners. The city should not eliminate public access for an entire neighborhood – a right of way already owned by the city and to the benefit of exclusivity for the property owners.

The easement acquired by this vacation is only one of many necessary to complete this section of the Guemes Trail Right of Way. This process will set a precedent applicable to all such future easements in this section of the trail as well as others where private property easements are necessary to complete the trail .

The ambiguities represented by the consolidation of this vacation request represent a lack of clarity within the process best remedied by the separation of the easements into two separate requests. The precedent of eliminating localized public shoreline access in exchange for the trail easement defeats the purpose of neighborhood connections to the trail, best remedied by retaining a pedestrian right of way as I indicated earlier. Precedents in land use decisions need to be based on clear procedures and standards as well as public benefit.

Council members need to consider whether the process of this vacation

request/easement acquisition meets that standard and should be used as a template for similar actions in the future. I would therefor respectfully request that councilmembers remand this request back to city staff to improve the clarity of the process and the public access value of the vacation request, or deny the vacation request outright as presented.

Thank you for your consideration of my comments,

Brian R. Wetcher



City Council Agenda Bill

Meeting Date: May 3, 2021

Agenda Item: 6.b.

Agenda Item Title: Continued Public Hearing: Critical Area Regulations Draft 3

Staff Contact(s): TESS COOPER

<u>Approved for Submittal to Council by</u>	<u>Action Type</u>
DON MEASAMER	Public Hearing
LIBBY GRAGE	

Item Summary: The proposed non-project legislative action is to amend the Critical Area regulations in accordance with the Growth Management Act requirements. The critical areas ordinance regulates certain activities and development in and near wetlands, streams, fish & wildlife habitat conservation areas, geologically hazardous areas, frequently flooded areas, and critical aquifer recharge areas. The draft includes updates in accordance with state law and best available science, reorganization, and functional changes to certain requirements.

Budget Impact:
N/A

Previous Action: Public Hearing opened on April 19 and had been left open to the present meeting.

Recommended Motion: N/A - Discussion

Alternative Actions:

Attachments (listed in order presented):

1. Ch 19.70 Critical Areas Regulations Draft 3.1
2. 2nd Draft Major Changes (Planning Commission)
3. Comments as of 4-13-21
4. Critical Area Maps - DRAFT
5. Public Comments received by City Clerk after 4/19/21 packet publication
6. Additional comments as of 4-19-21
7. Table of additional changes to Draft 2

8. Final comments as of 4-23-2021
9. Draft 3 Public Comment Summary
10. Public Comments received by City Clerk after 5/3/21 packet publication
11. Staff Slide Presentation

DRAFT Ordinance No. ____

An Ordinance adopting, repealing, and amending AMC Chapter 19.70 and Chapter 17.70 relating to critical areas regulations.

Whereas _____;

Whereas _____;

Whereas _____;

Whereas _____;

Whereas RCW 36.70A.170 and RCW 36.70A.172 provide that the City must designate critical areas and include the best available science in developing policies and development regulations to protect the functions and values of critical areas;

Whereas RCW 36.70A.130 requires continuing review, evaluation and periodic update of development regulations, including critical areas regulations,

Whereas

Now, therefore, the City Council of the City of Anacortes does ordain as follows:

Section 1. The Anacortes Municipal Code is amended as shown in Attachment A.

Section 2. Consistent with RCW 35A.12.130, this ordinance takes effect five days after passage and publication.

PASSED and APPROVED this ____ day of _____, 2021.

CITY OF ANACORTES:

Laurie Gere, Mayor

Attest:

Steve Hoglund, City Clerk-Treasurer

Style Definition: TOC 2: Tab stops: 6.49", Right,Leader: ...

Style Definition: TOC 1: Tab stops: 6.49", Right,Leader: ...

Approved as to Form:

Darcy Swetnam, City Attorney

Attachment A Amendments to the Anacortes Municipal Code

[12.18 ACFL Management Section added.](#)

Chapter 17.70 Critical Areas Regulations are repealed except that

Recodify Article II. – Frequently Flooded Areas (FEMA Approved), AMC 17.70.020 through AMC 17.70.070 to Chapter 19.74 and retitle “Floodplain Management”.

[Table 19.20.030-1 Permit Processes added.](#)

[19.78 Clearing and Grading section reference to Critical Area activities not subject to C&G thresholds.](#)

Chapter 19.70 Critical Areas Regulations

The following chapter and sections in Title 19 are created or amended:

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DIVISION 7 – ENVIRONMENT

CHAPTER 19.70 CRITICAL AREAS

INTRODUCTION: GENERAL PROVISIONS

19.70.010 Purpose.

- A. The purpose of this chapter is to designate critical areas and to establish standards for the protection of their functions and values, in compliance with the provisions of the Washington State Growth Management Act of 1990 (Ch. 36.70A RCW), and consistent with the goals and policies of the Anacortes Comprehensive Plan.
- B. By identifying and regulating development and alterations to critical areas and their buffers, this chapter seeks to accomplish the following goals:
 - 1. Protect members of the public and public resources and facilities from injury, loss of life, or property damage due to landslides and steep slope failures, erosion, seismic events, or flooding;
 - 2. Protect, maintain and restore healthy, functioning ecosystems through the protection of unique, fragile, and valuable elements of the environment, including, but not limited to ground and surface waters, wetlands, and fish and wildlife and their habitats, and to conserve the biodiversity of plant and animal species;
 - 3. Direct activities not dependent on critical area resources to less environmentally sensitive sites and mitigate unavoidable impacts to critical areas by regulating alterations in and adjacent to critical areas;
 - 4. Prevent cumulative adverse environmental impacts to water quality, wetlands, and fish and wildlife habitat, and the overall net loss of wetlands, frequently flooded areas, and habitat conservation areas;
 - 5. Alert owners, potential purchasers, real estate agents, appraisers, lenders, builders, developers and other members of the public to natural conditions that pose a hazard or may otherwise limit development;
 - 6. Serve as a basis for exercise of the City's substantive authority under the State Environmental Policy Act (SEPA).
- C. The regulations of this Chapter are intended to protect critical areas in accordance with the Growth Management Act, through the application of best available science, as determined according to [WAC 365-195-900](#) through [365-195-925](#), and in consultation with state and federal agencies and other qualified professionals.

- D. This Chapter is intended to be administered with limited flexibility and attention to site-specific characteristics. It is not the intent of this Chapter to make a parcel of property unusable by denying its owner reasonable economic use of the property, or to prevent the provision of public facilities and services necessary to support existing development and that planned for by the community without decreasing current service levels below minimum standards.
- E. The City's enactment or enforcement of this Chapter must not be construed for the benefit of any individual person or group of persons other than the general public.

19.70.015 Applicability.

~~A.~~ Unless explicitly exempted, the provisions of this chapter apply to all land uses, development activity, and all structures and facilities within the City of Anacortes that are within the critical area, within the maximum buffer distance of, or likely to affect the functions and values of, one or more critical areas.

~~B.~~ Relationship to other regulations.

1. Shorelines of the state and shorelands as defined in RCW 90.58.030, and critical areas occurring within the jurisdiction of shorelines of the state and shorelands ("shoreline jurisdiction"), are regulated and protected by through the Anacortes Shoreline Master Program, (AMC Title 18.1619.72), Shoreline Master Program, including Appendix A—Shoreline Critical Areas Regulations, as amended. Activities occurring within shoreline jurisdiction are reviewed through the shoreline permit review and issuance process; a separate critical areas permit is not required. The Shoreline Master Program incorporates by reference portions of this Chapter (Ch. 19.70); however, certain provisions of this chapter that are not consistent with the Shoreline Management Act, 90.85 RCW and supporting Washington Administrative Code chapters, do not apply in shoreline jurisdiction.
2. These critical areas regulations apply in addition to zoning and other regulations adopted by the City. Notwithstanding AMC 19.12.040(E), in the event of any conflict between these regulations and any other regulations of the City, the regulations apply that provide greater protection to the critical areas' functions and values, as determined by the Decision Maker/Director.
3. When any provision of this chapter or any existing easement, covenant, or deed restriction conflicts with this chapter, that which provides more protection to the critical areas applies.
4. Compliance with the provisions of this Chapter does not constitute compliance with other federal, state, or local regulations and permit requirements that may be required. The applicant is responsible for complying with other agency requirements, apart from the process established in this Chapter.

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~~A.~~ Unless explicitly exempted, the provisions of this chapter apply to all land uses, development activity, and all structures and facilities within the City of Anacortes that are within the critical area, within the maximum buffer distance of, or likely to affect the functions and values of, one or more critical areas.

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19.70.020 Identification, classification, and rating of critical areas.

- A. Critical Areas Maps.** The general locations of many critical areas in Anacortes are displayed on the City of Anacortes' Critical Areas Maps, which are hereby adopted by reference. The maps are used to alert the public of the potential location of critical areas in Anacortes. As new environmental information related to critical areas becomes available, the City is authorized to make changes as necessary to the Critical Areas Maps.
- B. Actual site conditions.** Regardless of whether a critical area is shown on the Critical Areas Map, the actual presence or absence of the features defined in this code as critical areas will govern. The City Prior to acting on any development permit the City may require an applicant to submit technical information to indicate whether critical areas actually exist on or adjacent to the applicant's site based on the definitions of critical areas in this code. This will be administered as a critical area identification form AMC 19.70.110 included with appropriate permit forms.
- C. Classification and rating.** To promote consistent application of the standards and requirements of this chapter, critical areas within the City will be rated or classified using best available science according to their characteristics, function and value, and/or their sensitivity to disturbance.
1. Classification of critical areas will be determined by the City using the following tools:
 - a. Application of the criteria contained in these regulations;
 - b. Consideration of the critical area reports submitted by qualified professionals in connection with applications subject to these regulations; and
 - c. Review of maps and other resources adopted pursuant to this chapter.
 2. Rating categories will not change due to illegal modifications. If the development proposal site contains or is within a critical area suspected of illegal modifications the rating will be based on pre-modification conditions of the critical area. Abatement of the unauthorized modification will be required prior to authorization of the current development proposal being processed for the subject site.

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19.70.025 Protection of critical areas.

- A.** Critical areas and their required buffers may not be altered except as allowed by this Chapter.
- B.** Any action taken pursuant to this chapter must result in equivalent or greater functions and values of the critical areas associated with the proposed action, as determined by the best available science.
- C.** All actions and development must be designed and constructed in accordance with mitigation sequencing per AMC 19.70. ~~135-125~~ to achieve no net loss of critical area functions and values.
- D.** Applicants must first demonstrate an actual inability to avoid or reduce impacts, before restoration and compensation of impacts will be allowed.

- E. No activity or use may be allowed that results in a net loss of the functions or value of critical areas.
- F. Any individual critical area adjoined by another type of critical area must have the buffer and meet the requirements that provide the most protection to the critical areas involved.

19.70.030 ~~General Requirements~~ Project Evaluation

- A. As part of the review, the city will:
 1. Verify the information submitted by the applicant;
 2. Evaluate the project area and vicinity for critical areas;
 3. Determine whether the proposed project is likely to impact the functions or values of critical areas; and
 4. Determine if the proposed project adequately addresses the impacts and avoids impacts to the critical area associated with the project.
- B. If the proposed project is within, adjacent to, or is likely to impact a critical area, the city will:
 1. Require a critical area report from the applicant that has been prepared by a qualified professional, to be reviewed and evaluated;
 2. Determine whether the development proposal conforms to the purposes and performance standards of this chapter, including the criteria in AMC 19.70.030.035, Review criteria;
 3. Assess the potential impacts to the critical area and determine if they can be avoided or minimized; and
 4. Determine if any mitigation proposed by the applicant is sufficient to protect the functions and values of the critical area and public health, safety, and welfare concerns consistent with the goals, purposes, objectives, and requirements of this chapter.

19.70.035 Critical Areas Review.

- A. **When required.** A proposal to modify any critical area and/or required buffer including, but not limited to, clearing, grading, draining, removal or alteration of vegetation, construction of structures, utilities and related infrastructure must require a critical area permit unless it qualifies as an exemption, as provided in AMC 19.70.035.0040. Except for within shoreline jurisdiction, administration of this chapter shall be through the SMP and appropriate Shoreline Permit administration process.
- B. **Best Management Practices.** All activities, including those allowed without critical areas review, must be conducted using the best management practices appropriate for that activity that result in the least amount of impact to the critical areas. Best management practices must be used for tree and vegetation protection, construction management, erosion and sedimentation control, water quality protection, and regulation of chemical applications. The use of best management

practices is required to ensure that the activity does not result in degradation to the critical area. Appropriate BMP sources include Ecology's Construction Storm Water General Permit and NRCS Conservation Practices. Any incidental damage to, or alteration of, a critical area and/or buffer must be restored, rehabilitated, or replaced at the responsible party's expense.

C. Modifications to Existing Nonconforming Structures and Uses. In these provisions the burden of proof is on the applicant to bring evidence in support of their position. Existing structures, activities, and uses that were established legally but do not meet the current critical area, buffer, or buffer setback requirements may continue in accordance to AMC 19.49.040, and may be modified as follows:

1. Routine maintenance and repairs;
2. Structural modifications or additions that do not intensify the nonconformity of the structure or increase the area of hardscape lying within the critical area or buffer. The ~~Decision maker~~Director may require an updated critical areas report to confirm location of buffers and that the addition is located entirely outside the critical area or buffer;
3. Vertical additions above the ground floor that do not encroach further into the critical area or buffer beyond the existing exterior walls, except that critical areas review is required for additions in landslide hazard areas or buffers;
4. Restoration or replacement of a structure that is damaged by fire, natural disaster or other calamity when:
 - a. A complete application for reconstruction or replacement is submitted within one year of the damage; and
 - b. The restoration or replacement is made to conform to the current critical areas regulations, or if such regulations cannot be physically met without reducing the size of the building, the restoration or replacement may not intensify any nonconformity that existed prior to the damage.

c. Except that critical areas review is required for restoration and replacement in landslide hazard areas or buffers.

5. State Ferry Terminal. The existing developed footprint, except for infill between the toll booth area in the lowest parking lot, hillside walking paths, and a hillside side slope along the western side of the main terminal parking lot, and including all associated parking, at the Washington State Ferry Terminal facility. Redevelopment may occur within the existing footprint only, provided there is no net loss of ecological function and value in the adjacent buffer areas for Cannery Pond and Ship Harbor Interpretive Preserve wetlands.

D. Demolition. Demolition of structures located within critical areas or their buffers is permitted, excluding demolition of structures necessary to support or stabilize landslide hazard areas and will be subject to approval of a stormwater pollution prevention plan consistent with the

Commented [TC2]: Add section 5:

5. State Ferry Terminal. The existing developed footprint, except for infill between the toll booth area in the lowest parking lot, hillside walking paths, and a hillside side slope along the western side of the main terminal parking lot, and including all associated parking, at the Washington State Ferry Terminal facility, shall not be increased and redevelopment may occur provided there is no net loss of ecological function and value in the adjacent buffer areas for Cannery Pond and Ship Harbor Interpretive Preserve wetlands.

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adopted stormwater management manual and clearing limits that will adequately protect the critical area.

19.70.040 Exempt Activities.

- A. General requirements for all exempt activities.** Activities listed in this section are exempt from the rest of the provisions of this chapter only if they meet the specific terms of this section.
- B.** To be exempt from this chapter does not give permission to degrade a critical area or buffer or to ignore risk from natural hazards. All exempt activities must use reasonable methods to avoid potential impacts to critical areas and buffers. In every case, disturbance to the critical area must be minimized through best management practices and the use of low-impact equipment.
- C.** Any incidental damage to, or alteration of, a critical area or buffer that is not a necessary outcome of the exempted activity must be restored, rehabilitated, or replaced at the responsible party's expense.
- D.** This chapter may not exempt ~~this an~~ activity from the provisions of other [City permits such as Clearing and Grading for vegetation removal or ground disturbing activity or](#) agency permit requirements such as Washington Department of Fish and Wildlife [Hydrologic/Hydraulic](#) Permit, or Army Corp of Engineers regulatory requirements.
- E. Burden of proof.** [The burden of proof is on the applicant to bring forth evidence that the activity meets the precise description of Exemption.](#)

~~D.~~

~~E.~~ Table 19.70.040 Exempt Activities

Table 19.70.040 (A) describes activities that must meet the precise description to be allowed without following a critical area process. Activities are divided into the categories of permitted in the Critical Area and permitted in the Buffer, marked by a yes or no in the appropriate column.

EXEMPT ACTIVITIES:- (No review required, must strictly meet standards)	Critical Area	Buffer
Emergencies. Alterations in response to emergencies which threaten the public health, safety, and welfare or which pose an imminent risk of damage to private property, and that require remedial or preventative action in a timeframe too short to allow for compliance with the requirements of this chapter, if the following requirements are met: a. Only the minimum intervention necessary to reduce the risk to public health, safety, or welfare and/or the imminent risk of damage to private property may be authorized by this exemption. b. The alteration undertaken must be reported to the Decision makerDirector no later than 30 days after the alteration has occurred. Once notified, the Decision makerDirector must	Yes	Yes

Commented [CT3]: Remember to add a clause that even if an activity does not require a CA permit if the activity is in the vicinity of CA's and meets the definition of clearing or grading – then the activity will be administered through a clearing/grading permit. → with an edit to those code sections to disqualify the thresholds if in the vicinity of CA or Buffer

EXEMPT ACTIVITIES:- (No review required, must strictly meet standards)	Critical Area	Buffer
confirm that an emergency existed and determine what, if any, additional applications and/or measures are required of the property owner to protect the critical area(s) consistent with the provisions of this chapter, and to repair any damage to a pre-existing resource. e. If the Decision maker determines that the action taken, or any part of the action taken, was beyond the scope of an allowed emergency action, the Decision maker<u>Decision-maker may take action to enforce this chapter consistent with AMC Title 19 and AMC Title 20.</u> c. A: After the emergency, the person or agency undertaking the action must fully fund and conduct necessary site evaluations and critical area reports, mitigation plans, and restoration for any impacts to the critical area and buffers resulting from the emergency action. The person or agency undertaking the action must meet the review procedures contained herein. Mitigation activities must be initiated within one year of the date of the emergency or as directed by the Department. d. <u>If the Director determines that the action taken, or any part of the action taken, was beyond the scope of an allowed emergency action, or any required mitigation, the Director may take action to enforce this chapter consistent with AMC Title 19 and AMC Title 20.</u>		
Yard and garden activities. Maintenance or repair activities including, but not limited to, cutting, mowing lawn, weeding, hand removal of noxious and invasive species, harvesting and replanting of garden crops, pruning and planting of noninvasive ornamental vegetation or indigenous native species to maintain the general condition and extent of such areas; provided, that such maintenance or repair activities are limited to legally existing landscaping improvements and do not further expand into critical areas or associated buffers, do not alter topography, do not destroy or clear native vegetation, do not remove non-hazard trees in the buffer or critical area, and do not diminish water quality or quantity. a. Native growth protection areas, mitigation sites, or other areas protected via permit conditions, conservation easements or similar restrictive covenants (as defined in AMC 19.70.145135) are not covered by this exemption. b. If an activity has ceased for one year or more any future use of such land, building or structure must thereafter be in conformity with this chapter and the zone in which it is located.	No	Yes

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EXEMPT ACTIVITIES:- (No review required, must strictly meet standards)	Critical Area	Buffer
Site Investigation. Minimal site investigative work and studies necessary for preparing land use applications, including, but not limited to, surveys, soil logs and borings, percolation tests, water quality studies, scientific research, wildlife studies, and similar tests and investigations; provided that such activities do not require clearing, fill, construction of new roads, or heavy equipment, and only minimal amounts of excavation and disturbed areas must be immediately restored.	Yes	Yes
Passive Outdoor Activities. When it can be demonstrated that there will be no adverse effect, the following activities are allowed within critical areas and their buffers: educational activities, scientific research, and outdoor recreational activities, including but not limited to interpretive field trips, bird watching, public beach access including water related activities, bicycling, and hiking. This exemption does not include constructing new roads or trails, vegetation clearing, or collection of plants or animals. <u>Provided they do not require structures, grading, fill, draining, or dredging except as provided herein or authorized by a Critical Area Permit: Passive Outdoor Activities, including fishing, birdwatching, hiking, boating, biking, horseback riding, swimming, canoeing, and similar activities with limited environmental impact are exempt activities.</u>	Yes	Yes

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Table 19.70.040 (B)

EXEMPTIONS That require a letter of exemption be obtained from the decision maker Director prior to construction or initiation of activities. Subject to conditions by the Director Decision-maker to ensure compliance with this chapter.	Critical Area	Buffer
Utility Operation, Maintenance, Repair, or Replacement. Public water, electric, and natural gas distribution, public stormwater and sewer collection, cable communications, telephone, utility and related activities undertaken pursuant to City-approved best management practices, and best available science with regard to protection of threatened and endangered species, as follows: a. Normal and routine maintenance or repair of existing utility structures or rights-of-way; when the activity does not involve the expansion of facilities or improvements into a previously unimproved portion of critical areas or required buffers; b. Replacement, operation, repair, modification, installation or construction in an improved City road right-of-way or	Yes	Yes

EXEMPTIONS That require a letter of exemption be obtained from the decision-maker Director prior to construction or initiation of activities. Subject to conditions by the Director Decision-maker to ensure compliance with this chapter.	Critical Area	Buffer
City authorized private roadway of all electric facilities, lines, equipment or appurtenances, not including substations, with an associated voltage of 55,000 volts or less; to include relocation only when required by the City of Anacortes, which approves the new location of the facilities; c. Relocation of public sewer -or stormwater local collection, public water local distribution, natural gas, cable communication or telephone facilities, lines, pipes, mains, equipment or appurtenances, only when required by the City of Anacortes, which approves the new location of the facilities; d. Replacement, operation, repair, modification, relocation, installation or construction of public sewer or stormwater local collection, public water local distribution, natural gas, cable communication, or telephone facilities, lines, pipes, mains, equipment or appurtenances when such facilities are located within an improved public right-of-way or City-authorized private roadway; e. Repair and maintenance of existing private connections to public utilities and private stormwater management facilities; f. Regular maintenance of stormwater facilities that are within a segment of a regulated stream, such as conveyance ditches/swales within the right of way or within public drainage easements		
Transportation Infrastructure Operation, Maintenance, Repair, or Replacement. Maintenance, operation, repair, modification, or replacement of publicly improved roadways or City-authorized private roadways, including the road prism and associated stormwater management systems; as long as any such alteration does not involve expansion of roadways or related improvements into previously unimproved rights-of-way or portions of rights-of-way, and does not alter a critical area or required buffer, or watercourse, such as culverts or bridges, or result in the transport of sediment or increased stormwater. Retention and replanting of native vegetation must occur whenever possible along the right-of-way improvement and resulting disturbance	Yes	Yes
Recreation Areas Operation, Maintenance, Repair, or Replacement. Maintenance, operation, repair, modification, or replacement of existing Non-Motorized trails, and existing facilities within publicly improved	Yes	Yes

EXEMPTIONS That require a letter of exemption be obtained from the decision-maker Director prior to construction or initiation of activities. Subject to conditions by the Director Decision-maker to ensure compliance with this chapter.	Critical Area	Buffer
recreation areas, such as the Anacortes Community Forest Lands and public parks, may be performed subject to the following: a. The activity does not involve the expansion of facilities and disturbance to adjacent areas is minimized and disturbed areas must be immediately restored; b. Work is conducted using best management practices; c. Flow and circulation patterns and biological characteristics are not impaired and adverse impacts are minimized; e-d. Where trail relocation is the preferred method of repair, trail relocation further away from the Critical Area is not to be considered a new trail but is included in the exemption for operation, maintenance, repair, or replacement.		
Vegetation Management, i-including: 1. Removal of noxious weeds or invasive vegetation, as identified by the Washington State or Skagit County Noxious Weed Control Board, in a wetland buffer, stream buffer, other fish and wildlife habitat conservation areas and buffers, is allowed when: a. Undertaken with hand labor, including handheld mechanical tools, and integrated pest management; b. Plants that appear on the Washington State or Skagit County Noxious Weed Control Board lists must be handled and disposed of in accordance with the best management practices appropriate to that species and approved by the City when permit review is applicable; c. Areas cleared by removal of noxious and/or invasive plant species must be revegetated with site-appropriate native species at natural densities and the site must be stabilized against erosion in accordance with the stormwater manual adopted by the City; d. All work performed is above the ordinary high water mark and above the top of a stream bank; and e. The following limits may not be exceeded: Within City-owned property, no more than 3,000 square feet of soil may be exposed at any one time; and within private property, not more than 500 square feet of area may be cleared, as calculated cumulatively, over one year, without a permit and critical area report prepared by a qualified professional. 2. Vegetation management consistent with a previously approved critical area mitigation, restoration, remediation, or enhancement	Yes	Yes

EXEMPTIONS That require a letter of exemption be obtained from the decision-makerDirector prior to construction or initiation of activities. Subject to conditions by the Director Decision-maker to ensure compliance with this chapter.	Critical Area	Buffer
plan that requires ongoing maintenance and vegetation management beyond final inspection and the required monitoring period for the permitted project. 3. Hazard Trees. a. The felling of hazard trees may be permitted when necessary to: i. Control fire; or ii. Halt the spread of disease or damaging insects consistent with 76.09 RCW; or iii. Avoid a threat to existing structures, above ground utility lines or other facilities. iv. Remove an actual threat to life or property from slope instability that would be caused by toppling. b. Unless there is an emergency pursuant to Emergency Exemptions above, the landowner must first obtain prior written approval from the Department. A tree risk assessment prepared by an ISA certified Arborist must be submitted by the applicant to the Department that includes the following information: i. Identification of the tree(s) proposed to be removed; ii. A conclusion that the condition constitutes an actual threat to life or property; iii. An assessment of whether a portion of the tree suitable for a snag for wildlife habitat may be safely retained. iv. If a tree to be removed provides priority habitat, such as an eagle perch or occupied nest, a description of timing and methods of removal that will minimize and mitigate impacts. v. If a tree to be removed is located within a landslide hazard area or buffer, an evaluation of potential impacts on slope stability must be completed by a qualified professional, including recommendations for replanting and other measures to avoid adverse impacts to slope stability. c. All work must be done using handheld implements only, unless the property owner requests and the Decision-makerDecision-maker approves otherwise in writing.		

EXEMPTIONS That require a letter of exemption be obtained from the decision-maker <u>Director</u> prior to construction or initiation of activities. Subject to conditions by the <u>Director</u> Decision -maker to ensure compliance with this chapter.	Critical Area	Buffer
d. <u>d.</u> Any removed tree or vegetation must be replaced in-kind, with similar or appropriate native species, within 1 year in accordance with an approved restoration plan including species, size, and maintenance plan including species, size, and maintenance plan.		
Clearing, grading, and the construction of fences and arbors are allowed within the required 10-foot stream setback for a piped stream segment if no other critical area or buffer is present.	No	Yes

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19.70.045 Permitted Alterations.

A. Applicability. An applicant may seek an alteration of a critical area and/or critical area buffer through a permitted alteration when application of the standards renders compliance with these provisions as infeasible and the proposed development meets the specific terms of this section and can be considered a reasonable use.

B. General requirements. The actions in the permitted alteration table below, must be considered permitted alterations, unless as otherwise specified under AMC 19.70.240 Specific Wetland Category Development Standards, and provided they are consistent with the general standards for mitigation sequencing and other applicable requirements established in this chapter.

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~~B.~~

C. Review Process:

1. A critical area permit must be required for all permitted alterations. Requests for such permits must be reviewed using the procedures outlined in chapter 19.20, table 19.20.030. No permit must be issued unless it can be shown that the proposed development is fully consistent with the requirements of this chapter.
2. In addition to other project related documents, all permitted alterations must require a critical area assessment report per section 19.70.~~115~~ to evaluate the permitted alteration. The report must include:
 - a. A description of the function and condition of the critical area and or buffer that would be altered;
 - b. An analysis of the effect of the development proposal on the critical area and or buffer;

- c. A description of actions that can be taken to modify the development proposal to avoid or reduce the alteration of the critical area and/or buffer and a discussion of whether these modifications are practical and reasonable;
 - d. A mitigation plan as required by this chapter.
3. Burden of proof. The burden of proof is on the applicant to bring forth evidence in support of the application and upon which any decision has to be made on the application.
 4. Public comment. Consistent with AMC 19.20.030The City must ensure the opportunity for public comment, including that from appropriate Federal, State, and Tribal natural resource agencies, to ensure the use of best available science before deciding on approval.

D. Decision criteria. A permit for alterations to of a critical areas and/or buffer width requirements of this Chapter may only be issued if the applicant demonstrates that all of the following criteria are met:

1. Special circumstances applicable to the subject property, including size, shape, or topography, and the strict application of this chapter is found to deprive the subject property of rights and privileges enjoyed by other properties in the vicinity; provided, however, that the fact that those surrounding properties have been developed under regulations in force prior to the adoption of this chapter may not be the sole basis for granting approval;
2. The issuance of a variance to zoning requirements (setback, height, coverage, etc.) by itself will not provide sufficient relief to avoid the need for a permitted alteration to the critical area and/or buffer and other requirements for the critical areas regulated by this Chapter;
3. Mitigation sequencing per AMC 19.70.~~135~~125(A) has been applied;
4. The proposed alteration is supported by best available science; and
5. The proposed alteration allows for development of the subject parcel with the least impact on critical areas while providing a reasonable use of the property.

E. Conditions may be required. In granting any approval, conditions and safeguards may be prescribed as are necessary to secure adequate protection of critical areas from adverse impacts, protect adjacent property, and to ensure conformity with this chapter.

F. Table 19.70.~~040~~045 Permitted Activities.

Table 19.70.045 describes activities that must meet the precise description to be allowed ~~with~~ following the prescribed critical area process. Activities are divided into the categories of permitted in the Critical Area and permitted in the Buffer, marked by a yes or no in the appropriate column.

Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)	Critical Area	Buffer
Buffer Modifications, <u>including</u> : increased buffer width, buffer averaging, and buffer alterations as described specifically in this chapter.	No	Yes

Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)	Critical Area	Buffer
Public ServicesRoads and Utilities. To allow development by a public agency<u>public services</u> when the strict application of the standards in this Chapter would otherwise unreasonably prohibit the provision of public <u>services and amenities.</u> “Public services” include, but are not limited to, water supply, sewer and stormwater management facility, electric power, telephone, cable television, gas, and transportation for persons and freight. - Public services may be allowed to alter critical areas and buffers when: - Mitigation sequencing per AMC 19.70.135<u>125</u>(A) has been applied; - The application of the critical areas regulations would unreasonably restrict the ability of the public agency to provide public services; - There is no other practical alternative to the proposed development with less impact on the critical area; - The proposed development does not create a health or safety hazard on or off the development site, and will<u>must</u> not be detrimental to the properties or improvements in the vicinity; - Any alterations permitted to the critical area <u>and buffer</u> are mitigated in accordance with AMC 19.70.135 and relevant mitigation standards for the impacted critical areas(s) type; - The proposal is consistent with the Anacortes Comprehensive Plan and other applicable regulations. - Conditions authorized. Conditions may be established as necessary to mitigate impacts to critical areas and to conform to the standards required in this Chapter. <u>3. It will be a condition of any alteration granted a public agency and services exception that only the portion of the alteration that must be located in a critical area may be so located.</u>	Yes	Yes
Conservation, Restoration, and Fish Habitat Enhancement Projects. Conservation or restoration activities aimed at protecting or enhancing the soil, water, vegetation, or wildlife; including voluntary fish, wildlife, and wetland restoration or enhancement activities not required as project mitigation that have been approved by the U.S. Fish and Wildlife Service, the Washington State Department of Ecology, Washington State Department of Fish and Wildlife, or other appropriate local, state, federal, or tribal jurisdiction and/or that meet the criteria of RCW 77.55.181(1) and that are reviewed and approved according to the provisions of RCW 77.55.181. A Biological Evaluation Report is required to determine whether the proposal would conserve, preserve, or enhance critical area functions in the long-term to minimize temporary environmental impacts.	Yes	Yes

Commented [TC5]: Change to:

Public Roads and Utilities. To allow public services, when the strict application of the standards in this Chapter would otherwise unreasonably prohibit the provision of public amenities...

And add #3:

3. It will be a condition of any alteration granted a public agency and services exception that only the portion of the alteration that must be located in a critical area may be so located.

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Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)	Critical Area	Buffer
Chemical Applications. Chemical applications. The application of herbicides, pesticides, organic or mineral-derived fertilizers, or other hazardous substances, if necessary for the control of nuisance weeds and algae; except that their use will be restricted in accordance with the State Department of Ecology and State Department of Fish and Wildlife Management recommendations, and regulations of the State Department of Agriculture and the U.S. Environmental Protection Agency.	Yes	Yes
Recreational Areas / Facilities. Low impact activities which are consistent with the purpose and function of the critical area buffer <u>(not to include the ACFL)</u> and do not detract from its integrity may be permitted within the buffer depending on the sensitivity of the critical area. <u>A1.</u> Limited public park or public recreational access including trails, viewing platforms, fishing access (no wider than 6 foot), and foot bridges, provided that all of the following are satisfied: a. The area/facility is part of a public park that is dependent on its location for recreational function; and b. The area/facility is limited to the minimum necessary to accomplish the recreational function; and c. The removal of trees and native vegetation is minimized; and d. The balance of the development is consistent with other requirements of this chapter; and e. The project is identified in the Anacortes Comprehensive Plan or Parks <u>and ACFL</u> Master Plans. <u>B2.</u> Private pedestrian walkways and public trails must meet the following standards: a. The trail is generally parallel to the perimeter of the critical area; b. The trail is located in the outer 25% of the buffer area and is designated to avoid removal of s trees and native vegetation; c. The trail does not exceed 6 feet in width, and is limited to native soils or pervious surfaces. Raised boardwalks utilizing non-treated pilings may be acceptable; and <u>d.</u> The trail may be subject to closure during critical spawning, migration or breeding time periods of sensitive species that are present. <u>C3.</u> Informational signs. Construction and placement of informational signs or educational demonstration facilities no more than 9 square feet surface area and 4 feet high, as long as there is no permanent infringement on hydrology or stream flow <u>and non-treated wood is used;</u> <u>D4.</u> Limited excavating and filling necessary for the repair and maintenance of piers, walkways, observation decks, wildlife management shelters,	No	Yes

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Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)	Critical Area	Buffer
boathouses, and other similar water related structures, provided they are built on pilings to allow unobstructed flow of water and preserve the natural contour of the critical area .		
Single family Residences and Normal necessary appurtenancesAppurtenances. New single family dwellings on existing legal lots may intrude into critical areas or their buffers when all of the following conditions are met: a. It is demonstrated that it is not feasible to avoid the critical area or buffer through avoidance or buffer averaging, or reconfiguration of lots in the same ownership at the date of adoption of this Ordinance, and the development is the minimum necessary to achieve reasonable use of the lot as determined by the Planning Decision-makerDecision-maker; and b. Alteration of critical areas and their buffers including all clearing, grading, and structures, and appurtenances, has not and will not exceed cumulatively 2800 square feet of disturbance; and c. This action does not allow critical areas or their buffers to be converted to lawn or residential landscaping beyond a minimal area needed to maintain an approved structure; and d. Mitigation sequencing provided in this Chapter under AMC 19.70.125 is applied and the proposal includes on-site mitigation to the extent feasible as determined by the Critical Area Report. d-e. Normal appurtenances included in this provision include garages, decks, and walkways incidental to residential living and that do not constitute a special privilege.	Yes	Yes
New to Table Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes	Yes	Yes

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Recreational Areas / Facilities. Low impact activities which are consistent with the purpose and function of the critical area buffer and do not detract from its integrity may be permitted within the buffer (not including the ACFL), depending on the sensitivity of the critical area.
A. Limited public park or public recreational access including but not limited to trails, viewing platforms, fishing access (no wider than 6 foot), and foot bridges, provided that all of the following are satisfied:

- a. The area/facility is part of a public park that is dependent on its location for recreational function; and
- b. The area/facility is limited to the minimum necessary to accomplish the recreational function; and
- c. The removal of trees and native vegetation is minimized; and
- d. The balance of the development is consistent with other requirements of this chapter; and
- e. The project is identified in the Anacortes Comprehensive Plan or Parks Comprehensive Plan .

B. Private pedestrian walkways and public trails must meet the following standards:

- a. The trail is generally parallel to the perimeter of the critical area;
 - b. The trail is located in the outer 25% of the buffer area and is designated to avoid removal of trees and native vegetation;
 - c. The trail does not exceed 6 feet in width, and is limited to native soils or pervious surfaces. Raised boardwalks utilizing non-treated pilings may be acceptable; and
- The trail may be subject to closure during critical spawning, migration or breeding time periods of sensitive species that are present.

C. Informational signs. Construction and placement of informational signs or educational demonstration facilities no more than 9 square feet surface area and 4 feet high, as long as there is no permanent infringement on hydrology or stream flow and non-treated wood is used;

D. Limited excavating and filling necessary for the repair and maintenance of piers, walkways, observation decks, wildlife management shelters, boathouses, and other similar water related structures, provided they are built on pilings to allow unobstructed flow of water and preserve the natural contour of the wetland, except as authorized by special permit.

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Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes Comprehensive Plan, The ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and AMC 12.18 ACFL.

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Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)	Critical Area	Buffer
Comprehensive Plan, The ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and AMC 12.18 ACFL.		
New to Table Critical Area Aquifer Recharge Areas. All regulated activities listed under AMC 19.70.540.	Yes	Yes

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Regulated Activities in Critical Aquifer Recharge Areas. All regulated activities listed under AMC 19.70.540.

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19.70.050 Reasonable ~~use~~[Use exception](#) ~~Exception and~~ ~~Critical Area~~ Variance.

- A. **Applicability.** If the application of this Chapter would result in denial of all reasonable and economically viable use of a property, and if such reasonable and economically viable use of the property cannot be obtained by consideration of a permitted alteration pursuant to AMC 19.70.040045, then a landowner may seek a reasonable use exception from the standards of this Chapter. Reasonable use exceptions are considered a critical area variance and are intended as a last resort and only when a variance can meet the requirements of this Chapter.
- B. **General Requirements.** Reasonable use is a legal concept articulated by federal and state courts in regulatory takings cases. Within the context of these cases and for the purposes of this title, reasonable use means uses allowed by the underlying zoning designation and subdivision of property is not allowed. When no possible alternative exists, a reasonable use exceptions must be considered a critical area variance, provided they are consistent with the general standards for variances under 19.38.040 and other applicable requirements established in this chapter.
- C. **[Procedures for Review](#) ~~process~~:**
1. A variance permit must be required for all reasonable use exceptions. Requests for such permits must be reviewed using the procedures applicable to Type 3 Hearing Examiner decisions outlined in chapter AMC 19.20.030. ~~A~~No permit ~~may not~~ must be issued unless it can be shown that the proposed development is fully consistent with the variance approval criteria enumerated in AMC Section 19.38.040 (variance criteria) as well as all of the requirements of this chapter.
 2. In addition to other project related documents, all ~~permitted alterations~~[critical area variances](#) must require a critical area assessment report per section AMC 19.70.125-115 to evaluate the ~~permitted alteration~~[proposed disturbance](#). The report must include:
 - a. A description of the function and condition of the critical area and or buffer that would be altered;
 - b. An analysis of the effect of the development proposal on the critical area and or buffer;
 - c. A description of actions that can be taken to modify the development proposal to avoid or reduce the alteration of the critical area and/or buffer and a discussion of whether these modifications are practical and reasonable;

- d. A mitigation plan as required by this chapter.
 - 3. Burden of proof. The burden of proof is on the applicant to bring forth evidence in support of the application and upon which any decision has to be made on the application.
 - 4. [Public Comment. Consistent with AMC 19.20.030](#) The City must ensure the opportunity for public comment, including that from appropriate Federal, State, and Tribal natural resource agencies, to ensure the use of best available science before ~~deciding on approval~~ [a decision is made](#).
- D. **Variance criteria.** A reasonable use exception may be granted only if the applicant demonstrates that all of the requested action is consistent with all of the variance approval criteria as set forth:

- ~~a-1.~~ The application of this chapter would deny all reasonable economic use of the property and that there is no reasonable economically viable use with a lesser impact on the critical area than that proposed; and
- 2. Special conditions and circumstances exist that are peculiar to the land, the lot, or something inherent in the land, and that are not applicable to other lands subject to the provisions of this chapter; and
- 3. The inability of the applicant to derive reasonable use of the property is not the result of actions by the current or previous owner in subdividing the property or adjusting a boundary line, thereby creating the undevelopable condition, after the effective date of the ordinance codified in this Chapter; and
- 4. Any proposed modification to a critical area will be evaluated through consideration of a critical areas report and mitigation plan prepared by a qualified professional pursuant to the requirements of this Chapter, and will be the minimum necessary to allow reasonable and economically viable use of the property. The critical areas report and mitigation plan must be prepared utilizing best available science; and
- 5. Mitigation sequencing per AMC 19.70.~~135~~[125](#)(A) has been applied, and the proposal mitigates impacts on the critical area to the maximum extent possible, while still allowing reasonable use of the lot; and
- 6. The proposed development does not pose a threat to [adjacent property or to](#) the public health and safety; and
- 7. The applicant has demonstrated that the criteria in AMC 19.38.040 (variance criteria) are met; and
- 8. Granting the variance requested will not confer on the applicant any special privilege that is denied by this chapter to other lands, structures, or buildings under similar circumstances; and
- 9. The granting of the variance is consistent with the general purpose and intent of the Anacortes Comprehensive Plan, and planning policies.

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- E. **Conditions.** Conditions of approval may be included as part of the decision, including modifications to the size and placement of structures and facilities to minimize impacts to critical areas and associated buffers and mitigation requirements that ensure that all impacts are mitigated to the maximum extent feasible utilizing best available science.
- F. **Variances – Geologically hazardous areas.** A variance must not authorize development within a geologically hazardous area or required setback or buffer from a geologically hazardous area unless a Qualified Professional has determined the development will not pose a threat to public safety or property.

PART 1: CRITICAL AREAS REVIEW PROCEDURES

19.70.110 Critical area identification form.

Prior to the City's consideration of any proposed activity ~~allowed pursuant to Permitted Activities AMC 19.70.040 or~~ found not to be exempt under AMC 19.70.035040, the applicant must submit to the Department a completed form identifying suspected critical areas on, and within 300 feet, of the site.

19.70.115 Critical Area Report.

- A. **Report required.** When the ~~Decision-maker determines~~ Director determines a proposed development is within, abutting, or is likely to adversely affect a critical area or buffer pursuant to the provisions of this chapter, ~~he/she must have the authority to~~ to the Director may require a critical areas assessment report ~~that is~~, prepared by a Qualified Professional. The assessment of critical areas and analysis of impacts must be commensurate with the value or sensitivity of a particular critical area and relative to the scale and potential impacts of the proposed activity. This provision is not intended to expand or limit an applicant's other obligations under WAC 197-11-100.
- B. **Third Party Review of Critical Area Reports.** The ~~Decision-maker~~ Director may require, at the applicant's expense, a third-party review of a critical area report by a Qualified Professional under contract with or employed by the City in any of the following circumstances:
1. The project requires a critical area permit, or critical area variance; or
 2. Third party review is specifically required by the provisions of this chapter for the critical area(s) or critical area buffer(s) potentially being impacted; or
 3. When the ~~Decision-maker~~ Director determines that such services are necessary to demonstrate compliance with the standards and guidelines of this chapter or other appropriate regulations.
- C. **Critical Area Report Types or Sections.** Critical area report requirements may be met in stages through multiple reports or combined in one report. A critical area report must include one or more of the following sections or report types unless exempted by the ~~Decision-maker~~ Director based on the extent of the potential critical area impacts. The scope and location of the

proposed project will determine which report(s) alone or combined are sufficient to meet the critical area report requirements for potentially impacted critical area type(s). The typical sequence of required sections or reports that will fulfill the requirements of this section include:

1. **Reconnaissance.** The existence, general location, and type of critical areas on, adjacent to, or likely to be impacted by activities on a project site. Determination of whether the project will adversely impact or be at risk from the potential critical areas based on maximum potential buffers for the particular critical area type. Possible application of exemptions should also be addressed;
2. **Delineation.** The extent, boundaries, rating or classification, and applicable standard buffers of critical areas where the project area could potentially impact the critical area or its buffer including an assessment of the characteristics of or functions and values of the critical area and buffers identified;
3. **Analysis.** The proposal and impact assessment report documenting the potential project impacts to the critical area and buffers including a discussion of the efforts taken to avoid, minimize, and reduce potential impacts to those areas per AMC 19.70.125(A);
4. **Mitigation.** The measures that prevent or compensate for the potential impacts of the project designed to meet the requirements of this chapter, AMC 19.70.125, Mitigation Plan Requirements, and the standards for the specific critical areas impacted. Mitigation includes, but is not limited to, adjustments to required buffer sizes, best practices to minimize impacts, and critical area or buffer enhancement, restoration, or preservation plans. Mitigation plans include but are not limited to habitat management plans, revegetation or replanting plans, and restoration plans;
5. **Maintenance and Monitoring.** The goals of the mitigation proposed, performance standards for success, monitoring methods and reporting schedule, and contingency actions. Maintenance and monitoring plans must be consistent with the mitigation performance standards and requirements of this chapter, including the specific mitigation plan requirements outlined in each critical area type section.

D. Minimum Report Requirements. At a minimum, critical area reports must contain the following information:

1. The names and qualifications of the persons preparing the report and documentation of any fieldwork performed on the site;
2. A description of the proposal, proposal location including address and parcel number(s), and a vicinity map for the project;
3. Identification and characterization of all critical areas, water bodies, shorelines, and buffers on or within 300 feet of the proposed project area, The [Decision-maker](#) [Director](#) may require critical area and buffer dimensions be accurately surveyed, depending on the scope of the project;

4. Documentation of any fieldwork performed on the site, including field data sheets, for delineations, rating system forms, baseline hydrologic data, site photos, etc.;
5. A statement specifying the accuracy of the report and all assumptions made and relied upon;
6. A description of methodologies used to conduct the critical areas investigation, including references;
7. A scaled drawing of critical areas and buffer identified in the report including buffers for off-site critical areas that extend onto the project site.

E. Existing reports. Critical areas assessment reports must generally be valid for a period of five years. Unless otherwise provided, a critical areas report may incorporate, be supplemented by, or composed of any reports or studies required by other laws and regulations or previously prepared for and applicable to the development proposal site, as approved by the [Decision maker/Director](#). At the discretion of the [Decision maker/Director](#), reports previously compiled or submitted as part of a proposal for a development may be used as a critical areas report to the extent that the requirements of this section and the requirements for each specific critical area type are met. Supplemental critical area report(s) may be required to provide information or analysis to address changes to the project scope, potential impacts or to changes to applicable regulations that have been made subsequent to existing, valid critical area reports, or other circumstances.

F. Modifications to Report Requirements. The applicant may consult with the [Decision maker/Director](#), prior to or during preparation of the critical areas report, to obtain approval of modifications to the required contents of the report where, in the judgement of a qualified professional, more or less information is required to adequately address the potential critical area impacts and required mitigation.

~~4.1.1~~ In some cases, such as when it is determined that no specific critical area is present, a full report may not be necessary to determine compliance with the critical area regulations, and in those cases a letter or reconnaissance only report may be required.

~~5.2.2~~ Limitations to study area. The [Decision maker/Director](#) may limit the required geographic area of the critical areas report as appropriate if:

- a. The applicant, with assistance from the City of Anacortes, cannot obtain permission to access properties adjacent to the project area; or
- b. The proposed activity will affect only a limited part of the project site.

19.70.120 Application Requirements.

~~A. A~~ A complete application for a [critical area/Permitted Alteration](#) permit or [critical area/Reasonable Use Exception](#) permit must include the following information and

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materials on a form provided by the ~~Decision-maker~~Director. For the purpose of this section, a complete application includes:

1. The name and contact information of the applicant;
2. Adequate information to determine compliance with the requirements of the critical area regulations, including a critical area report, impact and hazard assessment, and mitigation requirements specific to each critical area type, as indicated in the corresponding sections of this chapter;
3. Identification of the development permit(s) requested and all other local, State, and/or Federal critical area-related permits required for the project;
4. Site plan, a scaled drawing of the development proposal including:
 - a. Property and project site boundaries.
 - b. An accurate depiction of all critical areas, including off-site critical areas and buffers that extend onto the project site, a desk survey is acceptable when access to the adjacent property has been denied.
 - c. The development proposal, including grading and clearing limits and areas of proposed impacts to critical areas and/or buffers (include square footage estimates).
 - d. A scaled depiction and description of the proposed stormwater pollution prevention plan consistent with the adopted stormwater manual, for the development and consideration of impacts to critical areas due to drainage alterations;
 - e. ~~5-~~An assessment of probable impacts to the critical areas resulting from the proposed development of the site based upon identified findings;
 - f. ~~6-~~A description of reasonable efforts made to apply mitigation sequencing pursuant to AMC 19.70.135, Mitigation requirements, to avoid, minimize, and mitigate impacts to critical areas; and
 - g. ~~7-~~ Plans for mitigation required to offset any critical areas impacts, in accordance with AMC 19.70.140, Mitigation plan requirements, and the corresponding mitigation performance standards sections of this chapter, including a discussion of the applicable development standards and cost estimates for determination financial guarantee requirements.

- B. **Additional Requirements.** The ~~Decision-maker~~Director may require additional information to be included in the critical areas permit submittal when determined to be necessary to the review of the proposed activity in accordance with this chapter. Additional information that may be required includes, but is not limited to:

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1. Historical data, including original and subsequent mapping, historical aerial photographs, data compilations and summaries, and available reports and records relating to the site or past operations at the site;
2. Grading and stormwater management plans; and
3. Information specific to the type, location, and nature of the critical area.

19.70.125 Mitigation requirements.

Mitigation must be sufficient to restore impacted functions and values, or compensate for the impacted functions and values of the critical area and to prevent risk from a hazard posed to a critical area by the proposed activity. Mitigation must not be implemented until after the ~~Decision-maker~~[Decision-maker](#) has provided approval of a critical areas report that includes a mitigation plan.

- A. **Mitigation sequencing.** This section applies to mitigation required with all critical areas reviews, approvals, and enforcement pursuant to this chapter. This section is supplemented with specific measures under [parts subchapters](#) for particular critical area types. Mitigation for specific development proposals may include a combination of the measures below and must be designed and constructed in accordance with the provisions of this section. Before impacting any critical areas, an applicant must demonstrate that the following actions have been taken in the following sequential order:
 1. Avoiding the impact altogether by not taking a certain action or parts of actions;
 2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation by using appropriate technology, or by taking affirmative steps, such as project redesign, relocation, or timing, to avoid or reduce impacts;
 3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment or by restoring or stabilizing the critical area through natural, engineering, or other methods;
 4. Reducing or eliminating the impacts or hazard over time by preservation and maintenance operations during the life of the action;
 5. Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or
 6. Monitoring, measuring and reporting the impact to the ~~Decision-maker~~[Decision-maker](#) and taking appropriate corrective measures.
- B. ~~Applicants must first demonstrate an inability to avoid or reduce impacts before the use of actions to mitigate potential impacts will be allowed. No activity or use may be allowed that results in a net loss of the functions or values of a critical area.~~
- C. **Type, Location and Timing of Mitigation.** Unless it is demonstrated that higher level of ecological functioning or greater reduction of hazard risk would result from an alternative approach or as otherwise allowed in this chapter, mitigation for adverse impacts must be based on best available science and must be in-kind, on-site, and prior to the activities that will

disturb the critical area. Mitigation measures that cannot be implemented prior to the critical area impacts must be completed immediately following disturbance and prior to use or occupancy of the action or development. Construction of mitigation projects must be timed to reduce impacts to existing fisheries, wildlife, and flora.

1. The ~~Decision-maker~~[Decision-maker](#) may authorize a one-time temporary delay in completing construction or installation of the mitigation when the applicant provides a written explanation from a ~~Qualified~~[Professional-Professional](#) as to the rationale for the delay and satisfactory financial guarantee that the installation will occur. An appropriate rationale would include identification of the environmental conditions that could produce a high probability of failure or significant construction difficulties (e.g. project delay lapses past a fisheries window, or installing plants should be delayed until the dormant season to ensure greater survival of installed materials). The delay must not create or perpetuate hazardous conditions or environmental damage or degradation, and the delay must not be injurious to the health, safety, or general welfare of the public.
2. **Alternative mitigation approaches.** If the applicant can demonstrate that off-site concurrent or advance mitigation would provide a higher level of ecological functioning or a greater reduction of hazard risk, off-site mitigation that occurs on Fidalgo Island will be considered by the ~~Decision-maker~~[Decision-maker](#).

19.70.130 Mitigation plan requirements

When mitigation is required, the applicant must submit for approval by the City a mitigation plan as part of the critical area report. The mitigation plan must include:

- A. **Environmental Goals and Objectives.** The mitigation plan must identify environmental goals and objectives of the mitigation proposed and including:
 1. A description of the anticipated impacts to the critical areas, the mitigating actions proposed, and the purposes of the compensation measures, including the site selection criteria; identification of compensation goals; identification of resource functions; and dates for beginning and completion of site compensation construction activities. The goals and objectives must be related to the functions and values of the impacted critical area; and
 2. A review of the best available science supporting the proposed mitigation and a description of the report author's experience to date in restoring or creating the type of critical area proposed.
- B. **Performance Standards.** The mitigation plan must include measurable specific criteria for evaluating whether or not the goals and objectives of the mitigation project have been successfully attained at the end of the required monitoring period and whether or not the requirements of this chapter have been met.
- C. **Detailed Construction Plans.** In order to convey proposed construction techniques and anticipated final outcome, the mitigation plan must include written specifications, descriptions, and drawings of the mitigation propose, including:

1. The proposed construction sequence, timing, and duration;
2. Best management practices including erosion and sediment control features to be implemented;
3. Site plans showing grading and excavation details, slope gradient, and final grade elevations with minimum two-foot contour intervals;
4. Cross-sectional drawings;
5. A planting plan specifying plant species, quantities, locations, size, spacing, and density; and
6. Measures to protect and maintain plants until established.

D. Monitoring Program and Contingency Plan. A monitoring and contingency plan is required for all projects requiring mitigation.

1. The mitigation plan must include a monitoring program to be implemented by the applicant to determine the success of the mitigation project and any necessary corrective actions. This program must determine if the original goals and objectives of the mitigation plan are being met.
2. A contingency plan must be established for indemnity in the event that the mitigation project is inadequate or fails. Contingency plans include identification of potential courses of action, and any corrective measures to be taken if monitoring or evaluation indicates project performance standards are not being met. Corrective measures must be taken when the qualified professional indicates, in a monitoring report, that the contingency actions are needed to ensure project success by the end of the monitoring period. A performance and maintenance bond, or other acceptable financial guarantee, is required to ensure the applicant's compliance with the terms of the mitigation agreement consistent with AMC 19.70.160, financial guarantee requirements.
3. Monitoring programs prepared to comply with this section must include the following requirements:
 - a. Best available scientific procedures must be used to establish the success or failure of the project. A protocol outlining the schedule for site monitoring (for example, monitoring must occur in years zero (as-built), one, three, and five after site construction), and how the monitoring data will be evaluated to determine if the performance standards are being met.
 - b. For vegetation determinations, permanent sampling points must be established.
 - c. The monitoring program must include measurable specific criteria, or performance standards, for evaluating whether or not the goals and objectives of the mitigation plan have been successfully attained.
 - d. A monitoring report must be submitted as needed to document milestones, successes, problems, and contingency actions of the mitigation project. Monitoring reports on the

current status of the mitigation project must be submitted, consistent with Subsection (e) of this section, to the City on the schedule identified in the monitoring plan, but not less than every other year. The reports are to be prepared by a qualified professional and reviewed by the City, or a qualified professional retained by the City, and should include monitoring information on wildlife, vegetation, water quality, water flow, stormwater storage and conveyance, and existing or potential degradation, as applicable.

- e. Monitoring programs must be established for a period necessary to establish that performance standards have been met, but not for less than a minimum of five years without approval from the ~~Decision-maker~~[Decision-maker](#). A longer monitoring period may be required depending on the mitigation goals.
 - f. If necessary, failures in the mitigation project must be corrected.
 - g. Dead or undesirable vegetation must be replaced with appropriate plantings.
 - h. Damage caused by erosion, settling, or other geomorphological processes must be repaired.
 - i. ~~The~~ mitigation project must be redesigned (if necessary) and the new design must be implemented and monitored, as in subsection (D)(3)(d) of this section.
 - j. Correction procedures must be approved by the ~~Decision-maker~~[Decision-maker](#); the ~~decision-maker~~[Decision-maker](#) may request review by a qualified professional.
 - k. If the mitigation goals are not obtained within the initial monitoring period, the applicant remains responsible for restoration of the impacted values and functions or hazard risk reduction until the mitigation goals agreed to in the mitigation plan are achieved.
- E. **Monitoring Reports.** Monitoring reports must be submitted to the City consistent with the approved monitoring plan.
- 1. The as-built report, required prior to final inspection, must, at a minimum, include documentation of the following:
 - a. Departures from the original approved plans;
 - b. Construction supervision provided by the qualified professional;
 - c. Approved project goals and performance standards;
 - d. Baseline data for monitoring per the approved monitoring methods;
 - e. Photos from established photo points; and
 - f. A site plan showing final mitigation as constructed or installed, monitoring points, and photo points.
 - 2. Subsequent monitoring reports must, at a minimum, include:
 - a. Monitoring visit observations, documentation, and analysis of monitoring data collected;
 - b. Photos from established photo points;

- c. Determination whether performance standards are being met; and
 - d. Maintenance and/or contingency action recommendations to ensure success of the project at the end of the monitoring period.
3. The applicant is responsible for reimbursement of the cost of review of monitoring reports and site inspections during the monitoring period which are completed by the City or a qualified professional under contract with or employed by the City.
- F. **Cost Estimates.** The mitigation plan must include cost estimates that will be used by the City to calculate the amounts of financial guarantees, if necessary, to ensure that the mitigation plan is fully implemented. Financial guarantees ensuring fulfillment of the compensation project, monitoring program, and any contingency measures must be posted in accordance with AMC 19.70.160, financial guarantee requirements.
- G. **Approved Mitigation Projects – Signature.** On completion of construction, an as-built report for any approved mitigation project must be prepared and signed off by the applicant’s qualified professional and approved by the City. Signature of the qualified professional on the required as-built report and approval by the ~~Decision-maker~~[Director](#) indicates that the construction has been completed as planned.

19.70.135 Title Notification.

- A. **Generally.** A critical area notice on title is required, as a condition of permit issuance or project approval, when a permit or development application is submitted for development on any property containing a critical area or buffer. The purpose is to inform subsequent purchasers of real property of the existence of critical areas.
- 1. The title notice requirement can be met through recording of a title notice on forms prepared by the City, establishment of a critical area tract, or recording of a native growth protection area easement, consistent with AMC 19.70.145(B) through (D) below, as applicable.
 - 2. The following must be noted on all critical area title notice documents:
 - a. Identification of ownership and long term maintenance responsibility of critical areas, buffers, and permanent field markings (e.g. fencing, signage);
 - b. Restrictions on development, vegetation removal, and application of hazardous substances (pesticides, herbicides, fertilizers) within the critical areas and buffers;
 - c. The right of the City to enforce the terms of the restrictions.
- B. **Title Notice.** The title notice applicable to the property must be approved by the ~~Decision-maker~~[Decision-maker](#) and City Attorney for compliance with this provision and be filed by the property owner, at their expense, with the Skagit County Auditor’s Office. The title holder will have the right to challenge this notice and to have it extinguished if the critical area designation

no longer applies. However, the titleholder is responsible for completing a critical area report, subject to approval by the ~~Decision-maker~~[Decision-maker](#), before the notice on title can be extinguished. The title notice runs with the land.

C. Critical Area Tract. Subdivisions, short subdivisions, and binding site plans must establish a separate critical areas tract as a permanent protective measure for wetlands, fish and wildlife habitat conservation areas, and ~~landslide~~[geological](#) hazard areas and their buffers. The plat or binding site plan for the project must note the long-term ownership/maintenance responsibility as well as clearly depict the critical areas tract, including all of the subject critical area, any required buffer, and any additional lands included voluntarily as part of the project. Should the critical area tract include several types of critical areas, separate critical areas tracts must be identified.

D. Native Growth Protection ~~Easements~~Area (NGPANGPE). ~~NGPA-NGPE~~ easements are required on a property where no subdivision, short subdivision, or binding site plan is proposed or required. Unless otherwise required in this chapter, ~~NGPA-NGPE~~ easements must be recorded on title for all affected parcels prior to approval of a development application or building permit, when two or more dwelling units and/or nonresidential development are proposed on one parcel, to delineate and protect critical areas and their buffers. The easement to be recorded must clearly depict the critical area(s), required buffer(s) and the limits of the ~~NGPA-NGPE~~ easement.

19.70.140 Field marking.

A. Temporary field marking during construction. The outer perimeter of the critical area buffer and the clearing limits identified by an approved permit or authorization must be marked in the field with temporary "clearing limits" fencing in such a way as to ensure that no unauthorized intrusion will occur. The marking is subject to inspection by the ~~Decision-maker~~[Director](#) prior to the commencement of permitted activities. This temporary marking and fencing must be maintained throughout construction and may not be removed until permanent fencing and/or signs, if required, are in place.

B. Permanent field marking. The ~~Decision-maker~~[Decision-maker](#) may require installation of permanent signs, markers, and fencing along the outer perimeter of a critical area or its buffer when it is determined necessary to protect the critical areas' functions and values. Permanent markings must be installed prior to final project approval or occupancy, as determined by the ~~Decision-maker~~[Decision-maker](#).

1. **Signs.** All critical areas tracts, easements, and dedications, should be clearly marked on the site using permanent markings, as follows:

a. Signs must be placed at least every 50 feet, with a minimum of one per lot, which include the following text, or similar, as approved by the ~~Decision-maker~~[Decision-maker](#):

City of Anacortes Designated Critical Area. Activities, including clearing and grading, removal of vegetation, pruning, cutting of trees or shrubs, planting of nonnative species, and other alterations may be prohibited. Help protect and care for this area. Please contact the City of Anacortes with questions or concerns.

b. Signs must be made of an enamel-coated metal face and attached to a metal post or another non-treated material of equal durability.

2. **Fencing.** Permanent fencing should be designed so as not to interfere with species migration or wildlife movement, unless exclusion fencing is more pertinent, and constructed in a manner that minimizes impacts to the critical areas and buffers. Proposed fencing type and materials will be determined on a case by case basis and must be approved by the ~~Decision-maker~~[Decision-maker](#) prior to installation.

C. **Maintenance and replacement.** It is the responsibility of the landowner, successors, or as otherwise assigned to maintain in perpetuity and replace, if necessary, all permanent fencing and field markings.

19.70.145 Construction plan review, monitoring, and inspection.

- A. The ~~Decision-maker~~[Director](#) may require project building and construction plans be reviewed by a qualified professional for confirmation of consistency with the critical areas report and recommendations prior to approval of construction plans.
- B. The ~~Decision-maker~~[Director](#) may require monitoring by a qualified professional during site alteration activities within, or adjacent to, critical areas or buffers, and/or a final inspection report by the qualified professional stating that construction has or has not implemented the design recommendations provided in the project critical areas report, and evaluation of any deviation from the recommendations.
- C. When the ~~Decision-maker~~[Director](#) determines that such services are necessary to demonstrate compliance with the standards and guidelines of this chapter, they will be at the applicant's expense.

19.70.150 Financial Guarantee Requirements.

When determined necessary by the ~~Decision-maker~~[Director](#), bonds, and other financial guarantees, and associated performance agreements or maintenance/defect/monitoring agreements are required for projects with required mitigation or restoration of impacts to critical areas or critical area buffers consistent with the following:

- A. A performance agreement and bond, or other acceptable financial guarantees, are required from the applicant when mitigation required pursuant to a development proposal is not completed prior to final permit approval, such as final plat approval or final building inspection. The amount of the performance bond(s) must equal 125 percent of the cost of the mitigation project.
- B. A performance agreement and bond, or other acceptable financial guarantees, are required from the applicant when restoration is required for remediation of a critical area violation. The amount of the performance bond(s) must equal 125 percent of the cost of the mitigation project.
- C. A maintenance/defect/monitoring agreement and bond, or other acceptable financial guarantees, are required to ensure the applicant's compliance with the conditions of the approved mitigation

plan pursuant to a development proposal or restoration plan for remediation of a violation. The amount of the maintenance bond(s) must equal 125 percent of the cost of the mitigation project in addition to the cost for monitoring for a minimum of five years. The monitoring portion of the financial guarantee may be reduced in proportion to work successfully completed over the period of the bond. The bonding period must coincide with the monitoring period.

19.70.165 Unauthorized Critical Area Alterations.

- A. When a critical area or its buffer has been altered in violation of this chapter, all ~~development~~ work must stop and the critical area and buffer must be restored. The ~~Decision maker~~Director may issue a stop work order to cease all ~~development~~work, and order restoration measures at the owner's or other responsible party's expense to remediate the impacts of the violation of the provisions of this chapter.

B. Requirement for Restoration Plan.

1. All ~~work~~development must remain stopped until a restoration plan is prepared by the responsible party and an approved after the fact permit is issued by the City. Such a plan must be prepared by a ~~qualified~~Qualified professionalProfessional using the best available science and must describe how the actions proposed meet the minimum requirements described in subsection C of this section.
2. The ~~Decision maker~~Director may, at the responsible party's expense, seek expert advice, including but not limited to third party review by a qualified professional under contract with or employed by the City, in determining if the plan meets the minimum performance standards for restoration. Submittal, review, and approval of required restoration plans for remediation of violations of this chapter must be completed through a site development permit application process.

C. Minimum Performance Standards for Restoration.

1. For alterations to critical aquifer recharge areas, wetlands, and fish and wildlife habitat conservation areas, the following minimum performance standards must be met for the restoration:
 - a. The pre-violation function and values of the affected critical areas and buffers must be restored, including but not limited to hydrologic, water quality and habitat functions;
 - b. The pre-violation soil types and configuration must be replicated;
 - c. The critical area and buffers must be replanted with a native vegetation community that reproduces the structure, species content and condition of the pre-violation vegetation community. Based on the historical or pre-violation vegetation community, native plant species must be replaced at minimum of a 5:1 ratio or installed at a density of 5 foot-on-center unless

approved by the ~~Decision-maker~~[Decision-maker](#). The pre-violation functions and values should be replicated at the location of the alteration; and

- d. Information demonstrating compliance with the requirements in AMC 19.70.~~140~~[125](#), Mitigation plan requirements, and the applicable mitigation sections for the affected type(s) of critical area(s) and their buffer(s) must be submitted to the ~~Decision-maker~~[Decision-maker](#) with a complete site development permit application.
- e. These standards may be modified by the ~~Decision-maker~~[Decision-maker](#) when it can be demonstrated that greater functional and habitat values can be obtained.

2. For alterations to special flood hazard and geologically hazardous areas, the following minimum performance standards must be met for the restoration of a critical area:

- a. The hazard must be reduced to a level equal to, or less than, the pre-violation hazard;
- b. Any risk of personal injury resulting from the alteration must be eliminated or minimized; and
- c. The hazard area and buffers must be replanted with native vegetation sufficient to minimize the hazard.
- d. These standards may be modified by the ~~Decision-maker~~[Decision-maker](#) if the violator can demonstrate that greater safety can be obtained.

D. Site Investigation. The ~~Decision-maker~~[Director](#) is authorized to take such actions as are necessary to enforce this chapter. The ~~Decision-maker~~[Director](#) (or ~~Decision-maker~~[Director's](#) authorized representative) must present proper credentials and obtain permission before entering onto private property.

E. Penalties. Any responsible party violating the provisions of this chapter may be subject to applicable penalties per AMC Title 20 Civil Enforcement and Penalties plus the following:

- 3. A square footage cost of \$3.00 per square foot of impacted critical area buffer; and a square footage cost of \$15.00 per square foot of impacted critical area; and
- 4. A per tree penalty in the amount of \$3,000 per non-significant tree and \$9,000 per Significant Tree, for trees removed, or otherwise damaged, within a critical area or buffer in violation of the provisions of this chapter.

19.70.170 Final Decision and Appeals.

- A. **Completion of the critical area review.** The city's determination regarding critical areas pursuant to this chapter is final concurrent with the final decision to approve, condition, or deny the underlying permit for the development proposal or other activity involved.
- B. **Appeals.** Any decision to approve, condition, or deny a development activity proposal or other activity based on the requirements of this chapter may be appealed according to, and as part of, the appeal procedure for the underlying permit or approval involved.

PART 2: WETLANDS

19.70.210 Wetlands – Description and Purpose.

It is the purpose of this Chapter to protect the functions and values of wetlands, which serve many important ecological and environmental functions and help to protect public health, safety, and welfare by providing flood storage and conveyance, and erosion control, while also providing fish and wildlife habitat, recreation, water quality protection, water storage, education, scientific research opportunities and other public benefits.

19.70.215 Wetlands - Designation and Rating.

A. Designation. All areas meeting the definition of a wetland and the wetland identification criteria pursuant to this chapter, regardless of any formal identification, are hereby designated critical areas and are subject to the provisions of this chapter.

B. Rating. Wetlands must be rated by a qualified professional according to the Washington State Department of Ecology Wetland Rating System for Western Washington - 2014 Update (Ecology Publication #14-06-029, October 2014), or as revised. Wetland rating categories will be applied as the wetland exists on the date of adoption of the rating system by the City, as the wetland naturally changes in accordance with permitted activities.

1. **Category I.** Category I wetlands are those that represent unique or rare wetland types, are more sensitive to disturbance than most wetlands, are relatively undisturbed and contain ecological attributes that are impossible to replace within a human lifetime, or provide a high level of functions. The following types of wetlands are Category I:
 - a. Relatively undisturbed estuarine wetlands larger than one acre;
 - b. Wetlands of high conservation value identified by scientists of the Washington Natural Heritage Program/Department of Natural Resources (DNR);
 - c. Bogs;
 - d. Mature forested wetlands larger than one acre;
 - e. Wetlands in coastal lagoons; and
 - f. Wetlands that perform many functions well and have a total score of 23 points or more in the wetland rating.
2. **Category II.** Category II wetlands are those wetlands that are difficult, though not impossible, to replace, and provide high levels of some functions. The following types of wetlands are Category II:
 - a. Estuarine wetlands smaller than 1 acre or disturbed estuarine wetlands larger than 1 acre;

- b. Wetlands with a moderately high level of functions and a total score of 20 to 22 points in the wetland rating.
 - c. Wetlands in coastal lagoons that are relatively undisturbed and equal to or smaller than 1/10 ac (4350 square feet).
3. **Category III.** Category III wetlands are those with a moderate level of functions, generally have been disturbed in some ways, can often be adequately replaced with a well-planned mitigation project, and are often less diverse or more isolated from other natural resources in the landscape than Category II wetlands. The following types of wetlands are Category III:
- a. Wetlands with a moderate level of functions with a total score of 16 to 19 points in the wetland rating.
4. **Category IV.** Category IV wetlands have the lowest levels of functions and are often heavily disturbed, with a total score of 15 points or less in the wetland rating. The functions provided by Category IV wetlands are generally easier to replace, and in some cases can be improved. However, experience has shown that replacement of functions cannot be guaranteed in any specific case. These wetlands may provide some important functions that need protected.
- B. **Illegal Modifications.** When a violation occurs wetland rating categories do not change due to illegal modifications or alterations. A wetland's category must be based on the pre-violation condition of the wetland.

19.70.220 Wetlands – Mapping and delineation.

- A. **Mapping.** The approximate location and extent of potential wetlands are shown in the wetland data layer maintained in the City of Anacortes geographic information system (GIS). In addition, the following maps and inventories, that depict areas of hydric soils and potential wetland areas, are hereby adopted by reference as amended:
- 1. Soils maps produced by the U.S. Department of Agriculture, National Resources Conservation Service; and
 - 2. The National Wetlands Inventory, produced by the U.S. Fish and Wildlife Service.
- B. **Reference Only.** The maps and resources cited above are to be used as a guide for the Department, project applicants, and/or property owners and may be continuously updated as new critical areas are identified. They are a reference and do not provide a final critical area designation.
- C. **Identification and Delineation.** Identification of wetlands and delineation of their boundaries pursuant to this chapter must be done in accordance with the adopted Federal wetland delineation manual and applicable regional supplements per WAC [173-22-035](#). The exact location of a wetland's boundary must be determined through the performance of a field investigation by a qualified professional. Evidence documenting the results of the

boundary survey, including evidence of a lack of wetland indicators if no wetlands are identified, must be submitted to the City.

19.70.225 Wetlands – General Development Standards.

- A. All development activities and uses are prohibited in wetlands and wetland buffers, except as provided for in this chapter, and only when it is demonstrated that the activity will not result in a loss of the functions and values of the wetland through the application of mitigation sequencing in AMC 19.70.135.
- B. **Exemptions.** Exemptions to this chapter are listed in the provisions established in AMC 19.70.035 Exemption activities.
- C. **Subdivisions.** The subdivision and/or short subdivision of land in wetlands and associated buffers are subject to the following:
 - 1. Land that is located wholly within a wetland and/or its buffer may not be subdivided; and
 - 2. Land that is located partially within a wetland and/or its buffer may be subdivided; provided they each lot will meet all zoning standards in AMC 19.42 without encroaching into the wetland or buffer. the minimum lot size calculations as required in AMC 19.40.

19.70.230 Wetlands – Specific Wetland Category Development Standards.

- A. **Category I Wetlands.** Development activities and uses that result in alteration of Category I wetlands and their associated buffers are prohibited, unless the denial will prevent all reasonable economic use of the property. The development may be permitted through a Critical Area Variance if it is determined to be the minimum impact possible and a Reasonable Use as prescribed in AMC 19.70.045.
- B. **Category II, III and IV Wetlands.** Development activities that result in alteration of Category II, III or IV wetlands may be permitted upon demonstration, through a critical areas report meeting the requirements of this Chapter, that:
 - 1. Mitigation sequencing has been applied per AMC 19.70.135125(A);
 - 2. The proposed alteration will not degrade the quantitative and qualitative functioning of the wetland, or that any degradation can be adequately mitigated to protect or compensate for the wetland functions that are lost;
 - 3. Small, Hydrologically Isolated Category III and IV Wetlands (less than 1,000 sq. ft.). The Decision-makerDecision-maker may allow small, hydrologically isolated Category III and IV wetlands to be exempt from the requirement to avoid impacts (AMC 19.70.135125(A)(1) Mitigation requirements) and allow alteration of such wetlands if all of the following conditions are met:

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3. Small, Hydrologically Isolated Category IV Wetlands (less than 1,000 sq. ft.). The Decision-maker may allow small, hydrologically isolated Category IV wetlands to be exempt from the requirement to avoid impacts (AMC 19.70.135(A)(1) Mitigation requirements) and allow alteration of such wetlands if all of the following conditions are met:

- a. The remaining mitigation sequencing actions of AMC 19.70.135125(A) (2)-(6) are followed;
 - b. The wetland is less than 1,000 square feet in area;
 - c. The wetland does not have unique characteristics that would be difficult to replace through standard compensatory mitigation practices.
 - d. The wetland is a low quality Category III or IV wetland with a habitat score of less than 5 points in the adopted rating system;
 - e. The wetland does not provide significant suitable breeding habitat for native amphibian species. Suitable breeding habitat may be indicated by adequate stable and seasonal inundation that is persistent from February to at least through April and presence of thin-stemmed emergent vegetation and/or clean water;
 - f. The wetland does not contain habitat identified as essential for local populations of priority species identified by the Washington Department of Fish and Wildlife or species of local importance which are regulated as fish and wildlife habitat conservation areas in [Chapter 19.70.300 Part 3 \(FWHCA_section\)](#);
 - g. The wetland is not associated with shorelines of the state or their associated buffers;
 - h. The wetland is not associated with riparian areas or buffers;
 - i. The wetland is not part of a wetland mosaic; and
 - j. A mitigation plan to replace lost wetland functions and values is developed, approved, and implemented consistent with AMC 19.70.140125.
 - k. In order to verify that the wetland meets these exemption conditions, a critical area report for wetlands meeting the requirements in this chapter must be submitted.
4. Small, Hydrologically Isolated Category III and Category IV Wetlands (less than 1,000 sq. ft.). Wetlands less than 1,000 square feet that meet the criteria in subsection (B)(3) of this section (above) and that do not contain federally listed species or their critical habitat are exempt from the buffer provisions contained in this Chapter. In order to verify that the wetland meets this exemption, a critical area report for wetlands meeting the requirements in this chapter must be submitted.

19.70.235 Wetlands – Required buffer areas.

- A. **Buffer Requirements.** Wetland buffers must be established to protect the integrity, functions and values of the wetland. The standard buffer widths in Tables 19.70.250 (A) (B) and (C) have been established in accordance with the best available science. The buffer widths must be determined based on the category of wetland, surrounding land use intensity, and the habitat score as assigned by a qualified wetland professional using the most up to date version of the Washington State Wetland Rating System for Western Washington.
1. **Measurement of Wetland Buffers.** All buffers must be measured horizontally from edge of the wetland boundary as surveyed in the field. The width of the wetland buffer must be determined according to Tables 16.55.340(B), (C) and (D).
 2. **Buffer Standards.** The buffer standards required by this chapter presume the existence of a dense vegetation community in the buffer adequate to protect the wetland functions and values. When a buffer lacks adequate vegetation, the ~~decision-maker~~Decision-maker may increase the standard buffer, require buffer planting or other enhancements, and/or deny a proposal for buffer reduction or buffer averaging.
- B. For the purposes of buffer determination below, Land Use Intensity rating is as follows:

Table 19.70.235 (A)

High Land Use Intensity	Land use that includes the following uses or activities: commercial, industrial, institutional, retail sales, nonresidential use in zones where the primary intent is residential, <u>high density all</u> residential zones (R4, R4A, <u>R3, R3A, R2, R2A, R1, OT</u>), high-intensity recreation (such as golf courses, ball fields,), and <u>and</u> hobby farms.
Moderate Land Use Intensity	Land use that includes the following uses or activities: medium density residential (R2, R2A, R3, R3A), moderate-intensity open space (parks, trails, and logging roads).
Low Land Use Intensity	Land use that includes the following uses or activities: low density residential (R1), forestry (cutting of trees only), low-intensity open space (such as passive recreation and natural resources preservation), unpaved trails.

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Land use that includes the following uses or activities: commercial, industrial, institutional, retail sales, nonresidential use in zones where the primary intent is residential, high density all residential zones (R4, R4A, R3, R3A, R2, R2A, R1, OT), high-intensity recreation (such as golf courses, ball fields,), hobby farms.

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Land use that includes the following uses or activities: moderate-intensity open space (parks, trails, and logging roads).

Commented [CT12]: Change to:

Land use that includes the following uses or activities: forestry (cutting of trees only), low-intensity open space (such as passive recreation and natural resources preservation), unpaved trails.

C. There are three sets of buffer standards, based on these parameters:

1. Buffer Widths for wetlands that have a high level of function for wildlife habitat as indicated by a habitat function score of 8 or 9 points on the wetland rating form:

Table 19.70.235 (B).

Wetland Category	Buffer Width (feet)		
	High Intensity	Moderate Intensity	Low Intensity
Category I	200 300	150 225	150
Category II	200 300	150 225	100
Category III	150	110	75
Category IV	50	40	25

Commented [CT13]: The following changes to the table:

2. Buffer Widths for wetlands that have a moderate level of function for wildlife habitat as indicated by a habitat function score of 6 or 7 points on the wetland rating form:

Table 19.70.235 (C).

Wetland Category	Buffer Width (feet)		
	High Intensity	Moderate Intensity	Low Intensity
Category I	150	110	75
Category II	150	110	75
Category III	150	100 110	60 75
Category IV	50	40	25

Commented [CT14]: Add the following section:

Reducing Buffer Widths.

1. For wetlands that score 6 points or more for habitat function, buffer widths for high intensity may be reduced to moderate intensity if both of the following criteria are met:
 - a. A relatively undisturbed, vegetated corridor at least 100 feet wide is protected between the wetland and any other relatively undisturbed area, as defined in the 2014 wetland rating system, or any other Priority Habitat as defined by the Washington State Department of Fish and Wildlife. The latest definitions of Priority Habitats and their locations are available on the WDFW web site at: <http://wdfw.wa.gov/hab/phshabs.htm>. The corridor must be protected for the entire distance between the wetland and the relatively undisturbed area or Priority Habitat by some type of legal protection such as a conservation easement. Presence or absence of a nearby habitat must be confirmed by a qualified biologist.

b. The measures in Table XX are implemented, where applicable, to minimize the impacts of the adjacent land uses.

2. For wetlands that score 3-5 habitat points, only the measures in Table 17.70.250(E) are required for the use of moderate intensity buffer widths.

3. If an applicant chooses not to apply the mitigation measures in Table 17.70.250(E), or is unable to provide a protected corridor where available, then high intensity buffer widths must be used.

Add Table : 19.70.250 (E)

3. Buffer Widths for wetlands that have a low level of function for wildlife habitat as indicated by a habitat function score of 3 to 5 points on the wetland rating form:

Table 19.70.235 (D).

Wetland Category	Buffer Width (feet)		
	High Intensity	Moderate Intensity	Low Intensity
Category I	100	75	50
Category II	100	75	50
Category III	80	60	50 40
Category IV	50	40	25

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D. Reducing Buffer Widths.

1. For wetlands that score 6 points or more for habitat function, buffer widths for high intensity may be reduced to moderate intensity if both of the following criteria are met:

a. A relatively undisturbed, vegetated corridor at least 100 feet wide is protected between the wetland and any other relatively undisturbed area, as defined in the 2014 wetland rating system, or any other Priority Habitat as defined by the Washington State Department of Fish and Wildlife. The latest definitions of Priority Habitats and their locations are available on the WDFW web site at: <http://wdfw.wa.gov/hab/phshabs.htm>). The corridor must be protected for the entire distance between the wetland and the relatively undisturbed area or Priority Habitat by some type of legal protection such as a conservation easement. Presence or absence of a nearby habitat must be confirmed by a qualified biologist.

2. The measures in Table 19.70.235(E) are implemented, where applicable, to minimize the impacts of the adjacent land uses.

3. For wetlands that score 3-5 habitat points, only the measures in Table 17.70.250(E) are required for the use of moderate intensity buffer widths.

4. If an applicant chooses not to apply the mitigation measures in Table 17.70.250(E), or is unable to provide a protected corridor where available, then high intensity buffer widths must be used

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Table 19.70.235 (E)

Disturbance	Required Measures to Minimize Impacts
Lights	• Direct lights away from wetland
Noise	• Locate activity that generates noise away from wetland • If warranted, enhance existing buffer with native vegetation plantings adjacent to noise source • For activities that generate relatively continuous, potentially disruptive noise, such as certain heavy industry or mining, establish an additional 10' heavily vegetated buffer strip immediately adjacent to the outer wetland buffer
Toxic runoff	• Route all new, untreated runoff away from wetland while ensuring wetland is not dewatered • Establish covenants limiting use of pesticides within 150 ft of wetland • Apply integrated pest management
Stormwater runoff	• Retrofit stormwater detention and treatment for roads and existing adjacent development • Prevent channelized flow from lawns that directly enters the buffer • Use Low Intensity Development techniques (for more information refer to the stormwater manual)

Disturbance	Required Measures to Minimize Impacts
Change in water regime (increase or decrease in the frequency, duration, timing, extent, depth or variability of water in a wetland)	• Infiltrate or treat, detain, and disperse into buffer new runoff from impervious surfaces and new lawns
Pets and human disturbance	• Use privacy fencing OR plant dense vegetation to delineate buffer edge and to discourage disturbance using vegetation appropriate for the ecoregion • Place wetland and its buffer in a separate tract or protect with a conservation easement
Dust	• Use best management practices to control dust

A. Increasing buffer widths. Buffer widths may be increased, on a case-by-case basis, as determined by the ~~Decision-maker~~Decision-maker. This determination must be supported by appropriate documentation showing that it is necessary to protect wetland functions and values. Documentation must include, but is not limited to, any of the following:

1. The wetland is used by a plant or animal species listed by the Federal government or the State as endangered, threatened, candidate, sensitive, monitored, or documented priority species or habitats, or the wetland is essential or outstanding habitat for those species or has unusual nesting or resting sites such as heron rookeries or raptor nesting trees; or
2. The adjacent land has slopes greater than 15 percent and is susceptible to severe erosion, and erosion-control measures will not effectively prevent adverse wetland impacts; or
3. The adjacent land has minimal vegetative cover on slopes greater than 30%. In lieu of increasing the buffer width where ~~existing~~existing buffer vegetation is inadequate to protect the wetland functions and values, development and implementation of a wetland buffer restoration/enhancement plan in accordance with AMC 19.70.270 may be substituted.

B. Averaging buffer widths. The ~~Decision-maker~~Decision-maker may allow averaging of wetland buffer widths on a case-by-case basis when the critical areas report demonstrates that the following criteria are met:

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~~i.a.~~ There is not a feasible alternative to the site design that could be accomplished without buffer averaging;

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~~ii.b.~~ The buffer averaging does not reduce the functions or values of the wetland, either through preservation of total buffer area or enhancement of buffer areas;

~~iii.c.~~ The total area contained in the buffer area after averaging is no less than that which would be contained within the standard buffer.

~~iv.d.~~ The wetland contains variation in sensitivity due to existing physical characteristics or the character of the buffer varies in slope, soils, or vegetation, and the wetland would benefit from a wider buffer in places and would not be adversely impacted by a narrow buffer in other places;

~~v.e.~~ The buffer width at its narrowest point is not reduced to less than 75 percent of the standard width, for Category I and II. No less than 50 percent or 35 feet for Category III, and 15 feet for Category IV, whichever is greater.

~~B.~~ **C. Measurement of Wetland Buffers.** All buffers must be measured perpendicular from the wetland boundary as surveyed in the field. The buffer for a wetland created, restored, or enhanced as a compensation for approved wetland alterations must be the same as the buffer required for the category of the created, restored, or enhanced wetland.

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~~C.~~ **D. Buffers on mitigation sites.** Buffer widths must be applied to mitigation sites consistent with the wetland ratings and buffer requirements of this chapter for subsequent development proposals based on expected category of the wetland once the mitigation actions are taken. Only fully vegetated buffers with predominantly native plants will be included in the new buffer area. Lawns, walkways, driveways, and other mowed or paved areas will not count towards the required buffer calculations.

~~D.~~ **E. Buffer Maintenance.** Except as otherwise specified or allowed in accordance with this Chapter, wetland buffers must be retained in an undisturbed or enhanced condition. In the case of compensatory mitigation sites, removal of invasive nonnative weeds is required for the duration of the mitigation bond.

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~~E.~~ **F. Buffer impacts.** When buffer impacts occur, compensatory mitigation must be provided at a minimum ratio of 1:1 for the area impacted. The mitigation must occur on the same site when feasible or within the same wetland system preferably. The mitigation must ensure that the wetland functions and values are not diminished due to the buffer impacts.

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~~F.~~ **G. Stormwater management facilities.** Stormwater management facilities may be allowed in Category III and IV wetland buffers if they meet all of the criteria identified below:

~~1.4.~~ The wetland is classified as a Category III or a Category IV wetland with a habitat score of 3-5 points or less, and

~~2.5.~~ There will be “no net loss” of functions and values of the wetlands, and

~~3.6.~~ The wetland does not contain a breeding population of any native amphibian species, and

~~4.7.~~ The hydrologic functions of the wetland can be improved as outlined in questions 3, 4, 5 of Chart 4 and questions 2, 3, 4 of Chart 5 in the “Guide for Selecting Mitigation Sites Using a Watershed Approach,” (available here: <http://www.ecy.wa.gov/biblio/0906032.html>); or the wetland is part of a priority restoration plan that achieves restoration goals identified in a Shoreline Master Program or other local or regional watershed plan;

~~5.8.~~ The wetland lies in the natural routing of the runoff, and the discharge follows the natural routing, and

~~6.9.~~ All regulations regarding stormwater and wetland management are followed, including but not limited to local and state wetland and stormwater codes, manuals, and permits, and

~~7.10.~~ Modifications will require permits. Existing functions and values that are lost would have to be compensated/replaced through an approved mitigation plan.

G. H. Setbacks from buffers. Buildings, structures, paving, and other hard surfacing must be set back a minimum distance of 10 feet from the edge of the wetland buffer, or edge of the wetland if no buffer is required, unless otherwise determined by the ~~Decision-maker~~ **Decision-maker** that a smaller distance would meet the intent of this subsection. This setback is to avoid conflicts with tree branches and/or critical root zones of trees that are in the buffer or will be planted in the buffer. The following may be allowed in the building setback from the buffer if they do not cause damage to the critical root zone of trees in the buffer:

1. Landscaping;
2. Uncovered decks, roof eaves and overhangs, unroofed stairways and steps;
3. Pervious ground surfaces, such as driveways, patios, and parking may be allowed; provided that it is engineered as a **pervious-permeable pavement** system as defined in AMC 19.12.020. Such improvements may be subject to the requirements in AMC 19.76, Stormwater Management.

H. I. Functionally Separated and Isolated Buffers. Consistent with the definition of “buffer” AMC 19.12.020, areas that are functionally isolated and physically separated from a wetland due to existing, legally established roadways, railroads or other legally established structures or paved areas eight feet or more in width that occur between the area in question and the wetland must be considered physically isolated and functionally separated buffer. Once determined by the ~~Decision-maker~~ **Decision-maker**, based on a submitted critical area report, to be a physically separated and functionally isolated wetland buffer, development proposals are allowed in these areas.

19.70.240 Wetlands - Critical areas report additional requirements

A. Additional Report Contents for Wetlands. In addition to the minimum report contents required per AMC 19.70.125 wetland reports must also include;

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1. For each wetland identified on site and off site within 300 feet of the project site provide: the wetland rating, including a description of and score for each function, per wetland ratings (AMC 19.70.210) required buffers (AMC 19.70.250); hydrogeomorphic classification; wetland acreage based on a professional survey from the field delineation (acreages for on-site portion and entire wetland area including off-site portions); Cowardin classification of vegetation communities; habitat elements; soil conditions based on site assessment and/or soil survey information; and to the extent possible, hydrologic information such as location and condition of inlet/outlets (if they can be legally accessed), estimated water depths within the wetland, and estimated hydroperiod patterns based on visual cues (e.g., algal mats, drift lines, flood debris, etc.). Provide acreage estimates, classifications, and ratings based on entire wetland complexes, not only the portion present on the proposed project site;
2. A discussion of the potential impacts to the wetland(s) associated with anticipated hydroperiod alterations from the project;
3. A description of the proposed actions, including an estimation of acreages of impacts to wetlands and buffers based on the field delineation and survey and an analysis of site development alternatives, including a no-development alternative;
4. An assessment of the probable cumulative impacts to the wetlands and buffers resulting from the proposed development;
5. A description of reasonable efforts made to apply mitigation sequencing pursuant to AMC 19.70.130 to avoid, minimize, and mitigate impacts to critical areas and a discussion of measures, including avoidance, minimization, and compensation, proposed to preserve existing wetlands and restore any wetlands that were degraded prior to the current proposed land-use activity;
6. A conservation strategy for habitat and native vegetation that addresses methods to protect and enhance on-site habitat and wetland functions; and
7. An evaluation of the functions of the wetland and adjacent buffer. Include reference for the method used and data sheets.

B. **Additional Information.** When appropriate due to the proposed impacts or the project area conditions, the ~~Decision-maker~~[Director](#) may also require the critical area report to include:

1. A request for consultation with the Washington State Department of Fish and Wildlife (DFW), Washington State Department of Ecology (Ecology), local Native American ~~Indian~~ tribes, and/or other appropriate agency;
2. Copies of the Joint Aquatic Resource Permit Application (JARPA) and related approvals, such as a Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife (WDFW), when applicable to the project; and
3. Detailed surface and subsurface hydrologic features both on and adjacent to the site.

19.70.245 Wetlands – Compensatory mitigation performance standards and requirements.

A. Compensatory Mitigation Plan. When a project involves wetland and/or buffer impacts, a compensatory mitigation plan must be included as part of the required critical area report. Compensatory wetland mitigation plans must meet the minimum requirements [of](#) AMC 19.70.140 and demonstrate compliance with [ACMC](#) 19.70.135. Full guidance can be found in Wetland Mitigation in Washington State – Part 2: Developing Mitigation Plans (Version 1) (Ecology Publication No. 06-06-011b, March 2006, or as revised). The mitigation plan must meet the following additional standards:

1. Description of the existing wetland and buffer areas proposed to be impacted. Include acreage (or square footage), water regime, vegetation, soils, landscape position, surrounding land uses, and functions. Also describe impacts in terms of acreage by Cowardin classification, hydrogeomorphic classification, and wetland rating, based on wetland ratings (AMC 19.70.210(B));
2. Description of the compensatory mitigation site, including location and rationale for selection. Include an assessment of existing conditions: acreage (or square footage) of wetlands and uplands, water regime, sources of water, vegetation, soils, landscape position, surrounding land uses, and functions. Estimate future conditions in this location if the compensation actions are not undertaken (i.e., how would this site progress through natural succession);
3. A description of the proposed actions for compensation of wetland and upland areas affected by the project. Include overall goals of the proposed mitigation, including a description of the targeted functions, hydrogeomorphic classification, categories of wetlands, and mitigation ratios applied (if ratio approach used);
4. A description of the proposed mitigation construction activities, construction/installation notes, and timing of activities;
5. A discussion of ongoing management practices that will protect wetlands after the project site has been developed, including proposed monitoring and maintenance programs (for remaining wetlands and compensatory mitigation wetlands);
6. Proof of establishment of notice on title for the wetlands and buffers on the project site, including the compensatory mitigation areas; and
7. The scaled plan sheets for the compensatory mitigation must contain, at a minimum
 - a. An accurate depiction of the existing wetland and buffers, proposed areas of wetland and/or buffer impacts, location of proposed wetland and/or buffer compensation actions;
 - b. Existing topography, ground-proofed, at two-foot contour intervals in the zone of the proposed compensation actions if any grading activity is proposed to create the compensation area(s). Also existing cross-sections of

on-site wetland areas that are proposed to be impacted and cross-section(s) (estimated one-foot intervals) for the proposed areas of wetland or buffer compensation;

- c. Surface and subsurface hydrologic conditions, including an analysis of existing and proposed hydrologic regimes for enhanced, created, or restored compensatory mitigation areas. Also, illustrations of how data for existing hydrologic conditions were used to determine the estimates of future hydrologic conditions;
- d. Conditions expected from the proposed actions on site, including future hydrogeomorphic types, vegetation community types by dominant species (wetland and upland), and future water regimes;
- e. Required wetland buffers for existing wetlands and proposed compensation areas. Also, identify any zones where buffers are proposed to be reduced or enlarged outside of the standards identified in this chapter;
- f. A plant schedule for the compensation area, including all species by proposed community type and water regime, size and type of plant material to be installed, spacing of plants, typical clustering patterns, typical plant installation details and notes, total number of each species by community type, timing of installation; and
- g. Performance standards (measurable standards reflective of years post-installation) for upland and wetland communities, monitoring plan, contingency plan, and maintenance schedule, and actions. Standards for success must be established based on the performance standards identified and the functions and values being mitigated based on the guidance in Wetland Mitigation in Washington State – Part 2: Developing Mitigation Plans (Version 1) (Ecology Publication No. 06-06-011b, March 2006, or as revised).

B. Requirements for Compensatory Mitigation.

- 1. Compensatory mitigation for alterations to wetlands may be used only for impacts that cannot be avoided or minimized, except as otherwise exempted in this chapter AMC 19.70.240, and must achieve equivalent or greater biologic functions. Compensatory mitigation plans must be consistent with Wetland Mitigation in Washington State – Part 2: Developing Mitigation Plans (Version 1), (Ecology Publication No. 06-06-011b, March 2006, or as revised).
- 2. Mitigation ratios must be consistent with subsection I of this section.
- 3. Mitigation requirements may also be determined using the credit/debit tool described in “Calculating Credits and Debits for Compensatory Mitigation in Wetlands of Western

Washington: Final Report March 2012" (Ecology Publication No. 10-06-011, March 2012, or as revised) consistent with subsection H of this section.

C. Compensating for Lost or Impacted Wetland Functions. Compensatory mitigation must address the functions and values affected by the proposed project, with an intention to achieve functional equivalency or improvement of functions and values. The goal for the compensatory mitigation must be to provide similar wetland functions and values as those lost, except when either:

1. The lost wetland provides minimal functions and values, and the proposed compensatory mitigation action(s) will provide equal or greater functions and values or will provide functions and values shown to be limiting within a watershed through a formal Washington State watershed assessment plan or protocol; or
2. Out-of-kind replacement of wetland type or functions and values will best meet watershed goals formally identified by the City, such as replacement of historically diminished wetland types.

D. Preference of Mitigation Actions. Methods to achieve compensation for wetland functions and values must be approached in the following order of preference:

1. **Restoration.** The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural or historic functions to a former or degraded wetland. Restoration of wetlands includes re-establishment and rehabilitation.
 - a. **Re-establishment.** Returning natural or historic functions to a former wetland. Re-establishment results in a gain in wetland acres (and functions). Activities could include removing fill material, plugging ditches, or breaking drain tiles.
 - b. **Rehabilitation.** Repairing natural or historic functions of a degraded wetland. Rehabilitation results in a gain in wetland function but does not result in a gain in wetland acres. Activities could involve breaching a dike to reconnect wetlands to a floodplain or return tidal influence to a wetland.
2. **Creation.** Creation (establishment) of wetlands on disturbed upland sites, such as those with vegetative cover consisting primarily of nonnative species. This should be attempted only when there is an adequate source of water and it can be shown that the surface and subsurface hydrologic regime is conducive to the wetland community that is anticipated in the design.
3. **Enhancement.** Enhancement of significantly degraded wetlands in combination with restoration or creation. Enhancement alone will result in a loss of wetland acreage and is less effective at replacing the functions and values lost. Enhancement should be part of a mitigation package that includes replacing the impacted area and meeting appropriate ratio requirements.

4. **Preservation.** Preservation of high-quality, at-risk wetlands as compensation is generally acceptable when done in combination with restoration, creation, or enhancement; provided, that a minimum of 1:1 acreage replacement is provided by reestablishment or creation. Preservation of high-quality, at-risk wetlands and habitat may be considered as the sole means of compensation for wetland impacts when the following criteria are met:
 - a. Proposed wetland impacts will not have a significant adverse impact on habitat for listed fish, or other ESA-listed species;
 - b. There is no net loss of habitat functions within the watershed or basin;
 - c. Mitigation ratios for preservation as the sole means of mitigation must generally start at 20:1. Specific ratios should depend upon the significance of the preservation project and the quality of the wetland resources lost;
 - d. The impact area is small (generally less than one-half acre) and/or impacts are occurring to a low-functioning system (Category III or IV wetland); and
 - e. All preservation sites must include buffer areas adequate to protect the habitat and its functions from encroachment and degradation.
5. **Wetland Bank or Advanced Wetland Mitigation.** For future use since no current banks have a service area in Anacortes.

E. Type and Location of Compensatory Mitigation. Unless it is demonstrated that a higher level of ecological functioning would result from an alternative mitigation approach, compensatory mitigation for ecological functions should be either in kind and on site, or in kind and within the same stream reach, sub-basin, or drift cell (if estuarine wetlands are impacted). Compensatory mitigation actions must be conducted within the same sub-basin or on the site of the alteration, except when the following apply:

1. The conditions in AMC 19.70.270(B) are met.
2. There are no reasonable opportunities on site or within the sub-basin (e.g., on-site options would require elimination of high-functioning upland habitat), or opportunities on site or within the sub-basin do not have a high likelihood of success based on a determination of the capacity of the site to compensate for the impacts. Considerations should include:
 - a. Anticipated replacement ratios for wetland mitigation;
 - b. Buffer conditions and proposed widths;
 - c. Available water to maintain anticipated hydrogeomorphic classes of wetlands when restored; and
 - d. Proposed flood storage capacity, and potential to mitigate riparian fish and wildlife impacts (such as connectivity);

- e. Off-site mitigation has a greater likelihood of providing equal or improved wetland functions than the impacted wetland;
- f. Off-site locations must be in the same sub-basin, unless watershed goals for water quality, flood storage or conveyance, habitat, or other wetland functions have been established by the City and strongly justify location of mitigation at another site; and
- g. The design for the compensatory mitigation project needs to be appropriate for its location (i.e., position in the landscape). Therefore, compensatory mitigation should not result in the creation, restoration, or enhancement of an atypical wetland. An atypical wetland refers to a compensation wetland (e.g., created or enhanced) that does not match the type of existing wetland that would be found in the geomorphic setting of the site (i.e., the water source(s) and hydroperiod proposed for the mitigation site are not typical for the geomorphic setting). Likewise, it should not provide exaggerated morphology or require a berm or other engineered structures to hold back water. For example, excavating a permanently inundated pond in an existing, seasonally saturated or inundated wetland is one example of an enhancement project that could result in an atypical wetland. Another example would be excavating depressions in an existing wetland on a slope, which would require the construction of berms to hold the water.

F. Wetland Mitigation Banks. Credits from a wetland mitigation bank certified under [WAC 173-700](#) may be used to compensate for impacts located within the service area specified in the mitigation bank instrument, if:

- 1. The proposal would provide appropriate compensation for the proposed impacts; and
- 2. The impact site is located in the service area of the bank.
- 3. The proposed use of credits is consistent with the terms and conditions of the certified mitigation bank instrument.
- 4. Replacement ratios using bank credits are consistent with replacement ratios specified in the certified mitigation bank instrument.

G. In-Lieu Fee Mitigation. Credits from an approved in-lieu fee (ILF) program may be used when all of the following apply:

- 1. The ~~Decision-maker~~[Decision-maker](#) determines that it would provide environmentally appropriate compensation for the proposed impacts.
- 2. The proposed use of credits is consistent with the terms and conditions of the approved ILF program instrument.
- 3. Projects using ILF credits must have debits associated with the proposed impacts calculated by the applicant's qualified wetland professional using the credit assessment method specified in the approved instrument for the ILF program.
- 4. The impacts are located within the service area specified in the approved ILF instrument.

H. Permittee-responsible mitigation. This type of mitigation is defined in 33 CFR 332 as “an aquatic resource restoration, establishment, enhancement and/or preservation activity undertaken by the permittee (or an authorized agent or contractor) to provide compensatory mitigation for which the permittee retains full responsibility.” The permittee performs the mitigation either before the project impact occurs and before any project impact permit is issued (Advance Permittee-Responsible Mitigation) or at the same time as the project impact is occurring after the project impact permit is issued (Concurrent Permittee-Responsible Mitigation). The permittee is ultimately responsible for implementation and success of the mitigation. For advance mitigation, the permittee generates mitigation credits that may be used to compensate for future wetland or buffer impacts. Only the permittee may use the advance mitigation credits. Permittee-responsible mitigation may occur at the site of the permitted impacts or at an off-site location within the same watershed. Permittee-responsible mitigation must be used only if the applicant’s qualified wetland professional demonstrates to the [Decision-maker’s approval authority’s](#) satisfaction that the proposed approach is ecologically preferable to use of a bank or ILF program, consistent with the criteria in this section.

I. Alternative Mitigation Plan. The ~~Decision-maker~~[Decision-maker](#) may approve an alternative wetland mitigation plan that is based on best available science. Proposed alternative mitigation plans must provide an equivalent or better level of protection of wetland functions and values than would be provided by the strict application of this chapter.

1. The following will be considered in the approval of an alternative mitigation plan:

- a. The plan uses a watershed approach consistent with [Selecting Wetland Mitigation Sites Using a Watershed Approach \(Western Washington\)](#) (Ecology Publication #09-06-032, Olympia, WA, December 2009).
- b. Creation or enhancement of a larger system of natural areas and open space is preferable to the preservation of many individual small habitat areas.
- c. Mitigation according to Section D is not feasible due to site constraints including but not limited to parcel size, stream type, wetland category, or geologically hazardous areas.
- d. There is a clear potential for success of the proposed compensation at the identified site.
- e. The Plan must contain clear and measurable standards for achieving compliance with the specific provisions of the plan, consistent with AMC 19.70.135.
- f. The plan must be reviewed and approved as part of the overall approval of the proposed use.
- g. A wetland of a different type may be justified based on regional needs or functions and values; the replacement ratios may not be reduced or eliminated unless the reduction results in a preferred environmental alternative.

- h. Mitigation guarantees must meet the minimum requirements as outlined in AMC 19.70.160.
- i. Qualified professionals in each of the critical areas addressed must prepare the plan.
- j. The City may consult with agencies with expertise and jurisdiction over the critical areas during the review to assist with analysis and identification of appropriate performance measures that adequately safeguard critical areas.

J. **Wetland Mitigation Ratios.** The ratios below are based on the assumption that the rehabilitation or enhancement actions implemented represent the average degree of improvement possible for the site. Proposals to implement more effective rehabilitation or enhancement actions may result in a lower ratio, while less effective actions may result in a higher ratio. The distinction between rehabilitation and enhancement is not clear-cut. Instead, rehabilitation and enhancement actions span a continuum. Proposals that fall within the gray area between rehabilitation and enhancement will result in a ratio that lies between the ratios for rehabilitation and the ratios for enhancement.

Table 19.70.245 – Wetland Mitigation Ratios

Category and Type of Wetland	Creation or Reestablishment	Rehabilitation Only	Re-Est or Creation (R/C) and Re-hab (RH)	Re-Est or Creation (R/C) and Enhancement (E)	Enhancement Only
Category I Mature Forested	6:1	12:1	1:1 R/C & 10:1 RH	1:1 R/C & 20:1 E	24:1
Category I – based on score for functions	4:1	8:1	1:1 R/C & 6:1 RH	1:1 R/C & 12:1 E	16:1
Category I Natural Heritage Site	Not allowed	6:1 Rehabilitation of a Natural Heritage Site	Not allowed	Not allowed	Case-by-case
Category I Bog	Not allowed	6:1 Rehabilitation of a bog	Not allowed	Not allowed	Case-by-case
Category I Estuarine	Case-by-case	6:1 Rehabilitation of an	Case-by-case	Case-by-case	Case-by-case

Category and Type of Wetland	Creation or Reestablishment	Rehabilitation Only	Re-Est or Creation (R/C) and Re-hab (RH)	Re-Est or Creation (R/C) and Enhancement (E)	Enhancement Only
		estuarine wetland			
Category II	3:1	6:1	1:1 R/C & 4:1 RH	1:1 R/C & 8:1 E	12:1
Category III	2:1	4:1	1:1 R/C & 2:1 RH	1:1 R/C & 4:1 E	8:1
Category IV	1.5:1	3:1	1:1 R/C & 1:1 RH	1:1 R/C & 2:1 E	6:1

- K. **Buffer Mitigation Ratios.** Impacts to buffers must be mitigated at a 1:1 ratio. Compensatory buffer mitigation must replace those buffer functions lost from development.
- L. **Mitigation Performance Standards.** Wetland mitigation plans must be consistent with AMC 19.70.130 Mitigation requirements and 19.70.135 Mitigation plan requirements and Wetland Mitigation in Washington State, Part 1: Agency Policies and Guidance (Version 1, Ecology Publication #06-06-011a), or as amended, and best available science.
- M. **Minimum Standards.** The design standards in this section must be incorporated into mitigation plans submitted to the City for impacts to wetlands and/or wetland buffers. The following standards apply to any mitigation proposed within Category I, II, III and IV wetlands and their buffers. Modifications to these design standards consistent with the guidance in Wetland Mitigation in Washington State – Part 2: Developing Mitigation Plans (Version 1) (Ecology Publication No. 06-06-011b, March 2006, or as revised) may be considered for approval by the ~~Decision-maker~~[Decision-maker](#) as alternatives to the following standards:
1. Plants native to the region (not introduced, non-native or exotic species) must be used.
 2. Plant species selection must be consistent with the existing or projected hydrologic regime, including base water levels and stormwater event fluctuations.
 3. Plant species selection must be consistent with the site environmental conditions such as slope, aspect, soils and exposure to sun, wind and rain.
 4. Plants should be commercially available or available from local sources.
 5. Native plant species high in food and cover value for fish and wildlife should be prioritized, as appropriate for the site.

6. Plant selection must be approved by a qualified professional.
7. The following standards apply to wetland design and construction:
 - a. For wetland creation sites, preliminary investigations of existing hydrology at the site must be completed to confirm that the site has adequate source hydrology (e.g., high groundwater, precipitation or riverine flooding) to support wetland conditions.
 - b. Water depth in areas of seasonal or occasional inundation must not exceed three feet (0.914 meters), unless the proposed mitigation is compensating for impacts to unvegetated/open water areas.
 - c. If creating or rehabilitating a slope wetland, the grade or slope within the wetland must not exceed 6 percent, unless otherwise approved by the ~~Decision-maker~~[Decision-maker](#).
 - d. Slopes within the wetland contributing basin and the buffer zone must not be steeper than 3:1 (horizontal to vertical).
 - e. The wetland (excluding the buffer area) should not contain more than 20 percent unvegetated/open water areas as measured at the seasonal high water mark, unless the mitigation is compensating for vegetated.
 - f. Site soils must be free of contamination and/or hazardous materials, and must have adequate organic content and porosity to support the proposed native plant community.
 - g. Planting densities and placement of plants should be determined by a qualified professional and shown on the design plans.
8. The planting plan must be approved by the City.
9. Stockpiling soil and construction materials should be confined to upland areas and contract specifications should limit stockpiling of earthen materials to durations in accordance with City clearing and grading standards, unless otherwise approved by the City.
10. Planting instructions must be submitted which describe placement, diversity, and spacing of seeds, tubers, bulbs, rhizomes, sprigs, plugs, and transplanted stock.
11. Controlled release fertilizer (if required) must be used in upland areas only (buffers and other non-wetland areas) and must be installed into the planting hole only at the time of planting. No fertilizer must be applied to the ground surface.
12. An irrigation system must be installed or watering afforded by trucks or hoses to provide water for installed plants and seeded areas to supplement rainfall to ensure

that plants receive approximately 0.5 inches of water per week during the dry season of the first two years after plant installation.

13. All construction specifications and methods must be approved by a qualified professional and the City.
14. Construction management provided must be provided by a qualified professional. Ongoing work on site must be inspected by the City.

PART 3: FISH AND WILDLIFE HABITAT CONSERVATION AREAS

19.70.310. Fish and wildlife habitat – Description and Purpose

- A. Fish and wildlife habitat conservation areas are lands managed for maintaining populations of species in suitable habitats within their natural geographic distribution so that the habitat available is sufficient to support viable populations over the long term and isolated subpopulations are not created. In addition to their intrinsic value, certain species of fish and wildlife represent important historic, cultural, recreational and economic resources.
- B. It is the purpose of this Chapter to protect fish and wildlife populations and their associated habitats and provide special consideration to conservation or protection measures necessary to preserve or enhance anadromous species.

19.70.315 Fish and wildlife habitat – Designation.

- A. Fish and Wildlife Habitat Conservation Areas (FWHCAs) are designated as follows:

1. ~~Areas with which endangered, threatened, and sensitive species listed by the federal government or the State of Washington have a primary association;~~Critical saltwater habitats, which include all kelp beds, eelgrass beds, spawning and holding areas for forage fish, such as herring, smelt and sand lance; subsistence, commercial and recreational shellfish beds; mudflats, intertidal habitats with vascular plants, and areas with which priority species have a primary association.
2. ~~Commercial and recreational shellfish areas, including public and private tidelands suitable for shellfish harvest and shellfish protection districts established pursuant to RCW 90.72;~~
3. ~~Kelp and eelgrass beds and herring and smelt spawning areas;~~
- 4-2. Naturally occurring ponds under 20 acres with submerged aquatic beds that provide fish or wildlife habitat as further defined in WAC 365-190-130(4)(e);
- 5-3. Waters of the State, including streams as classified in WAC 222-16-030;

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~~6-4.~~ Lakes, ponds, streams, and rivers planted with game fish by a governmental or tribal entity;

~~7-5.~~ Areas with which anadromous fish species have a primary association;

~~8-6.~~ State natural area preserves, natural resource conservation areas, and state wildlife areas as established by WA DNR;

~~9-7.~~ Areas of rare plant species and high quality ecosystems as identified by the Washington State Department of Natural Resources through the Natural Heritage Program in Chapter [79.70](#) RCW.

~~10-8.~~ State priority habitats and areas associated with State priority species defined and listed by the State Department of Fish and Wildlife in the Priority Habitats and Species List Updated January 2019. Priority habitats and species known to be identified and mapped by WDFW (<http://apps.wdfw.wa.gov/phsontheweb/>) in Anacortes include, but may not be limited to, the following:

- a. Biodiversity areas;
- b. Bald eagle habitat protected pursuant to the Federal Bald and Golden Eagle Protection Act;
- c. Chinook/fall chinook salmon;
- d. Coho salmon;
- e. Great blue heron nest sites and breeding areas;
- f. Osprey nest sites;
- g. Peregrine falcon nest sites and breeding areas;
- h. Purple martin breeding areas;
- i. Resident coastal cutthroat trout;
- j. Winter steelhead trout;
- k. Water fowl concentrations.

~~11-9.~~ The following Habitats and Species of Local Importance have been designated by the City:

- a. The Anacortes Community Forestlands.
- b. The March Point Heronry.
- c. The one and one-half acre "Park Reserve" at Cap Sante bounded by 3rd Street, East Park Drive, and Curtis Drive.
- d. [Ship Harbor Wetland.](#)

Commented [CT15]: Add:

Add the following wetland for extra habitat protections, in replace of the regionally/locally significant wetland provision:

- d. Ship Harbor Wetland
- e. Cannery Pond Wetland
- f. Category II wetlands within the watersheds of Little Cranberry Lake, Whistle Lake, and Heart Lake and with seasonal surface water connections.
- g. Smiley's Bottom Wetland

e. Cannery Pond Wetland.

f. Category II wetlands within the watersheds of Little Cranberry Lake, Whistle Lake, and Hearth Lake and with seasonal surface water connections.

e.g. Smiley's Bottom Wetland.

- B. In addition to the FWHCAs identified in Subsection (A)(11) of this section, additional habitats and species of local importance may be designated by the City using the following process:
1. Designation process. The city may consider nominations for habitat areas and species to be designated as locally important on an annual basis as part of the annual comprehensive plan and development regulation update process, based on the following criteria:
 - a. Local populations of native species that are in danger of extirpation based on existing trends, likely to become endangered, or are vulnerable or declining;
 - b. The habitat represents either a high quality native habitat, or the habitat has a high potential to recover to a suitable condition and which is of limited availability, is highly vulnerable to alteration, or provides landscape connectivity which contributes to the integrity of the surrounding landscape;
 - c. The species or habitat has recreation, commercial, game, tribal, or other intrinsic value;
 - d. Long-term persistence of a species is dependent on protection, maintenance, and/or restoration of the nominated habitat;
 - e. Protection by other county, state, or federal policies, laws, regulations, or non-regulatory tools is not adequate to prevent degradation of the species or habitat; and
 - f. Without protection, there is a likelihood that the species or habitat will be diminished.
 2. The nomination must indicate whether specific habitat features are to be protected (for example, nest sites, breeding areas, and nurseries) or whether the habitat or ecosystem is being nominated in its entirety.
 3. The nomination may include management strategies for the species or habitats, which must be supported by best available science. Where restoration of habitat is proposed, a specific plan for restoration must be provided.

- C. All areas within the city meeting one or more of these criteria, regardless of any formal identification, are hereby designated critical areas and are subject to the provisions of this chapter.

19.70.320 Fish and wildlife habitat – Mapping.

- A. **Mapping.** The approximate location and extent of some FWHCA's are shown in the data layers maintained in the City of Anacortes geographic information system (GIS). In addition, the following maps and inventories are hereby adopted by reference, as amended:
 - 1. [Washington Department of Fish and Wildlife Priority Habitat and Species maps](#);
 - 2. Washington Department of Natural Resources, [Official Water Type Reference maps](#);
 - 3. Washington Department of Natural Resources [Puget Sound Intertidal Habitat Inventory maps](#);
 - 4. Washington Department of Natural Resources [Shore Zone inventory](#);
 - 5. Washington Department of Natural Resources [Natural Heritage Program mapping data](#);
 - 6. Washington Department of Health Annual [Inventory of Shellfish Harvest Areas](#);
 - 7. Anadromous and resident fish distribution maps contained in the habitat limiting factors reports published by the Washington Conservation Commission and others;
 - 8. Washington Department of Natural Resources State Natural Area Preserves and Natural Resource Conservation Area maps; and
 - 9. NOAA Northwest Region Critical Habitat Mapper or equivalent source:
<http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm>
- B. **Reference Only.** The maps and resources cited above are to be used as a guide for the City of Anacortes Planning, Community & Economic Development Department, project applicants, and/or property owners and may be continuously updated as new critical areas are identified. They are a reference and do not provide a final critical area designation.

19.70.325 Fish and wildlife habitat – General Development Standards for all FWHCA's.

- A. All new development activities and uses are prohibited from habitat conservation areas and their buffers except in accordance with this Chapter [unless within shoreline jurisdiction and hereby regulated by the AMC 19.72 Shoreline Regulations and Shoreline Master Program.](#) FWHCA's or their buffers may be altered only if the proposed alteration of the habitat or the mitigation proposed does not degrade the functions and values of the habitat.
- B. **Exemptions.** Exemptions to this chapter are listed in the provisions established in AMC 19.70.035 Exemption Activities.

- C. Approvals and the Best Available Science.** Any approval of alterations or impacts to a FWHCA area must be supported by the best available science as described in the required Critical Area Report.
- D. Approvals of Activities may be conditioned.** The ~~decision-maker~~[Decision-maker](#) may condition approvals of activities allowed within or adjacent to a fish and wildlife habitat conservation area as necessary to minimize or mitigate any potential adverse impacts. Conditions will be based on the best available science and may include, but are not limited to, the following:
1. Establishment of buffers;
 2. Preservation of important vegetation and/or habitat features such as snags and downed wood specific to the priority wildlife species in the fish and wildlife habitat conservation area;
 3. Limitation of access to the habitat area, including fencing to deter unauthorized access;
 4. Seasonal restriction of construction activities;
 5. Establishment of a duration and timetable for periodic review of mitigation activities; and
 6. Requirement of a performance bond, when necessary, to ensure completion and success of proposed mitigation.
- E. Seasonal Restrictions.** When a species is more susceptible to adverse impacts during specific periods of the year, seasonal restrictions may apply. Larger buffers may be required and activities may be further restricted during the specified season.
- F. Subdivisions.** The subdivision and short subdivision of land in FWHCA's and associated buffers is subject to the following:
1. Land that is located wholly within a FWHCA or its buffer may not be subdivided;
 2. Land that is located partially within a FWHCA may be subdivided only if an accessible and contiguous portion of each new lot that meets the minimum lot size requirements for the zone is located outside of the FWHCA and its buffer.
 3. Access roads and utilities serving a proposed subdivision may be permitted within the FWHCA and associated buffers only if the applicant's qualified professional(s) demonstrate, and the ~~Decision-maker~~[Decision-maker](#) determines, that no other feasible alternative exists, all unavoidable impacts are fully mitigated, and the use is consistent with this chapter.
- G. Non-indigenous species.** No plant, wildlife, or fish species not indigenous to Fidalgo Island may be introduced to a FWHCA unless authorized by a state or federal permit approval.

19.70.330 Fish and wildlife habitat – Specific Standards for Streams

A. Typing. Stream types must be classified according to WAC 222-16-030. Stream classifications must include the following:

1. Type F streams are those that provide fish habitat;
2. Type Np streams are perennial waters that do not contain fish habitat; and
3. Type Ns streams are seasonal waters that do not contain fish habitat, but are physically connected by an above-ground channel system to Type F, or Np waters.
4. In the case that available information on stream typing is unclear, stream typing will be performed by a qualified professional, provided by the applicant, using a site visit, mapping, and all available information.

B. Required Buffer Areas. Protective riparian buffers must be required to preserve stream/riparian functions and values. The purpose of riparian buffers is to protect riparian functions that influence in-stream and near-stream habitat quality

1. **Measurement of Stream Buffers.** Stream buffers are measured from the ordinary high water mark (OHWM), or the top of the bank if the OHWM cannot be determined. Buffers must be measured with rounded ends where streams enter or exit piped segments. Piped stream setbacks should be measured from the centerline of the pipe.
2. **Standard Stream Buffer Widths.** Buffer widths must reflect the sensitivity of the stream type, the risks associated with development and, in those circumstances permitted by these regulations, the type and intensity of human activity and site design proposed to be conducted on or near the stream area. The following standard buffers are established for streams:

Table 19.70.300 Stream Buffers

DNR Water Type (WAC 222-16-030)	Standard Buffer Width
Type F Streams that are known to be used by fish, or meet the physical criteria to be potentially used by fish.	50 feet
Type Np Streams that have year round flow and do not meet the physical criteria of a Type F. This also includes streams that have been proven not to contain fish using methods described in Forest Practices Board Manual Section 13.	50 feet
Type Ns	50 feet

Streams that do not have surface flow during at least some portion of the year, and do not meet the physical criteria of a Type F stream.	
Piped Streams and Roadside Ditched Segments Those segments of streams, regardless of their type, that are fully enclosed in an underground pipe or culvert, or conveyed through a public roadside ditch as part of the City stormwater infrastructure.	10 feet

3. **Increased Stream Buffer Widths.** The stream buffer widths may be increased by the [Decision-maker](#) as follows:

- When the qualified professional determines that the minimum width is insufficient to prevent habitat degradation and to protect the structure and functions of the habitat area as a result of a habitat assessment required pursuant to AMC 19.70.360;
- When the frequently flooded area exceeds the minimum stream buffer width, the stream buffer must extend to the outer edge of the frequently flooded area;
- When a channel migration zone is present, the stream buffer must extend to the outer edge of the channel migration zone;
- When the habitat area is in an area of high blowdown potential, the stream buffer width must be expanded an additional 50 feet on the windward side;
- When the habitat area is within an erosion or landslide hazard area, or buffer, the stream buffer width must be the recommended distance, or the erosion or landslide hazard area or buffer, whichever is greater.

C. **Buffer Reduction Standards.** The [Decision-Maker](#) may allow the reduction of buffer widths on a case-by-case basis when the critical areas report demonstrates the following criteria are met:

- There is no feasible alternative to the site design that could be accomplished without buffer reduction;
- The total buffer width is not reduced to less than 35 feet in stretches of natural stream channel with intact native vegetation within the buffer, and the buffer reduction does not reduce the functions or values of the stream or buffer;
- The total buffer width is not reduced to less than 25 feet in stretches of modified stream channel with little to no intact native vegetation within the buffer, and the buffer reduction

plan must include an enhancement plan to increase the functions or values of the stream or buffer.

D. Building setbacks from stream buffers. Buildings, structures, paving, and other hard surfacing must be setback a minimum distance of 10 feet from the edge of the stream buffer unless determined by the ~~Decision-maker~~[Decision-maker](#) that a smaller distance would meet the intent of this subsection. This setback is to avoid conflicts with tree branches and/or critical root zones of trees that are in the buffer or will be planted in the buffer. The following may be allowed in the building setback from the buffer if they do not cause damage to the critical root zone of trees in the buffer:

1. Landscaping;
2. Uncovered decks, roof eaves and overhangs, unroofed stairways and steps;
3. Pervious ground surfaces, such as driveways, patios, and parking may be allowed; provided that they are engineered as a [pervious-permeable pavement](#) system as defined in AMC [19.12.020](#). Such improvements may be subject to the requirements in AMC [19.76](#), Stormwater Management.

E. Functionally Separated and Isolated Stream Buffers. Consistent with the definition of “buffers” in this chapter, areas that are functionally isolated and physically separated from a stream due to existing, legally established public roadways, railroads or other legally established structures or paved areas eight feet or more in width that occur between the area in question and the stream must be considered physically isolated and functionally separated stream buffers. Once determined by the ~~Decision-Maker~~[Decision-maker](#), based on a submitted critical area report, to be a physically separated and functionally isolated stream buffer, development proposals are allowed in these areas.

F. Additional Allowed Activities in streams. Activities, uses and alterations of streams are prohibited unless otherwise listed as exempt or allowed according to the provisions of 19.70.035, 19.70.040, and 19.70.045. No alteration to a stream buffer may be permitted unless consistent with the provisions of this section and the specific standards for development outlined below.

1. **Type F and Type Np Streams Relocation.** Relocation of Type F or Np streams may be permitted only when the proposed relocation is **part of an approved mitigation or rehabilitation/restoration plan**, and will result in equal or better habitat and water quality, and will not diminish the flow capacity of the stream. The applicant must demonstrate proper mitigation sequencing.
2. **Type Ns Streams Relocation.** Relocation of Type Ns streams may be permitted only when the proposed relocation will result in equal or better habitat and water quality, and will not diminish the flow capacity of the stream. The applicant must demonstrate proper mitigation sequencing.

3. **Stream Crossing.** Crossing of streams may be permitted, and are required to be designed to allow fish passage based on state and federal fish passage criteria.

G. Piped Watercourses and Roadside Ditches. It is recognized that within the urban environment many historical streams have been substantially modified to accommodate development. Many of the regulated and mapped streams within the City of Anacortes pass through natural reaches, modified reaches, piped reaches, and sometimes along manmade roadside ditches.

1. Development along piped watercourses and roadside ditched segments of regulated streams are subject to a 10 foot setback from the centerline of the stream course and is subject to the recording of a utility easement granted to the city for access and maintenance of the watercourse infrastructure.
2. The voluntary opening and restoration or rehabilitation of previously channelized, culverted, or piped streams is highly encouraged and may be approved by the ~~Decision-Maker~~[Decision-maker](#), when the following is demonstrated within a critical areas report:
 - a. The restoration will result in a net gain in FWHCA functions, including an improvement in water quality and ecological functioning;
 - b. Opened channels must be designed to support fish and wildlife habitat and uninhibited fish access, unless demonstrated to be infeasible;
 - c. A reduction to the standard buffer is allowed to a minimum of 25 ~~feet~~[feet](#), or as recommended by a qualified professional in the Critical Area Report. Measured from the Ordinary High Water Mark (OHWM) and which includes habitat improvements, and measures to prevent erosion, landslide and water quality impacts;
 - d. The proposal will not significantly increase the threat of erosion, flooding, slope stability or other hazards on the site or on adjacent properties.
 - e. The proposal must demonstrate that there conveyance will maintain the flow capacity and not create flooding elsewhere in the drainage basin.

H. Stream Enhancement Measures. Only those enhancement measures deemed most applicable and/or appropriate for stream channel or buffer enhancement projects will be considered in a buffer modification proposal, and must be supported by best available science and a critical area report. These include, but are not limited to:

1. Removal of fish barriers to restore accessibility to fish.
2. Enhancement of fish habitat using log structures incorporated as part of a fish habitat enhancement plan.
3. Enhancement of fish and wildlife habitat structures that are likely to be used by wildlife, including wood duck houses, bat boxes, nesting platforms, snags, rootwads/stumps, birdhouses, and heron nesting areas.

4. Planting native vegetation within the buffer area, especially vegetation that would increase value for fish and wildlife, increase stream bank or slope stability, improve water quality, or provide aesthetic/recreational value; or
5. Creation of a surface channel where a stream was previously underground, in a culvert or pipe. Surface channels which area “daylighted” must be located within a buffer area and must be designed with energy dissipating functions or channel roughness features such as meanders and rootwads to reduce future bank failures or nearby flooding;
6. Removal or modification of existing stream culverts (such as road crossings) to improve fish passage, stream habitat, and flow capacities; or
7. Upgrading of retention/detention facilities or other stormwater management facilities beyond required levels.

19.70.335 Fish and wildlife habitat – Specific Standards for Other FWHCAs

A. Endangered, Threatened, and Sensitive Species. Fish and wildlife habitat conservation areas or buffers with which species that are State or Federally listed as endangered, threatened, or sensitive species, and anadromous fish species are subject to the following:

1. No development is allowed within a fish and wildlife habitat conservation area or buffer with which State or Federally endangered, threatened, or sensitive species have a primary association, except that which is provided for by a management plan established by the Washington Department of Fish and Wildlife or applicable State or Federal agency.
2. Whenever activities are proposed adjacent to a fish and wildlife habitat conservation area with which State or Federally endangered, threatened, or sensitive species have a primary association, such area must be protected through the application of protection measures in accordance with a critical area report prepared by a qualified professional and approved by the City. Approval for alteration of the fish and wildlife habitat conservation area or its buffer may not occur prior to consultation with the Washington Department of Fish and Wildlife for animal species, the Washington State Department of Natural Resources for plant species, and other appropriate Federal or State agencies.

B. Other Priority Habitats and Species. Fish and wildlife habitat conservation areas or buffers with which species that are not State or Federally listed as endangered, threatened, or sensitive species, and are not anadromous fish species are subject to the following:

1. Development activities and uses that result in unavoidable impacts may be permitted in priority species habitat areas and associated buffers in accordance with an approved critical area report with habitat assessment/management plan, and only if the proposed activity is the only reasonable alternative that will accomplish the applicant’s objectives. Full compensation for the loss of acreage and functions of habitat and buffer areas must be provided in compliance with the mitigation performance standards and requirements of these regulations.

C. City-Designated Habitats and Species of Local Importance

1. Anacortes Community Forest Lands:

Purpose. The Anacortes Community Forest Lands include three lakes and their watersheds, numerous wetlands, rock bluffs, old growth forests, grassy knolls, windswept hilltops, sheltered caves, and a variety of other habitats and microclimates that provide a unique and irreplaceable habitat for both imperiled and commonplace species. This land has been dedicated by the City for the preservation of forest lands and species, as described in the Conservation Easement documents, the ACFL Comprehensive Plan, and in AMC Title 12.

- a. Recreation and Recreation-Related Facilities. Construction of public recreation-related facilities such as trails, benches, interpretive displays, and viewing platforms, may be allowed in fish and wildlife habitat conservation areas or buffers
- b. Proposed alterations must be consistent with the adopted Anacortes Community Forest Lands Comprehensive Plan, as amended.
- c. Noxious and Invasive Plants. The Skagit County noxious weed ordinance and the ACFL invasive plant control program must be carefully considered in any adjacent development decision. Nonnative plants known to be invasive into the ACFL must be prohibited in landscaping plans of adjacent developments. Where such developments have CC&Rs, reference to this requirement must be included therein.
- d. Right of Way Vacations. In the case of street or alley vacations contiguous with an ACFL boundary, the half of the area vacated which is adjacent to the ACFL must be incorporated into the ACFL and subject to all ACFL related requirements.
- e. Private Access to ACFL. No new accesses will be established to the ACFL without prior request for such access to the parks and recreation department and the forest advisory board and approval by the city council.
- f. Burning. No burn piles or outdoor fires must ever be left unattended while ignited and in the event sparks or flames come within three hundred feet of the ACFL, the fire must immediately be brought under control or extinguished.
- g. Boundary Identification. City staff will work closely with property owners and developers to ensure that survey lines adjacent to the ACFL boundary are clearly and correctly marked before any timber and/or vegetation is removed from adjacent property. The forest manager will be involved in the final inspection of boundary lines.
- h. ACFL Buffers. City staff will work closely with builders to secure thirty-foot ACFL buffers using all available incentives.

2. March Point Heronry:

2.

Commented [CT16]: Add Purpose Statement:

Purpose. The Anacortes Community Forest Lands include three lakes and their watersheds, numerous wetlands, rock bluffs, old growth forests, grassy knolls, windswept hilltops, sheltered caves, and a variety of other habitats and microclimates that provide a unique and irreplaceable habitat for both imperiled and commonplace species. This land has been dedicated by the City for the preservation of forest lands and species, as described in the Conservation Easement documents, the ACFL Comprehensive Plan, and in the newly created Anacortes Municipal Code Title 12.

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Purpose. Because Skagit County is home to the greatest concentration of nesting Great Blue Heron in the Salish Sea, March Point being the largest, the City has identified the March Point Heronry as a habitat of local importance.

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a. Purpose. Because Skagit County is home to the greatest concentration of nesting Great Blue Heron in the Salish Sea, March Point being the largest, the City has identified the March Point Heronry as a habitat of local importance.

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b.a. Proposed development activities within 1,000 feet, or that is likely to impact the colony, must provide a critical areas assessment report and habitat management plan that follows at a minimum the guidelines provided by WDFW's Management Recommendations for Washington's Priority Species (March 2012).

https://wdfw.wa.gov/publications/00026/abbreviated_great_blue_heron.pdf.

c.b. Buffers will be implemented as described in the buffer section below.

d.c. Colony protection is required for minimum 10-years after abandonment.

D. Required Buffer for Non-Stream FWHCA's:

1. **Marine FWHCA's Buffers.** Buffer for all designated fish and wildlife habitats or species within marine shorelines must be regulated by [AMC 19.72 Shoreline Regulations and the Shoreline Master Program](#), ~~incorporated Critical Area regulations.~~
2. **All Other Non-Stream FWHCA Buffers.** Buffers from fish and wildlife habitat conservation areas must be established to protect the functions and values of the critical area from the impacts of proposed adjacent activities.
 - a. Buffer widths for fish and wildlife habitat areas must be based on consideration of the following factors: species-specific recommendations of the Washington State Department of Fish and Wildlife; recommendations contained in a habitat management plan submitted by a qualified professional; and the nature and intensity of land uses and activities occurring on the land adjacent to the site. Buffers must:
 - i. Consist of an undisturbed area of native vegetation, or areas identified for restoration, sufficient to protect the integrity, functions, and values of the affected habitat;
 - ii. Reflect the sensitivity of the habitat and the type and intensity of human activity proposed to be conducted nearby;
 - iii. Be consistent with the applicable species-specific management recommendations issued by the Washington Department of Fish and Wildlife.
 - b. Nesting bald eagles and bald eagle habitat must be protected consistent with the U.S. Fish and Wildlife Service (USFWS) National bald eagle management guidelines, or the state or federal regulations in place at the time of application. Whenever activities are proposed adjacent to a confirmed nest territory or communal roost, a bald eagle habitat management plan must be developed by a qualified professional. Activities are adjacent to managed bald eagle sites when they are within 660 feet of a nest or within one-half

mile (2,640 feet) of a shoreline foraging area. Approval of the activity must not occur prior to consultation with the state or federal agency with authority on bald eagle pairs and their nest.

- c. ~~Great Blue Heron nesting and breeding areas: Development near a verified heron breeding habitat including nesting colony areas, former nesting colonies, pre-nesting staging areas, and breeding season foraging habitat require:~~

- i. A year-round urban buffer of 197 feet,
- ii. For unusually loud activities that occur during breeding season (February – September) a seasonal buffer of 656 feet, and a Blasting buffer of ~~3,280~~1,320 feet.

- iii. ~~For properties without an existing and approved management plan; A~~ management plan developed by a qualified professional to follow, at a minimum, WDFW's Management Recommendations for Washington's Priority Species (March 2012) ~~and that identifies the nesting and breeding site as well as pre-nesting staging area, and breeding season foraging habitat~~

- ~~iii-iv.~~iv. ~~For the March's Point Colony, given the observed and documented sensitivity of this mega-colony to human intrusion and the fact that the colony is in a rare, isolated, but tight location, a year-round buffer of 984 feet.~~

19.70.340 Fish and wildlife habitat – Buffer Width Averaging for All FWHCA's.

- A. Approval Criteria. The ~~Decision-maker~~Decision-maker may allow the averaging of FWHCA buffer widths when the critical areas report demonstrates the following:
1. In-stream or buffer habitat functions, will be increased or maintained where native buffer vegetation is generally intact, or increased where existing buffer vegetation is inadequate to protect functions and values; and
 2. The buffer averaging does not reduce the functions or values of the stream or FWHCA buffer; and
 3. The total area contained in the buffer area after averaging on the development proposal site is no less than that which would be contained within the standard buffer, and all increases in buffer dimension for averaging must be parallel to the ~~FWHCA buffer~~; and
 4. The stream or FWHCA buffer contains variations in sensitivity due to existing physical characteristics or the character of the buffer varies in slope, soils, or vegetation; and
 5. The buffer width is not reduced in any location to less than 50 percent of the standard width or 35 feet, whichever is greater, on a case-by-case basis as a result of a habitat assessment pursuant to AMC 19.70.380 (B)(4); and

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Great Blue Heron nesting and breeding areas: Development near a verified heron breeding habitat including nesting colony areas, and former nesting colonies:

- i. A year-round urban buffer of 197 feet,*
- ii. For unusually loud activities that occur during breeding season (February – September) a seasonal buffer of 656 feet, and a Blasting/Extreme noise buffer of 1,320 feet.*
- iii. For properties without an existing and approved management plan; a management plan developed by a qualified professional to follow, at a minimum, WDFW's Management Recommendations for Washington's Priority Species (March 2012) and that identifies the nesting and breeding site as well as pre-nesting staging areas, and breeding season foraging habitat.*
- iv. For the March's Point Colony, given the observed and documented sensitivity of this mega-colony to human intrusion and the fact that the colony is in a rare, isolated but tight location, a year-round buffer of 984 feet.*

6. The buffer has not been reduced in accordance with this section. Buffer averaging is not allowed if the buffer has been reduced; and
7. There were no feasible alternatives to the site design without buffer averaging; and
8. Buffer enhancement will be provided.
9. The buffer width reduction will not be located within another critical area or associated buffer; and
10. Only those portions of the FWHCA buffer within the project area or subject parcel may be considered in the total buffer area for buffer averaging.

19.70.345 Fish and wildlife habitat – Stormwater Management Facilities.

Establishment of low-impact stormwater management facilities, such as stormwater dispersion outfalls and bioswales, may be allowed within fish and wildlife habitat conservation area buffers consistent with the adopted stormwater manual; provided, that:

- A. No other location is feasible; and
- B. There will be “no net loss” of functions and values of the fish and wildlife habitat conservation area; and
- C. The critical area lies in the natural routing of the runoff, and the discharge follows the natural routing; and
- D. Stormwater dispersion outfalls, bioswales, bioretention facilities, and other low-impact facilities consistent with the adopted stormwater manual may be allowed within the outer 25% of the buffer when determined by a qualified professional that the location of the facilities will enhance the buffer area and protect the stream; and
- E. Such facilities are designed consistent with the requirements of AMC 19.76.

19.70.350 Fish and wildlife habitat – Critical area report additional requirements.

- A. **Additional Report Contents for FWHCA's.** In addition to the minimum report contents required per AMC 19.70.125 FWHCA reports must also include;
 1. Documentation of any fieldwork performed on the site, including field data sheets for delineations, water typing and other habitat conservation area classification, baseline hydrologic data, site photos, etc.;
 2. A description of the methodologies used to conduct the delineations, classifications, or impact analyses, including reference;
 3. A discussion of the potential impacts to the critical area or buffer associated with the proposed development including an assessment of cumulative impacts.
- B. **Habitat Assessment /Management Plan.** A habitat assessment /management plan is an investigation of the project area to evaluate the potential presence or absence of designated

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critical fish or wildlife species or habitat. A critical area report for a fish and wildlife habitat conservation area must contain an assessment of habitats including the following site- and proposal-related information at a minimum:

1. Detailed description of vegetation on and adjacent to the project area and its associated buffer;
2. Identification of any species of local importance, priority species, or endangered, threatened, sensitive, or candidate species that have a primary association with habitat on or adjacent to the project area, and assessment of potential project impacts to the use of the site by the species;
3. A discussion of any Federal, State, or local special management recommendations, including Washington Department of Fish and Wildlife habitat management recommendations, that have been developed for species or habitats located on or adjacent to the project area;
4. A detailed discussion of the direct and indirect potential impacts on habitat by the project, including potential impacts to water quality;
5. A discussion of measures, including avoidance, minimization, and mitigation, proposed to preserve existing habitats and restore any habitat that was degraded prior to the current proposed land use activity and to be conducted in accordance with AMC 19.70.135, Mitigation Requirements;
6. A discussion of ongoing management practices that will protect habitat after the project site has been developed, including proposed monitoring and maintenance programs.

C. Additional Technical Information Requirements for Streams. If no project impacts are anticipated and standard stream buffer widths are retained, a stream delineation report, general critical areas report or other reports, alone or in combination, may be submitted as consistent with the specific requirements of this section. In addition to the general critical area report requirements for fish and wildlife habitat conservation areas provided in subsections A through D of this section, technical information on streams must include the following information at a minimum:

1. A written assessment and accompanying maps of the stream and associated hydrologic features on and off site within 300 feet of the project area, including the following information at a minimum: Stream survey showing the field delineated ordinary high water mark(s);
 - a. Standard stream buffer boundary as determined by AMC 19.70.340;
 - b. Boundary for proposed stream buffers averaging, if applicable;
 - c. Vegetative, faunal, and hydrologic characteristics;
 - d. Soil and substrate conditions; and

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- e. Topographic elevations, at two-foot contours;
2. A detailed description and functional assessment of the stream channel and stream buffer under existing conditions pertaining to the protection of stream functions, fish habitat and, in particular, potential anadromous fisheries;
 3. A habitat and native vegetation conservation strategy that addresses methods to protect and enhance on-site habitat and stream functions;
 4. Proposed buffer enhancement, if needed, including a written assessment and accompanying maps and planting plans for buffer areas to be enhanced, including the following information at a minimum:
 - a. A description of existing buffer conditions;
 - b. A description of proposed buffer conditions and how proposed conditions will increase buffer functions in terms of stream and fish habitat protection;
 - c. Performance standards for measuring enhancement success through a monitoring period of at least five years; and
 - d. Provisions for monitoring and submission of monitoring reports documenting buffer conditions, as compared to performance standards, for enhancement success;
 - e. A discussion of ongoing management practices that will protect stream functions and habitat value through maintenance of vegetation density within the stream buffer.
- D. Additional Technical Information for Heron Habitat.**
1. The Report must identify the Heron Management Area (HMA). A HMA consist of the nesting colony, year-round and seasonal buffer, foraging habitat, and when present, a pre-nesting congregation area.
 2. All survey activity such as nest tree identification and flagging **should occur in the non-breeding season (mid-September to mid-February)**, and preferably right after breeding season ends.
 3. Identify the nesting colony's boundary. To do this flag all nest trees at the colony's outer perimeter. Mark each of these trees on a map. If a nest tree's canopy overlaps the canopy of an adjacent tree, flag the adjacent tree and consider this to be a nest tree. The outermost nest trees will be used to map the nesting colony boundary.
 4. Map outer perimeter of the 197 foot year-round buffer. Using the buffer radius, draw a circle around each peripheral nest tree.
 5. Map seasonal buffer if any unusually loud activities will occur during breeding season (February – September). Measure the seasonal buffer starting at the outer edge of the year-round buffer.

6. Locate potential foraging habitat by mapping all waterbodies within a 1.9 mile radius of the colony. The perimeter and shallow portions are especially important for foraging.

E. Additional FWHCA information. When appropriate due to the type of habitat or species present, or the project area conditions, the ~~Decision Maker~~[Decision-maker](#) may also require the critical area report to include:

1. A request for consultation with the Washington State Department of Fish and Wildlife (DFW), Washington Department of Ecology (Ecology), local Native American ~~Indian~~ tribes or other appropriate agency;
2. Copies of the Joint Aquatic Resource Permit Application (JARPA) and related approvals, such as a Hydraulic Project Approval (HPA) from the WDFW, when applicable to the project; and
3. Detailed surface and subsurface hydrologic features both on and adjacent to the site.

19.70.355 Fish and wildlife habitat – Mitigation performance standards and requirements.

- A. Compensatory mitigation for FWHCA's must follow the plan requirements described under AMC 19.70.135.

PART4: GEOLOGICALLY HAZARDOUS AREAS

19.70.410 Geologically Hazardous Areas– Description and Purpose.

- A. Geologically hazardous areas include areas susceptible to the effects of erosion, landslides, earthquake, or other geologic events. They pose a threat to health and safety of citizens when incompatible development is sited in areas of significant hazard.
- B. The primary purpose of these regulations is to avoid and minimize potential impacts to life and property from geologic hazards, conserve soil resources, and minimize structural damage relating to these hazards. The purpose is accomplished through appropriate levels of study and analysis, application of sound engineering principles, and regulation or limitation of land uses, including maintenance of existing vegetation, regulation of clearing and grading activities, and control of stormwater.

19.70.415 Geologically Hazardous Areas - Designation.

- A. Areas susceptible to one or more of the following types of hazards are designated as a geologically hazardous area:
 1. **Erosion Hazard Areas.** Erosion hazard areas include areas likely to become unstable, such as bluffs, steep slopes, and areas with unconsolidated soils. The following are considered known or suspected erosion hazards:
 - a. Areas located within the following soil map units: Nos. 46 and 47 Dystric Xerochrepts; No. 90 Lithic Haploxerolls-Rock outcrop complex (LH), or mapped severe erosion

hazard, as identified in the U.S. Department of Agriculture Natural Resources Conservation Service Soil Survey of Skagit County Area, WA (1989).

- b. Coastal, erosion-prone areas such as beaches or marine bluffs.
- c. Areas susceptible to rapid stream incision and stream bank erosion.

2. **Landslide Hazard Areas.** Landslide hazard areas are those areas subject to landslide activity based on a combination of geologic, topographic, and hydrologic factors. They include areas susceptible because of any combination of bedrock, soil, slope (gradient), slope aspect, structure, hydrology, or other factors. The following are known or suspected landslide hazards:

- a. Areas designated in the Washington State Department of Ecology Coastal Zone Atlas, Washington, Volume Two Skagit County (1978) as U (Unstable), UB, (Unstable Bluff), URS (Unstable Recent Slide), or UOS (Unstable Old Slide).
- b. Areas of previous failure such as earth slumps, earthflows, mudflows, lahars, debris flows, rock slides, landslides or other failures as observed in the field or as indicated on maps or in technical reports published by the U.S. Geological Survey, the Geology and Earth Resources Division of the Washington Department of Natural Resources, or other documents authorized by government agencies.
- c. Slopes having gradients of 15% or greater:
 - i. That intersect geologic contacts with permeable sediments overlying low-permeability sediment or bedrock and springs or groundwater seepage are present; or
 - ii. That are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials.
- d. Areas that have shown movement during the Holocene epoch (from ten thousand years ago to the present) or that are underlain or covered by mass wastage debris of that epoch.
- e. Slopes having gradients steeper than 80% subject to rock fall during seismic shaking.
- f. Potentially unstable areas resulting from rapid stream incision, stream bank erosion, and undercutting by wave action.
- g. Slopes with a gradient of 40% or more with a vertical relief of 10 feet or more, including marine bluffs, except areas composed of consolidated rock. A slope is delineated by establishing its toe and top and is measured by averaging the inclination over at least 10 feet of vertical relief.

3. **Seismic Hazard Areas.** Seismic hazard areas are lands that, due to a combination of soil and groundwater conditions, are subject to risk of damage as a result of earthquake

induced ground shaking, slope failure, settlement or subsidence, soil liquefaction, or surface faulting. The following are known or suspected seismic hazards:

- a. Areas having “high” and “moderate to high” risk of liquefaction as mapped on the Liquefaction Susceptibility and Site Class Maps of Western Washington State by County published by the Washington State Department of Natural Resources. These are typically underlain by cohesionless soils of low density typically and must [have a](#) low groundwater table.
 - b. Areas located within ¼ mile of an active fault as indicated on investigative maps or described in studies by the United States Geologic Survey, Geology and Earth Resources Division of the Washington Department of Natural Resources, or other documents authorized by government agencies, or identified during site inspection.
 - c. Those known or suspected landslide hazards referenced in Subsection (2) of this Section.
4. **Mine Hazard Areas.** Mine hazard areas are those areas underlain by or affected by mine workings such as adits, gangways, tunnels, drifts, or airshafts, and those areas of probable sink holes, gas releases, or subsidence due to mine workings. Factors that should be considered include: proximity to development, depth from ground surface to mine working, and geologic material.
5. **Volcanic Hazard Areas.** Volcanic hazard areas are areas subject to pyroclastic flows, lava flows, debris avalanche, and inundation by debris flows, lahars, mudflows, or related flooding resulting from volcanic activity. Though there are no significant risks identified for the City and immediate surrounding area, other than airborne particulate impacts from an eruptions
6. **Tsunami hazard areas.** Tsunami hazard areas include coastal areas and lake shoreline areas susceptible to flooding, inundation, debris impact, and/or mass wasting as the result of coastal wave action generated by seismic events or other geologic events. Suspected tsunami hazard areas are indicated on the Tsunami Hazard Map of the Anacortes-Whidbey Island Area, Washington: Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake.
7. **Other Hazard Areas.** Geologically hazardous areas may also include areas determined by the [Decision-maker](#)~~Director~~ to be susceptible to other geological events including mass wasting, debris flows, rock falls, and differential settlement.
- B. All areas within the city meeting one or more of these criteria, regardless of any formal identification, are hereby designated critical areas and are subject to the provisions of this chapter.

19.70.420 Geologically Hazardous Areas – Mapping.

- A. The approximate location and extent of geologically hazardous areas are shown on the City of Anacortes geologically hazardous data layers maintained in the City of Anacortes geographic information system (GIS). In addition, the following maps and resources providing information on the location and extent of geologically hazardous areas are hereby adopted by reference as amended:
1. Skagit County, Skagit County Potential Landslide and Erosion Areas, 2016;
 2. Washington Department of Ecology Coastal Zone Atlas (for marine bluffs);
 3. U.S. Geological Survey geologic maps, landslide hazard maps, and seismic hazard maps;
 4. Washington State Department of Natural Resources seismic hazard maps for Western Washington, including, but not limited to, the Liquefaction Susceptibility and Site Class Maps of Western Washington State by County;
 5. Washington State Department of Natural Resources slope stability maps;
 6. Soils maps produced by the U.S. Department of Agriculture, National Resources Conservation Service;
 7. National Oceanic and Atmospheric Administration tsunami hazard maps;
 8. Washington Department of Natural Resources Tsunami Hazard Map, or as updated, of the Anacortes-Whidbey Island Area, Washington: Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake.
- B. **Reference Only.** The maps and resources cited above are to be used as a guide for the City of Anacortes Planning, Community & Economic Development Department, project applicants, and/or property owners and may be continuously updated as new critical areas are identified. They are a reference and do not provide a final critical area designation.

19.70.425 Geologically Hazardous Areas – General Development Standards.

- A. All development activities and uses are prohibited in geologically hazardous areas and their buffers, except as provided for in this chapter, and only when it is demonstrated that the activity will not create undue risk to life, health, and safety.
- B. **Exemptions and Allowed Activities.** Exemptions are listed in the provisions established in AMC AMC 19.70.035 Exempt Activities.
- C. **Approvals.** Alterations of geologically hazardous areas or associated buffers may only occur pursuant to this chapter, and as determined by a qualified professional with concurrence by a 3rd party review, for activities that:
1. Will not increase the threat of the geological hazard to adjacent properties beyond pre-development conditions;

2. Will not adversely impact other critical areas;
 3. Are designed so that the hazard to the project is eliminated or mitigated to a level equal to or less than pre-development conditions; and
 4. Are determined to be safe as designed and under anticipated conditions by a qualified professional, licensed in the state of Washington.
- D. **Mitigation.** Proposed mitigation techniques are considered to provide long-term hazard reduction only if they do not require regular maintenance or other actions to maintain their function. Mitigation may be required to avoid any increase in risk above the preexisting conditions, including following abandonment of the activity.
- E. **Critical Facilities Prohibited.** Critical facilities may not be sited within geologically hazardous areas unless there is no other practical alternative.
- F. **International Building Code.** All development must conform to the provisions of the currently adopted International Building Code as amended by the City of Anacortes, including submittal of a critical areas report.

19.70.430 Geologically Hazardous Areas – Specific Development Standards

- A. **Erosion or Landslide Hazard Areas.** Except as otherwise provided in this Chapter, only those activities approved and permitted consistent with an approved critical area report in accordance with this Chapter are allowed in erosion or landslide hazard areas. Activities must meet the standards of AMC 19.70.430, General development standards, in addition to the specific requirements contained in this subsection.
1. **Standard Buffer.** A standard buffer of 50 feet is required from the closest edge of a landslide hazard area. The buffer must be maintained as undisturbed native vegetation, except when alteration of vegetation is approved by the ~~Decision-maker~~Decision-maker as part of the project.
 2. **Buffer reduction.** The ~~Decision-Maker~~Decision-maker may reduce the standard buffer by a ~~minimum-maximum~~ of 25% when the critical area report demonstrates that all of the following criteria are met:
 - a. No reasonable alternative to the buffer reduction exists;
 - b. Modified or reduced buffers, through design and engineering solutions, will provide protection to the proposed development and adjacent properties equal to that of the standard buffer;
 - c. The development will not increase surface water discharge or sedimentation to adjacent properties beyond pre-development conditions;
 - d. The development will not decrease slope stability on adjacent properties;
 - e. The proposed reduction will not adversely impact other critical areas;

- f. The critical areas report makes recommendations regarding planting of vegetation or other measures to minimize impacts and resist erosion.
 - g. When a buffer reduction is requested the ~~Decision-maker~~Decision-maker may require, at the applicant's expense, a third-party review of a critical area report by a Qualified Professional under contract with or employed by the City.
3. **Increased buffer.** The standard buffer may be increased by the ~~Decision-maker~~Decision-maker based on a critical areas report prepared by a qualified professional that indicates a greater buffer is necessary to protect the proposed development and/or adjacent properties.
4. **Alterations.**
- a. Alterations of a marine bluff or its buffer are prohibited except that minor development to provide public access (e.g. public trails, stairs or view points) may be permitted as regulated in the Shoreline Master Program, provided that impacts are mitigated and the development can be shown to be safe.
 - b. Alterations of an erosion or landslide hazard area and/or buffers may only occur for activities for which a critical areas report that contains a hazards analysis is submitted which determines that:
 - i. The activity will not increase surface water discharge or sedimentation to adjacent properties beyond predevelopment conditions;
 - ii. The activity will not decrease slope stability on adjacent properties;
 - iii. Such alteration will not adversely impact other critical areas or pose a potential threat risk to life, health, and safety.
 - c. Alterations must be designed to meet the following basic requirements:
 - i. The proposed alteration must not decrease the slope stability. The factor of safety against landslide occurrences for residential and commercial developments must be 1.5 for static conditions and 1.2 for dynamic conditions, unless approved by the ~~Decision-maker~~Decision-maker. Analysis of dynamic conditions must be based on a minimum horizontal acceleration as established by the current version of the International Building Code.
 - ii. Structures and improvements must be clustered to avoid geologically hazardous areas and other critical areas,
 - iii. Structures and improvements must minimize alterations to the natural contour of the slope, and foundations must be tiered where possible to conform to existing topography,
 - iv. Structures and improvements must be located to preserve the most critical portion of the site and its natural landforms and vegetation,

- v. The proposed development must not result in greater risk or a need for increased buffers on neighboring properties;
 - vi. Development must be designed to minimize impervious lot coverage;
 - vii. The ~~Decision-maker~~[Decision-maker](#) may accept an alternative design that deviates from one or more of these standards if a report by a qualified professional demonstrates that greater long-term slope stability can be achieved while meeting all other provisions of this title. The requirement for long-term slope stability must exclude designs that require regular and periodic maintenance to maintain their level of function.
- d. **Additional Requirements for Alteration of Landslide hazard areas and buffers.** Prior to permit issuance, the property owner must sign and record a notice on title, at the owner's sole expense, a covenant in a form acceptable to the City, which:
- i. Acknowledges and accepts the risks of development in the landslide hazard area;
 - ii. Waives any rights to claims against the City;
 - iii. Indemnifies and holds harmless the City against claims, losses, and damages;
 - iv. Informs subsequent owners of the property of the risks and the covenant; and
5. **Vegetation Retention and Maintenance.** Removal of vegetation from a landslide hazard area or related buffer is prohibited, except when allowed as follows:
- a. As part of an approved alteration, that follows the criteria and process outlined in AMC 19.70.440(A)(4).
 - b. Normal nondestructive pruning and trimming of vegetation for maintenance purposes or thinning of limbs of individual trees to provide a view corridor when a plan prepared by an ISA-certified arborist is provided and approved by the ~~Decision-maker~~[Decision-maker](#) and there are no other critical areas present.
 - c. All activity proposed on Marine Bluffs must be regulated and reviewed under the SMP and required shoreline permitting.
6. **Seasonal Restriction.** Clearing within an erosion or landslide hazard area or buffer may be allowed only from May 1st to October 1st of each year provided that the ~~Decision-maker~~[Decision-maker](#) may extend or shorten the dry season on a case-by-case basis depending on actual weather conditions and other factors deemed relevant.
7. **Utility Lines and Pipes.** Utility lines and pipes may be permitted in landslide hazard areas and buffers only when the applicant demonstrates that no other practical alternative is available. The line or pipe must be located aboveground and properly anchored and/or designed with the intent to function in the event of an underlying slide.
8. **Stormwater management.** Prior to any development activity, a plan for the collection, transport, treatment, and discharge of stormwater in accordance with the requirements of

AMC Chapter 19.76, or as amended, and in accordance with the adopted Stormwater Management Manual for Western Washington, must be submitted meeting the following requirements:

- a. All infiltration systems, such as stormwater detention and retention facilities, and curtain drains utilizing buried pipe or French drains, are prohibited in landslide hazard areas and their buffers unless the critical areas report determines such facilities or systems will not adversely affect slope stability.
- b. Stormwater may not be directed across the face of a landslide hazard or related buffer (including marine bluffs or ravines) except as follows:
 - i. Stormwater may be discharged at flow durations matching predeveloped conditions, with adequate energy dissipation, into existing channels that previously conveyed stormwater runoff in the predeveloped state;
 - ii. Stormwater may be dispersed upslope of the landslide hazard area onto a low-gradient undisturbed buffer demonstrated to be adequate to infiltrate all surface and stormwater runoff, if the critical areas report determines such facilities or systems will not adversely affect slope stability;
 - iii. If demonstrated that no other practical alternative is available, stormwater may be discharged from the hazard area into adjacent waters, provided it is collected above the hazard and directed to the water by a tight line drain (constructed of high-density polyethylene pipe with fuse-welded joints, or similar product that is technically equal or superior) and provided with an energy dissipating device at the point of discharge.

9. **Prohibited development.** On-site sewage disposal systems, including drain fields, are prohibited within erosion and landslide hazard areas and related buffers.

10. **Subdivisions.**

- a. The division of land in landslide hazard areas and associated buffers is subject to the following:

i. Land that is located wholly within a landslide hazard area or its buffer may not be subdivided. Land that is located partially within a landslide hazard area or its buffer may be divided provided that each resulting lot has sufficient buildable area outside of, and will not affect, the landslide hazard or its buffer;

ii. Access roads and utilities may be permitted within the landslide hazard area and associated buffers if the ~~Decision-maker~~[Decision-maker](#) determines that no other feasible alternative exists, and if the critical areas report determines such development will not adversely affect slope stability

b. Division of land within erosion hazard areas must comply with the following additional requirements:

i. Except as otherwise provided in this section, existing vegetation must be retained on all lots until building permits are approved for development on individual lots;

ii. If any vegetation on the lots is damaged or removed during construction of the subdivision infrastructure, the applicant must implement a revegetation plan in those areas that have been impacted prior to final inspection of the site development permit or the issuance of any building permit for the subject property;

iii. Clearing of vegetation on individual lots may be allowed prior to building permit approval if the ~~Decision-maker~~[Decision-maker](#) determines that:

1. Such clearing is a necessary part of a large-scale grading plan,
2. It is not feasible to perform such grading on an individual lot basis, and
3. Stormwater output from the graded area will meet established water quality standards.

B. Seismic Hazard Areas.

1. Activities proposed to be located in seismic hazard areas must meet the standards of AMC 19.70.430(B) and (E).

C. Mine Hazard Areas.

1. Activities proposed to be located in mine hazard area must meet the standards of AMC 19.70.430 General development standards, and the specific following requirements:
 - a. **Alterations.** Alterations of a mine hazard area and/or buffer are allowed, as follows:

- i. All alterations are permitted within a mine hazard area with a low potential for subsidence,
 - ii. Within a mine hazard area with a moderate potential for subsidence and at coal mine by-product stockpiles, all alterations are permitted subject to a mitigation plan to minimize risk of structural damage using appropriate criteria to evaluate the proposed use, as recommended in the hazard analysis, and
 - iii. Within a mine hazard area with a severe potential for subsidence only those activities allowed in AMC 19.70.035 **Exempt activities** of this chapter will be allowed.
- b. **Subdivisions.** The division of land in mine hazard areas and associated buffers is subject to the following:
 - i. Land that is located within two hundred feet of a mine hazard area with a severe potential for subsidence may not be subdivided. Land that is located partially within a mine hazard area may be divided provided that each resulting lot has sufficient buildable area that is two hundred feet away from the mine hazard area with a severe potential for subsidence. Land that is located within a mine hazard area with a low or moderate potential for subsidence may be subdivided;
 - ii. Access roads and utilities may be permitted within two hundred feet of a mine hazard area with a moderate or severe potential for subsidence if the city determines that no other feasible alternative exists.
- c. **Reclamation Activities.** Reclamation activities must conform to the provisions in Chapter 332-18 WAC Excavations For all reclamation activities, including grading, filling, and stockpile removal, as-built drawings must be submitted to the city in a format specified by the ~~Decision-maker~~[Decision-maker](#).

D. Tsunami Hazard Areas.

- 1. Non-residential activities on sites containing areas susceptible to inundation due to tsunami hazards must provide an evacuation and emergency management plan
- 2. The construction of structures designated Risk Categories III and IV as specified under currently adopted IBC are prohibited within a tsunami hazard area, except that:
 - a. A vertical evacuation tsunami refuge may be permitted to be located in a tsunami hazard zone provided it is constructed in accordance with FEMA P646;

- b. Community critical facilities may be permitted to be located within a tsunami hazard zone when such a location is necessary to fulfill their function, provided suitable structure and emergency evacuation measures have been incorporated.

19.70.435 Geologically Hazardous Areas - Critical Area Report Additional Requirements

- A. **Additional Report Contents for Geologically Hazardous Areas.** In addition to the minimum report contents required per AMC 19.70.125 reports must also include;
- B. **Third Party Review Required.** Critical areas reports on geologically hazardous areas are subject to third party review at the owner's sole expense as provided in AMC 19.70.125 (B) and in any of the following circumstances:
 - 1. A buffer reduction or alteration of a landslide hazard area is proposed.
- C. **Minimum Report Contents for Geologically Hazardous Areas.** The written critical area report(s) must contain the following information, at minimum:
 - 1. The report must generally follow the Washington State Department of Licensing Guidelines for Preparing Engineering Geology Reports in Washington (2006) and at a minimum report contents required per AMC 19.70.125;
 - 2. A detailed overview of the field investigations, exploration locations, site photos, published data and references; data and conclusions from past assessments of the site; investigations or studies that support the identification of geologically hazardous areas;
 - 3. A description of the methodologies used to conduct the geologically hazardous areas evaluations, classification, hazards assessments, and/or analyses of the proposal impacts, including references.
- 4. **Assessment of Geological Characteristics.** The assessment must include the following:
 - a. Classification of the type of geologic hazard(s) present in accordance with AMC 19.70.410.
 - b. An assessment of the geologic characteristics of the soils, sediments, and/or rock of the project area and potentially affected adjacent properties, and a review of the site history regarding landslides, erosion, and prior grading. Soils analysis must be accomplished in accordance with accepted classification systems in use in the region.
 - c. A description of load intensity, surface and groundwater conditions, public and private sewage disposal systems, fills, excavations, and all structural development; and
 - d. A description of the extent and type of vegetative cover;
 - e. An analysis of proposed surface and subsurface drainage, and the vulnerability of the site to erosion;

5. **Analysis of Proposal.** The report must include a detailed description of the project, its relationship to the geologic hazard(s), and its potential impact upon the hazard area, the project, the subject property, and affected adjacent properties.
6. **Minimum Buffer and Building Setback.** The report must make a recommendation for the minimum no-disturbance buffer and minimum building setback from any geologic hazard based upon the geotechnical analysis.
7. **Additional Technical Information Requirements for Specific Hazards:**
 - a. **Erosion and Landslide Hazard Areas.** The technical information required in a critical area report for a project within an erosion or landslide hazard area must also include the following:
 - i. An estimate of the present stability of the subject property, the stability of the subject property during construction, the stability of the subject property after all development activities are completed, and a discussion of the relative risks and slide potential relating to adjacent properties during each stage of development, including the effect of construction and placement of structures, clearing, grading, and removal of vegetation will have on the slope over the estimated life of the structures. Quantitative analysis of static and seismic slope stability, modeling, and/or seismic displacement analysis may be required by the [Decision-maker](#).
 - ii. A trend analysis of prior rates of erosion, if available.
 - iii. Consideration of the run-out hazard of landslide debris and/or the impacts of landslide run-out on downslope properties;
 - iv. Recommendations for stormwater improvements, locations and methods of erosion control, vegetation management, and/or other means for maintaining long-term soil stability;
 - v. Parameters for design of site improvements including appropriate foundations and retaining structures. These should include allowable load and resistance capacities for bearing and lateral loads, installation considerations, and estimates of settlement performance;
 - vi. Earthwork recommendations including clearing and site preparation criteria, fill placement and compaction criteria, temporary and permanent slope inclinations and protection, and temporary excavation support, if necessary; and
 - vii. Recommendations for mitigation measures to be implemented in order to minimize the risk to the site and adjacent properties, including slope stabilization measures, if appropriate.

b. **Seismic Hazard Areas.** The technical information required in a critical area report for a project within a seismic hazard area must also include the following:

- i. A complete discussion of the potential impacts of seismic activity on the site (for example, liquefaction, lateral spreading, fault rupture);
- ii. An evaluation of the subsurface soil and groundwater profile, physical properties of the subsurface profiles, and the liquefaction potential of the site;
- iii. Recommendations for mitigation measures to be implemented in order to minimize the risk to the project, and adjacent properties if appropriate.

c. **Tsunami Hazard Areas.** The technical information required in a critical area report for a project within a tsunami hazard area must also include:

- i. A discussion of the potential impacts of the tsunami hazard on the site; and
- ii. Recommendations as to structure construction techniques including but not limited to the use of coastal high hazard performance standards.
- iii. For all development other than single lot, single family residences, an emergency management plan including plans for emergency building exits routes, site evacuation routes, emergency training, notification of local emergency management officials, and an emergency warning system.

d. **Marine Bluffs** A geotechnical engineering report will be required when development is proposed within 50 feet (in all directions) of ~~the to or to the~~ crest of a marine bluff, or a distance equal to the height of the slope up to a distance of 100 feet from the crest (measured from the top), whichever is greater.

- i. The report must be based on best available science, existing and proposed uses, risks of slope failure, and coastal erosion rates over the last 75 years, if applicable.
- ii. All proposed development on a marine bluff or in the required buffer must be prohibited, except: as may be allowed [in the shoreline-specific Critical Areas Regulations under Subsection A 3.5 of Appendix A of this per AMC 19.72 and DR-6.9.1 of the Shoreline Master Program](#), or minor development to provide public access (e.g., public trails, stairs or view points), provided that impacts are mitigated and the development can be shown to be safe.

D. **All Geologically Hazardous Areas.** The ~~Decision-Maker~~Director may require additional information deemed necessary to adequately review the proposal.

1. **Site and Construction Plans.** The critical area submittal for geologically hazardous areas must include a copy of the site plans for the proposal, drawn at an engineering scale, showing:
 - a. The type and extent of geological hazard areas, ~~and~~ any other critical areas, and recommended and required buffers on, adjacent to, off site within 200 feet of, or that are likely to impact or be affected by the proposal;
 - b. Proposed development, including the location of existing and proposed structures, fill, clearing limits, significant trees to be removed, vegetation to be removed, proposed material stock pile locations, and stormwater management facilities;
 - c. The topography, in two-foot contours, of the project area and all hazard areas addressed in the report;
 - d. Height of slope, slope gradient, and cross-section of the project area indicating the stratigraphy of the site;
 - e. The location of springs, seeps, or other surface expressions of ground-water on or off site within 200 feet of the project area or that have the potential to affect or be affected by the proposal;
 - f. The location and description of surface water on or off site within 200 feet of the project area or that has the potential to be affected by the proposal.

PART 5: CRITICAL AQUIFER RECHARGE AREAS

19.70.510 Critical Aquifer Recharge Areas – Description and Purpose.

- A. Critical aquifer recharge areas provide the public with clean, safe, and available drinking water and contribute base flows to protect aquatic resources. Once groundwater is contaminated or depleted, it is difficult, costly, and sometimes impossible to clean up or to recharge.
- B. The purpose of this section is to protect critical aquifer recharge areas from degradation or depletion resulting from new and redeveloping land use activities. Due to the potential vulnerability of groundwater underlying certain aquifer recharge areas to contamination and the importance of such groundwater as sources of public water supply, it is the intent of this section to safeguard groundwater resources by mitigating or precluding future discharges of contaminants from new development activities and redevelopment activities.

19.70.515 Critical aquifer recharge areas - Applicability and hazardous materials questionnaire.

- A. **Applicability.** The provisions of this section apply to regulated facilities that are within or adjacent to those portions of the City of Anacortes designated as critical aquifer recharge

areas on the City of Anacortes Critical Areas Map. Regulated activities/facilities are defined as those commercial, industrial and home occupation uses that:

1. Process or handle hazardous materials in regulated quantities; and
2. Treat or store regulated quantities of hazardous materials.

B. Hazardous materials questionnaire required. Applications for development or redevelopment of regulated facilities within the boundaries of critical aquifer recharge areas must be accompanied by a completed hazardous materials questionnaire to determine the regulatory status of the applicant facility. The ~~Decision-maker~~[Decision-maker](#) must review the questionnaire to determine whether the facility is regulated under this chapter. If it is determined that the proposal includes a regulated facility that processes, handles, treats, and/or stores hazardous substances as defined by this chapter, the applicant must submit a critical areas report pursuant to this Chapter.

19.70.520 Critical Aquifer recharge areas – Designation.

A. Critical aquifer recharge areas include:

1. Areas served by groundwater which have been designated as a “Sole Source Aquifer Area” under the Federal Safe Drinking Water Act;
 - a. Areas within a “closed” or “low-flow” stream watershed designated by the Department of Ecology pursuant to RCW 90.22;
 - b. Areas designated as “Wellhead Protection Areas” pursuant to [WAC 246-290](#) and the groundwater contribution area pursuant to [WAC 246-291-125\(3\)\(d\)\(iii\)](#) or otherwise recognized by the ~~Decision-maker~~[Director](#) as needing wellhead protection. Wellhead protection areas include, for the purpose of this regulation, the identified recharge areas associated with:

- i. The 10-year groundwater time-of-travel for all Group A public water supply wells; or
 - i. The 5-year groundwater time-of-travel for all Group B public water supply wells with a wellhead protection plan filed with the Skagit County Health Department; or
 - ii. Plats serviced by five or more individual wells where the average lot size is equal to or less than two acres for which a wellhead protection plan has been completed and filed with the Skagit County Health Department; or
 - iii. The 1,000-foot radius for individual private drinking water supply wells, as identified by map criterion in section 10.70.530.
- B. All areas within the city meeting one or more of these criteria, regardless of any formal identification, are hereby designated critical areas and are subject to the provisions of this chapter.

19.70.525 Critical Aquifer Recharge Areas – Mapping.

- A. The approximate location and extent of critical aquifer recharge areas are shown on the City of Anacortes critical aquifer recharge area data layers maintained in the City of Anacortes geographic information system (GIS). In addition, the following maps and resources providing information on the location and extent of critical aquifer recharge areas are hereby adopted by reference as amended:
1. Areas with soils that have moderate to rapid permeability (>2 inches per hour) as listed in Table 14 of the Soil Survey of Skagit County.
 2. Source for identifying drinking water supply wells identified by Agencies such as Washington Department of Ecology and Skagit County Health Department.
- B. **Reference Only.** The maps and resources cited above are to be used as a guide for the City of Anacortes Planning, Community & Economic Development Department, project applicants, and/or property owners and may be continuously updated as new critical areas are identified. They are a reference and do not provide a final critical area designation.

19.70.530 Critical Aquifer Recharge Areas – General Development Standards

- A. Regulated activities/facilities may be permitted in a critical aquifer recharge area only if the applicant can demonstrate that the proposed activity will not cause contaminants to enter the aquifer and that the proposed activity will not adversely affect the recharging of the aquifer.
- B. The proposed regulated activity must comply with the water source protection requirements and recommendations of the federal Environmental Protection Agency, State Department of Health, and the Skagit County Health Department.

- C. **Storage tank permits.** The City of Anacortes specifically regulates and authorizes permits for underground storage tanks pursuant to the International Fire Code and this chapter. The Washington Department of Ecology also regulates and authorizes permits for underground storage tanks (WAC 173-360). The Anacortes Fire Department regulates and authorizes permits for the removal of underground storage tanks.
- D. Owners and operators of facilities with existing underground storage tanks that are located within a critical aquifer recharge area must comply with all release detection requirements as specified in WAC 173-360.
- E. **Spreading or injection of reclaimed water.** Water reuse projects for reclaimed water must be in accordance with the adopted water or sewer comprehensive plans that have been approved by the Washington Department of Ecology and Skagit County Health Department.
1. Surface spreading must meet the groundwater recharge criteria given in RCW 90.46.080 and 90.46.010(10).
 2. Direct injection must be in accordance with the standards developed by authority of RCW 90.46.042.
- F. **Prohibited activities and land uses.** The following land uses and activities for new development or redevelopment are prohibited within or adjacent to critical aquifer recharge areas:
1. Landfill activities as defined in WAC 173-304 and WAC 173-351;
 2. All underground injection wells as defined in Chapter 173-218 WAC;
 3. Disposal of hazardous or dangerous wastes;
 4. Mining, including:
 - a. Metals and hard rock mining;
 - b. Sand and gravel mining are prohibited in critical aquifer recharge areas determined to be highly susceptible or vulnerable unless a stormwater quality management plan is approved and followed by the applicant;
 5. Wood Treatment Facilities. Wood treatment facilities that allow any portion of the treatment process to occur over permeable surfaces (both natural and manmade);
 6. Storage, processing, or disposal of radioactive substances;
 7. Dry cleaning establishments using the solvent perchlorethylene; and
 8. Other:
 - a. Activities that would significantly reduce the recharge to aquifers currently or potentially used as a potable water source;

- b. Activities that would significantly reduce the recharge to aquifers that are a source of significant baseflow to a regulated stream;
- c. Activities that are not connected to an available sanitary sewer system are prohibited from critical aquifer recharge areas associated with sole source aquifers.

19.70.535 Critical Aquifer Recharge Areas – Specific Development Standards for Regulated Facilities

- A. The following mitigation measures, as applicable, are required for development of regulated facilities within a critical aquifer recharge area:
 - 1. Floor drains must not be allowed to drain to the stormwater system and must be designed and installed to meet the Uniform Plumbing Code (UPC) Section 303.
 - 2. If any roof venting carries contaminants, then the portion of the roof draining this area must go through pretreatment pursuant to UPC Section 304(b).
 - 3. All nonresidential vehicle washing must be self-contained or be discharged to a sanitary sewer system, if approved by the sewer utility, and is subject to UPC Sections 708 and 711.
 - 4. Utilize Integrated Pest Management (IPM) practices for pest control and Best Management Practices (BMPs) for the use of fertilizers as described by the Skagit County Local Hazardous Waste Management Program.
 - 5. Facilities installing new underground tanks. All new underground storage facilities used or to be used for the underground storage of hazardous substances or hazardous wastes must meet the requirements of WAC 173-360 and be designed and constructed so as to:
 - a. Prevent releases due to corrosion or structural failure for the operational life of the tank;
 - b. Be protected against corrosion, constructed of non-corrosive material, steel clad with a non-corrosive material, or designed to include a secondary containment system to prevent the release or threatened release of any stored substance; and
 - c. Use material in the construction or lining of the tank which is compatible with the substance to be stored.
 - 6. Aboveground tanks. All new aboveground storage facilities/tanks containing hazardous substances within a critical aquifer recharge area must be constructed, installed, used and maintained to:
 - a. Prevent the release of a hazardous substance to the ground, or groundwater;
 - b. Include an impervious containment area enclosing or underlying the tank or part thereof;
 - c. Include a secondary containment system either built into the tank structure or a dike system built outside the tank. The secondary containment system or dike system must

have a capacity of at least 110 percent of the primary tank and conform to the requirements of UFC Chapter 7902.2.

7. Vehicle repair and servicing.
 - a. Commercial vehicle repair and servicing must be conducted over impermeable pads and within a covered structure capable of withstanding normally expected weather conditions. Chemicals used in the process of vehicle repair and servicing must be stored in a manner that protects them from weather and provides containment should leaks occur.
 - b. Dry wells are not allowed on sites used for vehicle repair and servicing. Dry wells existing on the site prior to facility establishment must be abandoned using techniques approved by the state Department of Ecology prior to commencement of the proposed activity.
8. Additional protective measures may be required if deemed necessary by the City of Anacortes.
9. State and federal regulations – The uses listed below will be conditioned as necessary to protect critical aquifer recharge areas in accordance with the applicable state and federal regulations.

Statutes, Regulations and Guidance Pertaining to Groundwater Impacting Activities

Activity	Statute – Regulation – Guidance
Above Ground Storage Tanks	Chapter 173-303-640 WAC
Animal Feedlots	Chapter 173-216 WAC , Chapter 173-220 WAC
Automobile Washers	Chapter 173-216 WAC, Best Management Practices for Vehicle and Equipment Discharges (WDOE WQ-R-95-56)
Below Ground Storage Tanks	Chapter 173-360 WAC
Chemical Treatment Storage and Disposal Facilities	Chapter 173-303 WAC
Hazardous Waste Generator (Boat Repair Shops, Biological Research Facility, Dry Cleaners, Furniture Stripping, Motor Vehicle Service Garages, Photographic Processing, Printing and Publishing Shops, etc.)	Chapter 173-303 WAC
Injection wells	Federal 40 CFR Parts 144 and 146, Chapter 173-218 WAC

Junk Yards and Salvage Yards	Chapter 173-304 WAC, Best Management Practices to Prevent Stormwater Pollution at Vehicle Recycler Facilities (WDOE 94—146)
Oil and Gas Drilling	WAC 332-12-450, Chapter 173-218 WAC
Wastewater Facilities	Chapter 173-240 WAC
On-Site Sewage Systems (<3,500 gal/day)	Chapter 246-272A WAC, Local Health Ordinances
Large On-Site Sewage Systems (3,500 to 1000,000 gal/day)	Chapter 246-272B WAC, State Health Ordinances
Pesticide Storage and Use	Chapter 17.21 RCW
Sawmills	Chapter 173-303 WAC, Chapter 173-304 WAC, Best Management Practices to Prevent Stormwater Pollution at Log Yards (WDOE 95-53)
Solid Waste Handling and Recycling Facilities	Chapter 173-304 WAC
Surface Mining	Chapter 332-18 WAC
Wastewater Application to Land Surface	Chapter 173-216 WAC, Chapter 173-200 WAC, WDOE Land Application Guidelines, Best Management Practices for Irrigated Agriculture

19.70.540 Critical Aquifer Recharge Areas – Critical area report additional requirements.

A. Additional Report Contents for CARA's. In addition to the minimum report contents required per AMC 19.70.125 CARA reports must also include;

B. Minimum Report Contents. A critical areas report must include a hydrogeologic assessment including, but not limited to, the following:

1. Information sources;
2. Geologic and hydrologic setting including available recharge, permeability/transmissivity information;
3. Available well logs, borings, seeps/springs within 1,000 feet of the project area;
4. Available water quality information;
5. Groundwater depth, flow direction and gradient based on available information;
6. Surface water location and recharge potential;
7. Water source supply to the site;
8. Any sampling schedules necessary;
9. Discussion of the effects of the proposed project on the groundwater resources;

10. Description of potential mitigation measures, should it be determined that the proposed project may have an adverse impact on groundwater resources; and

11. Other information as required by the City.

- C. If the hydrogeologic assessment determines that the facility will have no effect on groundwater resources, the facility is exempt from the development standards requirements in section 19.70.540 of this Chapter.
- D. If the hydrogeologic assessment determines that the facility could have an effect on groundwater resources, the ~~Decision-maker~~Decision-maker will require implementation of applicable development standards in sections 19.70.540.

PART 6: FREQUENTLY FLOODED AREAS

19.70.610 Frequently Flooded Areas – Description and Purpose.

- A. Frequently flooded areas perform important hydrologic functions and may present a risk to persons and property.
- B. It is the purpose of this chapter to promote the public health, safety and general welfare, and to minimize public and private losses due to flood conditions in specific areas caused by flooding, while protecting the functions and values of floodplains, including special consideration for anadromous fish habitat in combination with the provisions for Fish and Wildlife Habitat Conservation Areas in this chapter.

19.70.615 Frequently Flooded Areas – Designation.

- A. Frequently flooded areas include those areas established as special flood hazard areas under AMC 19.74 Floodplain Management, including those areas of special flood hazard identified by the Federal Insurance Administration in a scientific and engineering report entitled “The Flood Insurance Study for the City of Anacortes” dated March 17, 2003, and any revisions thereto, with accompanying flood insurance rate maps (FIRM), and any revisions thereto. The best available information for flood hazard area identification as outlined in AMC 19.74 Use of Other Base Flood Data in A and V zones is the basis for regulation until a new FIRM is issued that incorporates the data utilities under AMC 19.74 Use of Other Base Flood Data in A and V zones.
- B. Tsunami hazard areas are designated as geologically hazardous areas per AMC 19.70.410 and are subject to applicable development regulations outlined in AMC 19.70.430.
- C. Climate change and sea level rise are affecting many coastal communities and some within Puget Sound. Applicants are urged to become familiar with potential impacts of climate change and sea level rise if development is proposed near the marine shoreline or associated low-lying areas.

19.70.620 Frequently Flooded Areas – Mapping.

- A. **Reference Only.** The maps and resources cited above are to be used as a guide for the City of Anacortes Planning, Community & Economic Development Department, project applicants, and/or property owners and may be continuously updated as new critical areas are identified. They are a reference and do not provide a final critical area designation.

19.70.625 Frequently flooded areas – General Development Standards

- A. All development proposals must comply with AMC 19.74 Floodplain Management for general and specific flood hazard protection.

- B. Development may not reduce the base flood water storage ability. Construction, grading or other regulated activities that would reduce the flood water storage ability must be mitigated by creating compensatory storage on or off site.
- C. Alteration of Watercourses.
 - 1. Projects that will relocate a watercourse must also submit a request for Conditional Letter of Map Revision, where required by FEMA. The project may not be approved unless FEMA issues the CLOMR (which requires ESA consultation) and the provisions of the letter are made part of the permit requirements.
 - 2. The ~~Decision-maker~~[Decision-maker](#) must notify adjacent communities (if applicable) and the Department of Ecology prior to any alteration or relocation of a watercourse, and submit evidence of such notification to FEMA.
 - 3. Maintenance must be provided within the altered or relocated portion of said watercourse so that flood carrying capacity is not diminished. If the maintenance program does not call for cutting of native vegetation, the system must be oversized at the time of construction to compensate for said vegetation growth or any other natural factor that may need future maintenance.
- D. Base flood data and flood hazard notes must be shown on the face of any recorded plat or binding site plan, including, but not limited to, base flood elevations, flood protection elevation, boundary of floodplain, and zero rise floodway.
- E. All development must conform to the provisions of the currently adopted International Building Code, including submittal of a critical areas report.

19.70.630 Frequently Flooded Areas – Critical Areas Report Additional Requirements

- A. Additional Report Contents for FFA's. In addition to the minimum report contents required per AMC 19.70.125 FFA reports must also include;
- B. Minimum Report Contents. A critical areas report must include a habitat assessment prepared in accordance with [Regional Guidance for Floodplain Habitat Assessment and Mitigation](#) (FEMA Region X, 2013), or as hereafter amended. The assessment must determine if the project would adversely affect:
 - 1. The primary constituent elements identified when a species is listed as threatened or endangered;
 - 2. Essential fish habitat designated by the National Marine Fisheries Service;
 - 3. Fish and wildlife habitat conservation areas;
 - 4. Vegetation communities and habitat structures;
 - 5. Water quality;

6. Water quantity, including flood and low flow depths, volumes and velocities;
 7. The channel's natural planform pattern and migration processes;
 8. Spawning substrate, if applicable; and/or
 9. Floodplain refugia, if applicable.
- C. If the assessment concludes that the activity is expected to have an adverse effect on water quality and/or aquatic or riparian habitat or habitat functions, the project must be designed in a way to off-set those impacts. Project mitigation ~~will is~~ not ~~be~~ permitted in accordance with Regional Guidance for Floodplain Habitat Assessment and Mitigation, FEMA Region X, 2013.
- D. The following activities do not require completion of a habitat assessment:
1. Repair of existing building in its existing footprint, including damage by fire or other casualties;
 2. Removal of noxious weeds;
 3. Replacement of nonnative vegetation with native vegetation;
 4. Ongoing activities such as lawn and garden maintenance;
 5. Removal of hazard trees;
 6. Normal maintenance of public utilities and facilities;
 7. Restoration or enhancement of floodplains, riparian areas and streams that meets federal and state standards.

DEFINITIONS

“Adjacent” means areas adjacent to critical areas must be considered to be within the jurisdiction of these requirements and regulations to support the intent of this title and ensure protection of the functions and values of critical areas. Adjacent must include lands within a distance equal to the required buffer for the critical area as determined by the provisions of this chapter.

“Anadromous fish” means fish that spawn and rear in freshwater and mature in the marine environment. While Pacific salmon die after their first spawning, adult char (bull trout) can live for many years, moving in and out of saltwater and spawning each year. The life history of Pacific salmon and char contains critical periods of time when these fish are more susceptible to environmental and physical damage than at other times. The life history of salmon, for example, contains the following stages: upstream migration of adults, spawning, inter-gravel incubation, rearing, smoltification (the time period needed for juveniles to adjust their body functions to live in the marine environment), downstream migration, and ocean rearing to adults.

“Aquifer” means a body of soil or rock that contains sufficient saturated material to conduct groundwater and yield usable quantities of groundwater to wells or springs.

“Averaging” means establishing the required buffer setback from a critical area, within the permitted parcel of land only, so that areas within the parcel determined to be more environmentally sensitive than others will have a larger buffer than the less sensitive areas. For every increase in setback for one area of the parcel, there will be an equal corresponding decrease in another area of the parcel. The total land area within the buffer must remain the same as if the buffer were a uniform width. “Aquifer” means a body of soil or rock that contains sufficient saturated material to conduct groundwater and yield usable quantities of groundwater to wells or springs.

“Base flood” means a flood having a one percent chance of being equaled or exceeded in any given year, often referred to as the “100-year flood”.

“Base flood elevation” means the water surface elevation of the base flood in relation to the North American Vertical Datum of 1988. The Anacortes FIRMs still make reference to the 1929 National Geodetic Vertical Datum (NGVD). While using NAVD is acceptable, please recognize that surveyors and designers will need to convert the datum when preparing plans. FEMA Elevation Certificates require the use of the datum utilized on the FIRMs.

“Best available science” means current scientific information used in the process to designate, protect, or restore critical areas that is derived from a valid scientific process as defined by WAC 365-195-900 through 925. Sources of best available science are included in “Citations of Recommended Sources of Best Available Science for Designating and Protecting Critical Areas” published by the Washington State Department of Commerce.

“Best management practices (BMPs), critical areas” means physical or structural tools and/or management practices which, when used singularly or in combination, prevent or reduce adverse impacts to critical areas or their buffers.

“Buffer” is an area contiguous to a critical area that is required to protect the critical area and provide for the continued maintenance, functioning, and/or structural stability of a critical area.

“Critical aquifer recharge areas” are areas with a critical recharging effect on aquifers used for potable water, including areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water, or is susceptible to reduced recharge.

“Critical areas” means critical aquifer recharge areas, fish and wildlife habitat conservation areas, frequently flooded areas, geologically hazardous areas, streams, and wetlands, as defined in this Chapter.

“Development” means any human-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials.

“Ditches” are artificial drainage features created through purposeful human action, such as irrigation and drainage ditches, grass-lined swales, and canals. Purposeful creation from uplands must be demonstrated through documentation, photographs, statements, and/or other evidence in order to be unregulated by this chapter.

“Enhancement” means an action which increases the functions and values of a stream, wetland, or other critical area or buffer.

“Erosion” means the process by which soil particles are mobilized and transported by natural agents such as wind, rain-splash, frost action or surface water flow.

“Erosion hazard areas” are those areas containing soils which, according to the United States Department of Agriculture Natural Resources Conservation Service Soil Survey Program, may experience significant erosion. Erosion hazard areas also include coastal erosion-prone areas and channel migration zones.

“Federal Emergency Management Agency (FEMA) floodway” means the channel of the stream and that portion of the adjoining floodplain which is necessary to contain and discharge the base flood flow without increasing the base flood elevation more than one foot.

“Fish and wildlife habitat conservation areas” are areas that serve a critical role in sustaining needed habitats and species for the functional integrity of the ecosystem, and which, if altered, may reduce the likelihood that the species will persist over the long term. As defined in AMC 19.70.310.

“Floodway, zero rise” means the channel of a stream and that portion of the adjoining floodplain which is necessary to contain and discharge the base flood flow without any measurable increase in flood height. A measurable increase in base flood height means a calculated upward rise in the base flood elevation, equal to or greater than .01 foot, resulting from a comparison of existing conditions and changed conditions directly attributable to development in the floodplain. This definition is broader than that of the FEMA floodway, but always includes the FEMA floodway. The boundaries of the 100-year floodplain, as shown on the Flood Insurance Study for _____, are considered the boundaries of the zero-rise floodway unless otherwise delineated by a critical area study.

“Floodplain” means the total area subject to inundation by the base flood.

“Frequently flooded areas” are lands in the floodplain subject to at least a one percent or greater chance of flooding in any given year, or within areas subject to flooding due to high groundwater, high tides, with strong winds, sea level rise, and extreme weather events resulting from global climate change. These areas include, but are not limited to streams, rivers, lakes, coastal areas, wetlands, and areas where high groundwater forms ponds on the ground surface.

“Functions and values” means the beneficial services provided by critical areas to society, including, but not limited to, improving and maintaining water quality, providing fish and wildlife habitat, supporting terrestrial and aquatic food chains, reducing flooding and erosive flows, wave attenuation, historical or archaeological importance, educational opportunities, and recreation. These beneficial roles are not listed in order of priority.

“Geologically hazardous areas” means areas that because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns.

“Groundwater” means water in a saturated zone or stratum beneath the surface of the land or below a surface water body.

“Habitats of local importance” designated as fish and wildlife habitat conservation areas include those areas found to be locally important by the City of Anacortes.

“Hazard tree” means any tree determined by an International Society of Arboriculture (ISA)-certified arborist to be a hazard to people or property as a result of a risk assessment conducted according to ISA guiding principles.

“In-lieu-fee program” means an agreement between a regulatory agency (state, federal or local) and a single sponsor, generally a public natural resource agency or non-profit organization. Under an in-lieu-fee agreement, the mitigation sponsor collects funds from an individual or a number of individuals who are required to conduct compensatory mitigation required under a wetland regulatory program. The sponsor may use the funds pooled from multiple permittees to create one or a number of sites under the authority of the agreement to satisfy the permittees’ required mitigation.

“Landslide” means an episodic downslope movement of a mass including, but not limited to, soil, rock or snow.

“Landslide hazard areas” are areas at risk of mass movement due to a combination of geologic, topographic, and hydrologic factors.

“Mine hazard areas” are those areas directly underlain by, adjacent to, or affected by mine workings such as adits, tunnels, drifts, or airshafts, and those areas probable to sink holes, gas releases, or subsidence due to mine workings.

“Mitigation” means the use of any or all of the following actions listed in descending order of preference:

1. Avoiding the impact by not taking a certain action;
2. Minimizing the impact by limiting the degree or magnitude of the action by using appropriate technology or by taking affirmative steps to avoid or reduce the impact;
3. Rectifying the impact by repairing, rehabilitating or restoring the affected critical area or buffer;
4. Reducing or eliminating the impact over time by preserving or maintenance operations during the life of the development proposal;
5. Compensating for the impact by replacing, enhancing or providing substitute critical areas and environments;
6. Monitoring the impact and taking appropriate corrective measures.

“Mitigation” means avoiding, minimizing, or compensating for adverse critical areas impacts, using the sequential order of preference listed in 19.70.130, Mitigation requirements.

“Monitoring” means evaluating the impacts of development proposals on biologic, hydrologic and geologic systems and assessing the performance of required mitigation through the collection and analysis of data for the purpose of understanding and documenting changes in natural ecosystems, functions and features including, but not limited to, gathering baseline data.

“Native Growth Protection Area/ Easement” (NGPA/E) means.....

“Native vegetation” means plant species that occur naturally in a particular region or environment and were present before European colonization.

“Normal Appurtenances” means those structures secondary to a primary use that are common to and do not constitute a special privilege. Examples for residential uses include garages, deck, driveways, utilities, and fences.

“Noxious weed” means any plant which is highly destructive, competitive, or difficult to control by cultural or chemical practices, limited to those plants on the state noxious weed list contained in Chapter [16-750 WAC](#) and those regulated by Skagit County.

Piped stream means.....

“Primary association” means the fundamental link between a species and land or aquatic area where anadromous fish, endangered, threatened or sensitive species breed or feed.

“Prior Notification”

“Repair or maintenance” means an activity that restores the character, scope, size, and design of a serviceable area, structure, or land use to its previously authorized and undamaged condition. Activities that change the character, size, or scope of a project beyond the original design and drain, dredge, fill, flood, or otherwise alter critical areas are not included in this definition.

“Replacement” means.....

“Restoration” means measures taken to restore an altered or damaged natural feature, including: (a) Active steps taken to restore damaged wetlands, streams, protected habitat, or their buffers to the functioning condition that existed prior to an unauthorized alteration; and (b) Actions performed to re-establish structural and functional characteristics of a critical area that have been lost by alteration, past management activities, or catastrophic events.

“Seismic hazard areas” are areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, debris flows, lahars, or tsunamis.

“Shoreline jurisdiction” means.....

“Significant tree” means a deciduous or evergreen tree greater than six inches in diameter at five feet above grade.

“Slope” means an inclined ground surface, the inclination of which is expressed as a ratio or percentage of vertical distance to horizontal distance by the following formula: $-(\text{vertical distance} / \text{horizontal distance}) \times 100 = \% \text{ Slope}$

“Special Flood Hazard Area” means the land in the floodplain that is subject to a one percent or greater chance of flooding in any given year. Designation on maps always includes the letters A or V.

“Species of local importance” are those species that are of local concern designated by the City due to their population status or their sensitivity to habitat manipulation.

“Stream” means an area where open surface water produces a defined channel or bed, not including irrigation ditches, canals, storm or surface water runoff devices, or other entirely artificial watercourses, unless they are used by salmonids or are used to convey a watercourse naturally occurring prior to construction. A channel or bed need not contain water year-round, provided there is evidence of at least intermittent flow during years of normal rainfall.

“Unavoidable impacts” means adverse impacts that remain after all appropriate and practicable avoidance and minimization has been achieved.

“Volcanic hazard areas” include areas subject to pyroclastic flows, lava flows, and inundation by debris flows, lahars, mudflows, or related flooding from volcanic activity.

“Wetland” or “wetlands” means those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands include those artificial wetlands intentionally created from non-wetland areas created to mitigate conversion of wetlands.

“Wetland Mitigation Bank” means a site where wetlands are restored, created, enhanced, or in exceptional circumstances, preserved, expressly for the purpose of providing compensatory mitigation in advance of unavoidable impacts to wetlands or other aquatic resources that typically are unknown at the time of certification to compensate for future, permitted impacts to similar resources.

“Wetland mosaic” means an area with a concentration of multiple small wetlands, in which each patch of wetland is less than one acre; on average, patches are less than 100 feet from each other; and areas delineated as vegetated wetland are more than 50% of the total area of the entire mosaic, including uplands and open water.

Anacortes Critical Area Regulations

2nd Draft Changes

December 11, 2019

The following table lists the changes recommended for the 2nd draft the Anacortes Critical Area Regulations resulting from internal staff discussion, legal review, Planning Commission direction, and response to public comments.

AMC Reference	Recommended Change
Body of Text	<i>Change Required Administratively:</i> Grammar, numbering, and code citations will be reviewed and corrected by staff.
19.12, Definitions	<i>Change Requested by Public Comment:</i> Correction of the definition of Passive Recreation to include the missing section (A, B, C,D) from old definition that was in Title 17 but is no longer in Title 19 definitions. Current Language: <i>19.12.020: "Passive recreation" means a mix of uses on undeveloped land (including wetland buffers) or minimally improved lands which includes the following: naturally landscaped areas, nonlandscaped green spaces, picnic areas, water bodies, trails, interpretive trails and other similar structures or development.</i> Options: a. Leave definition as is in 19.12.020 b. Correct the definition to match previous 17.06.723 c. Change the definition of Passive Recreation all together.
Staff Recommendation	Staff recommends (option b.) correcting the definition to match the previous definition to read: <i>19.12.020 (17.06.723) "Passive recreation" refers to a mix of uses on undeveloped land (including wetland buffers) or minimally improved lands which includes the following: naturally landscaped areas, non-landscaped greenspaces, picnic areas, water bodies, trails, interpretive trails and other similar structures or development.</i> <i>Passive recreation may be defined as a non-motorized activity that:</i> <i>A. Offers constructive, restorative, and pleasurable human benefits and fosters appreciation and understanding of open space and its purpose;</i> <i>B. Is compatible with other passive recreation uses;</i> <i>C. Does not significantly impact natural, cultural, scientific, or agricultural values; and</i> <i>D. Requires only minimal visitor facilities and services directly related to safety and minimizes passive recreation impacts.</i>
19.12, Definitions	<i>Change requested by Dept. of Ecology.</i> "qualified professional." For wetlands, we [Ecology] recommend: A qualified professional for wetlands must be a professional wetland scientist with at least two years of full-time work experience as a wetlands professional, including delineating wetlands

AMC Reference	Recommended Change
	using the federal manual and supplements, preparing wetlands reports, conducting function assessments, and developing and implementing mitigation plans. Current language: <i>"Qualified professional" means a person with experience and training in the applicable field or critical area. A qualified professional must have obtained a B.S. or B.A. or equivalent degree in biology, engineering, environmental studies, fisheries, geology or related field, and have two years of related work experience.</i> Options: a. Leave definition as is in 19.12.020, b. Modify definition as suggested above.
Staff Recommendation	Staff recommends (option b.) modifying the definition to read: <i>"Qualified professional" means a person with experience and training in the applicable field or critical area. A qualified professional must have obtained a B.S. or B.A. or equivalent degree in biology, engineering, environmental studies, fisheries, geology or related field, and have two years of related work experience. <u>A qualified professional for wetlands must be a professional wetland scientist with at least two years of full-time work experience as a wetlands professional, including delineating wetlands using the federal manual and supplements, preparing wetlands reports, conducting function assessments, and developing and implementing mitigation plans.</u></i>
Table 19.20.030	<i>Change Required Administratively:</i> Because the Permit types have been modified by the new Critical Area Regulations it is important to include them in the Types of Review section 19.20.030 and the Review classification and process matrix shown in Table 19.20.030. Add: Type I – Exemption with Prior Written Notice, Type II – Critical Area Permitted Alteration Permit, Type III HE – Critical Area Variance Options: This is a necessary addition.
Staff Recommendation	Staff recommends the above amendment to Chapter 19.20 and the permit procedure table 19.20.030.
19.70.015 Applicability	<i>Change Requested by Staff:</i> Staff recommends wordsmithing the following section because it appears Draft 1 got edited incorrectly: Current Language: <i>19.70.015(A) Unless explicitly exempted, the provisions of this chapter apply to all land uses, development activity, and all structures and facilities within the City of Anacortes that are within the maximum buffer distance of, or likely to affect the functions and values of, one or more critical areas.</i> Options: This is a necessary addition.
Staff Recommendation	Staff recommends the following change:

AMC Reference	Recommended Change
	19.70.015(A) Unless explicitly exempted, the provisions of this chapter apply to all land uses, development activity, and all structures and facilities within the City of Anacortes that are <i>within</i>, within the maximum buffer distance of, or likely to affect the functions and values of, one or more critical areas.
19.70.035(C)	<i>Change Requested by Staff:</i> 19.70.035(C) Modifications to Existing Nonconforming Structures and Uses, modified from section 19.70.500 is missing (B) the State Ferry Terminal provision. Current Language: C. Modifications to Existing Nonconforming Structures and Uses. Existing structures and uses that were established legally but do not meet the current critical area, buffer, or buffer setback requirements may continue in accordance to AMC 19.49.040, and may be modified as follows: 1. Routine maintenance and repairs; 2. Structural modifications or additions that do not intensify the nonconformity of the structure or increase the area of hardscape lying within the critical area or buffer. The Decision maker may require an updated critical areas report to confirm location of buffers and that the addition is located entirely outside the critical area or buffer; 3. Vertical additions above the ground floor that do not encroach further into the critical area or buffer beyond the existing exterior walls, except that critical areas review is required for additions in landslide hazard areas or buffers; 4. Restoration or replacement of a structure that is damaged by fire, natural disaster or other calamity when: a. A complete application for reconstruction or replacement is submitted within one year of the damage; and b. The restoration or replacement is made to conform to the current critical areas regulations, or if such regulations cannot be physically met without reducing the size of the building, the restoration or replacement may not intensify any nonconformity that existed prior to the damage. c. Except that critical areas review is required for restoration and replacement in landslide hazard areas or buffers. Options: This is a necessary correction
Staff Recommendation	Staff recommends adding the following item #5 to the above section: 5. State Ferry Terminal. The existing developed footprint, except for infill between the toll booth area in the lowest parking lot, hillside walking paths, and a hillside side slope along the western side of the main terminal parking lot, and including all associated parking, at the Washington State Ferry Terminal facility, shall not be increased and redevelopment may occur provided there is no net loss of ecological function and value in the adjacent buffer areas for Cannery Pond and Ship Harbor Interpretive Preserve wetlands.
19.70.040 Exemption Table	<i>Change Requested by Public Comment:</i> Public comment has been received that the Exemption statement “when it can be demonstrated” is confusing, and that the Exemption should not include the term bicycles. Passive Outdoor Activities. When it can be demonstrated that there will be no adverse effect, the following activities are allowed within critical areas and their buffers: educational activities,

AMC Reference	Recommended Change
	<i>scientific research, and outdoor recreational activities, including but not limited to interpretive field trips, bird watching, public beach access including water-related activities, bicycling, and hiking. This exemption does not include constructing new roads or trails, vegetation clearing, or collection of plants or animals</i> Options: a. Leave as listed in Draft 2 (above), b. Modify the item to improve clarity and remove bicycles: <i>Passive Outdoor Activities.</i> <i>In accordance with 19.70.040(B) above, and when there will be no adverse effect, the following activities are allowed within critical areas and their buffers: educational activities, scientific research, and outdoor recreational activities, including but not limited to interpretive field trips, bird watching, public beach access including water-related activities, and hiking. This exemption does not include constructing new facilities, vegetation clearing, or collection of plants or animals.</i> c. Scrap the language in Draft 2 all together and revert back to the terms as listed in the current Critical Area Regulations under 17.70.380(B) Uses By Right.
Staff Recommendation	Due to the high number of comments and concerns with changes in Draft 2 using the words passive recreation and bicycling, staff recommends (option c.) reverting back to the wording of the Current Regulations under 17.70.380(B), thereby eliminating any changes to the allowed uses by right in critical areas or buffers. Exemption to read: <i>Provided they do not require structures, grading, fill, draining, or dredging except as provided herein or authorized by a Critical Area Permit: Outdoor recreational activities, including fishing, birdwatching, hiking, boating, horseback riding, swimming, canoeing, and similar activities with limited environmental impact are exempt activities.</i>
Table 19.70.050 Permitted Alterations	<i>Change requested by Staff:</i> Change the title “Public Services” to “Public Roads and Utilities” for clarity. Options: a. Keep the title as is, b. Change the title to Public Roads and Utilities.
Staff Recommendation	Staff recommends (option b.) providing additional clarity by changing the title and incorporating necessary language to read: <i>Public Roads and Utilities.</i> <i>To allow public improvements, when the strict application of the standards in this Chapter would otherwise unreasonably prohibit the provision of public amenities...</i>
Table 19.70.050 Permitted Alterations	<i>Change requested by Dept. of Ecology:</i> Permitted Alterations Table, Public Services: We recommend adding the following as #3: ○ It shall be a condition of any alteration granted a public agency and services exception that only the portion of the alteration that must be located in a critical area may be so located. Current Language:

AMC Reference	Recommended Change
	Public Services. <i>To allow development by a public agency when the strict application of the standards in this Chapter would otherwise unreasonably prohibit the provision of public amenities.</i> 1. <i>Public agency and services defined. For the purposes of this subsection, "public agency" means any agency, political subdivision, or unit of local government, or private utility regulated by the Washington Utilities and Transportation Commission, including, but not limited to, municipal corporations, special purpose districts and local service districts, private regulated utilities, any agency of the state of Washington, the United States or any state thereof, or any Indian tribe recognized as such by the federal government. "Public services" include, but are not limited to, water supply, sewer and stormwater management facility, electric power, telephone, cable television, gas, and transportation for persons and freight.</i> 2. <i>Public services may be allowed to alter critical areas and buffers when:</i> a. <i>Mitigation sequencing per AMC 19.70.135(A) has been applied;</i> b. <i>The application of the critical areas regulations would unreasonably restrict the ability of the public agency to provide public services;</i> c. <i>There is no other practical alternative to the proposed development with less impact on the critical area;</i> d. <i>The proposed development does not create a health or safety hazard on or off the development site, and will not be detrimental to the properties or improvements in the vicinity;</i> e. <i>Any alterations permitted to the critical area are mitigated in accordance with AMC 19.70.135 and relevant mitigation standards for the impacted critical areas(s) type;</i> f. <i>The proposal is consistent with the Anacortes Comprehensive Plan and other applicable regulations.</i> g. <i>Conditions authorized. Conditions may be established as necessary to mitigate impacts to critical areas and to conform to the standards required in this Chapter.</i> Options: a. Keep the item as is, b. Change the provision to incorporate Ecology's recommendation.
Staff Recommendation	Staff recommends adding the following item #3 to the above section: 3. <i>It will be a condition of any alteration granted a public agency and services exception that only the portion of the alteration that must be located in a critical area may be so located.</i>
Table 19.70.050, Permitted Alterations	<i>Change Requested by Staff and Dept. of Ecology:</i> The following minor changes are requested to the Recreation Areas/Facilities provision: 1. Remove ACFL from this section and create a new section in the Permitted Use table, 2. Add the language "including but not limited to", 3. Add: Non-treated wood should also be used for information signs. (Ecology) 4. Add the missing language of D from 17.70.380. Options: a. Leave current draft language with no change, b. Approve all changes as suggested below,

AMC Reference	Recommended Change						
	c. Approve some of the changes as directed by PC.						
Staff Recommendation	Staff recommends (option b.) the all of following changes: <table><tr><th>Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)</th><th>Critical Area</th><th>Buffer</th></tr><tr><td> Recreational Areas / Facilities <u>outside of ACFL</u> Low impact activities which are consistent with the purpose and function of the critical area buffer and do not detract from its integrity may be permitted within the buffer depending on the sensitivity of the critical area. A. Limited public park or public recreational access including <u>but not limited to</u> trails, viewing platforms, fishing access (no wider than 6 foot), and foot bridges, provided that all of the following are satisfied: a. The area/facility is part of a public park that is dependent on its location for recreational function; and b. The area/facility is limited to the minimum necessary to accomplish the recreational function; and c. The removal of trees and native vegetation is minimized; and d. The balance of the development is consistent with other requirements of this chapter; and e. The project is identified in the Anacortes Comprehensive Plan or Parks <u>Comprehensive Plan, and ACFL Master Plans.</u> B. Private pedestrian walkways and public trails must meet the following standards: a. The trail is generally parallel to the perimeter of the critical area; b. The trail is located in the outer 25% of the buffer area and is designated to avoid removal of s trees and native vegetation; c. The trail does not exceed 6 feet in width, and is limited to native soils or pervious surfaces. Raised boardwalks utilizing non-treated pilings may be acceptable; and The trail may be subject to closure during critical spawning, migration or breeding time periods of sensitive species that are present. C. Informational signs. Construction and placement of informational signs or educational demonstration facilities no more than 9 square feet surface area and 4 feet high, as long as there is no permanent infringement on hydrology or stream flow <u>and non-treated wood is used;</u> D. Limited excavating and filling necessary for the repair and maintenance of piers, walkways, observation decks, wildlife management shelters, boathouses, and other similar water related structures, provided they are built on pilings to allow unobstructed flow of water and preserve <u>the natural contour of the wetland, except as authorized by a Critical Area Variance.</u> </td><td>No</td><td>Yes</td></tr></table>	Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)	Critical Area	Buffer	Recreational Areas / Facilities <u>outside of ACFL</u> Low impact activities which are consistent with the purpose and function of the critical area buffer and do not detract from its integrity may be permitted within the buffer depending on the sensitivity of the critical area. A. Limited public park or public recreational access including <u>but not limited to</u> trails, viewing platforms, fishing access (no wider than 6 foot), and foot bridges, provided that all of the following are satisfied: a. The area/facility is part of a public park that is dependent on its location for recreational function; and b. The area/facility is limited to the minimum necessary to accomplish the recreational function; and c. The removal of trees and native vegetation is minimized; and d. The balance of the development is consistent with other requirements of this chapter; and e. The project is identified in the Anacortes Comprehensive Plan or Parks <u>Comprehensive Plan, and ACFL Master Plans.</u> B. Private pedestrian walkways and public trails must meet the following standards: a. The trail is generally parallel to the perimeter of the critical area; b. The trail is located in the outer 25% of the buffer area and is designated to avoid removal of s trees and native vegetation; c. The trail does not exceed 6 feet in width, and is limited to native soils or pervious surfaces. Raised boardwalks utilizing non-treated pilings may be acceptable; and The trail may be subject to closure during critical spawning, migration or breeding time periods of sensitive species that are present. C. Informational signs. Construction and placement of informational signs or educational demonstration facilities no more than 9 square feet surface area and 4 feet high, as long as there is no permanent infringement on hydrology or stream flow <u>and non-treated wood is used;</u> D. Limited excavating and filling necessary for the repair and maintenance of piers, walkways, observation decks, wildlife management shelters, boathouses, and other similar water related structures, provided they are built on pilings to allow unobstructed flow of water and preserve <u>the natural contour of the wetland, except as authorized by a Critical Area Variance.</u>	No	Yes
Permitted Alterations: (Critical Area Permit Required – Type 2 Administrative Decision)	Critical Area	Buffer					
Recreational Areas / Facilities <u>outside of ACFL</u> Low impact activities which are consistent with the purpose and function of the critical area buffer and do not detract from its integrity may be permitted within the buffer depending on the sensitivity of the critical area. A. Limited public park or public recreational access including <u>but not limited to</u> trails, viewing platforms, fishing access (no wider than 6 foot), and foot bridges, provided that all of the following are satisfied: a. The area/facility is part of a public park that is dependent on its location for recreational function; and b. The area/facility is limited to the minimum necessary to accomplish the recreational function; and c. The removal of trees and native vegetation is minimized; and d. The balance of the development is consistent with other requirements of this chapter; and e. The project is identified in the Anacortes Comprehensive Plan or Parks <u>Comprehensive Plan, and ACFL Master Plans.</u> B. Private pedestrian walkways and public trails must meet the following standards: a. The trail is generally parallel to the perimeter of the critical area; b. The trail is located in the outer 25% of the buffer area and is designated to avoid removal of s trees and native vegetation; c. The trail does not exceed 6 feet in width, and is limited to native soils or pervious surfaces. Raised boardwalks utilizing non-treated pilings may be acceptable; and The trail may be subject to closure during critical spawning, migration or breeding time periods of sensitive species that are present. C. Informational signs. Construction and placement of informational signs or educational demonstration facilities no more than 9 square feet surface area and 4 feet high, as long as there is no permanent infringement on hydrology or stream flow <u>and non-treated wood is used;</u> D. Limited excavating and filling necessary for the repair and maintenance of piers, walkways, observation decks, wildlife management shelters, boathouses, and other similar water related structures, provided they are built on pilings to allow unobstructed flow of water and preserve <u>the natural contour of the wetland, except as authorized by a Critical Area Variance.</u>	No	Yes					
Table 19.70.050, Permitted Alterations	Change Requested by Staff and Public comment: Staff recommends a new Permitted Alterations Table item for the ACFL to differentiate activities in the ACFL separate from other critical areas and buffers. This will give the ACFL its very own provisions under the Critical Area Permitted Alteration Permit. Options:						

AMC Reference	Recommended Change					
	a. Leaving Recreational Facilities/Areas in the ACFL as is in the current draft language (above without changes and changing the Critical Area designation to “Yes”), b. Give the ACFL its own designation in the Permitted Use Table.					
Staff Recommendation	Staff recommends (option b.) and the following addition to specify requirements for the ACFL:					
	<table><tr><td>Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes Comprehensive Plan, The ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and the newly created AMC 12.18 ACFL.</td><td>Yes</td><td>Yes</td></tr></table>	Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes Comprehensive Plan, The ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and the newly created AMC 12.18 ACFL.	Yes	Yes		
Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes Comprehensive Plan, The ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and the newly created AMC 12.18 ACFL.	Yes	Yes				
Table 19.70.050, Permitted Alterations	<i>Change Requested by Staff:</i> To make sure the code works administratively the provision for Regulated Activities in Critical Aquifer Recharge Areas needs to be incorporated into the Permitted Alterations table. Options: This is a necessary correction					
Staff Recommendation	Staff recommends the following addition to specify requirements for CARA's:					
	<table><tr><td>Regulated Activities in Critical Aquafer Recharge Areas. All regulated activities listed under AMC 19.70.540.</td><td>Yes</td><td>N/A</td></tr></table>	Regulated Activities in Critical Aquafer Recharge Areas. All regulated activities listed under AMC 19.70.540.	Yes	N/A		
Regulated Activities in Critical Aquafer Recharge Areas. All regulated activities listed under AMC 19.70.540.	Yes	N/A				
19.70.210, Wetland Designation	<i>Change requested by Public Comment:</i> Because section 17.70.230(D) was removed eliminating special protections for Regionally and Locally significant wetlands; the public is requesting that we put this section back into the Critical Area Code. Options: a. Leave the draft as is without Regionally/Locally Significant Wetlands, b. Put the section back in exactly as it was in 17.70.230(D), c. Add the provision back in with modified requirements.					
Staff Recommendation	Staff suggests (option c.) and the following language be added to 19.70.210(C) for the designation of Regionally Significant wetlands.					
	<i>C. Regionally Significant Wetlands. The following are automatically designated as Category I wetlands regardless of Rating and shall have a designated buffer per the rating system but in no case less than 110 feet pursuant to 19.70.250 Required Buffer areas:</i> 1. Cannery Pond (West of the State Ferry Terminal) 2. Ship Harbor Interpretive Preserve (East of the State Ferry Terminal),					

AMC Reference	Recommended Change
	3. Any other regulated Category II wetland, as rated under subsection (B)(2) of this section, that is within the watersheds of Little Cranberry Lake, Whistle Lake and Heart Lake and that drains by natural seasonal surface water connection into those lakes or their upstream associated wetland systems. D. Locally Significant wetlands. The following wetlands are designated as Category II wetlands regardless of Rating: 1. The wetlands on or adjacent to the Port of Anacortes owned property at the Anacortes Airport. Buffers shall conform to the Memorandum of Understanding between the Port and the City until the expiration of the Agreement.
19.70.240 Wetlands – Specific Wetland Category Development Standard	<i>Change requested by Dept of Ecology.</i> 19.70.240.B.3: The small wetland exemption should be applied to Category IV wetlands only. The draft language includes Category III wetlands. Paragraph 3.d should read, "The wetland is a low quality Category IV wetland with a habitat score of less than 6 points in the adopted rating system. Also "hydrologically isolated" should be replaced with "non-federally regulated," and this definition should be included: ○ Non-federally Regulated (formerly isolated) Wetland – A wetland that is determined by the United States Army Corps of Engineers (USACE) to not qualify as a Water of the United States. Non-federally regulated wetlands may perform important functions and are protected by state law (RCW 90.48) whether or not they are protected by federal law. Current Language: 3. <i>Small, Hydrologically Isolated Category III and IV Wetlands (less than 1,000 sq. ft.). The Decision maker may allow small, hydrologically isolated Category III and IV wetlands to be exempt from the requirement to avoid impacts (AMC 19.70.135(A)(1) Mitigation requirements) and allow alteration of such wetlands if all of the following conditions are met:</i> a. <i>The remaining mitigation sequencing actions of AMC 19.70.135(A) (2)-(6) are followed;</i> b. <i>The wetland is less than 1,000 square feet in area;</i> c. <i>The wetland does not have unique characteristics that would be difficult to replace through standard compensatory mitigation practices.</i> d. <i>The wetland is a low quality Category III or IV wetland with a habitat score of less than 5 points in the adopted rating system;</i> e. <i>The wetland does not provide significant suitable breeding habitat for native amphibian species. Suitable breeding habitat may be indicated by adequate stable and seasonal inundation that is persistent from February to at least through April and presence of thin-stemmed emergent vegetation and/or clean water;</i> f. <i>The wetland does not contain habitat identified as essential for local populations of priority species identified by the Washington Department of Fish and Wildlife or species of local importance which are regulated as fish and wildlife habitat conservation areas in Chapter 19.70.300 (FWHCA section);</i> g. <i>The wetland is not associated with shorelines of the state or their associated buffers;</i> h. <i>The wetland is not associated with riparian areas or buffers;</i> i. <i>The wetland is not part of a wetland mosaic; and</i> j. <i>A mitigation plan to replace lost wetland functions and values is developed, approved, and implemented consistent with AMC 19.70.140.</i>

AMC Reference	Recommended Change
	<i>k. In order to verify that the wetland meets these exemption conditions, a critical area report for wetlands meeting the requirements in this chapter must be submitted.</i> Options: a. Leave the designation of isolated wetlands as is in Draft 2, b. Incorporate the recommendations of Ecology.
Staff Recommendation	Staff recommends (option b.) to drop Category III wetlands and incorporate their suggested language to read: 3. <i>Small, Hydrologically Isolated Category IV Wetlands (less than 1,000 sq. ft.). The Decision maker may allow small, hydrologically isolated Category III and IV wetlands to be exempt from the requirement to avoid impacts (AMC 19.70.135(A)(1) Mitigation requirements) and allow alteration of such wetlands if all of the following conditions are met:</i> <i>a. The remaining mitigation sequencing actions of AMC 19.70.135(A) (2)-(6) are followed;</i> <i>b. The wetland is less than 1,000 square feet in area;</i> <i>c. The wetland does not have unique characteristics that would be difficult to replace through standard compensatory mitigation practices.</i> <i>d. The wetland is a low quality Category IV wetland with a habitat score of less than 6 points in the adopted rating system;</i> <i>e. The wetland does not provide significant suitable breeding habitat for native amphibian species. Suitable breeding habitat may be indicated by adequate stable and seasonal inundation that is persistent from February to at least through April and presence of thin-stemmed emergent vegetation and/or clean water;</i> <i>f. The wetland does not contain habitat identified as essential for local populations of priority species identified by the Washington Department of Fish and Wildlife or species of local importance which are regulated as fish and wildlife habitat conservation areas in Chapter 19.70.300 (FWHCA section);</i> <i>g. The wetland is not associated with shorelines of the state or their associated buffers;</i> <i>h. The wetland is not associated with riparian areas or buffers;</i> <i>i. The wetland is not part of a wetland mosaic; and</i> <i>j. A mitigation plan to replace lost wetland functions and values is developed, approved, and implemented consistent with AMC 19.70.140.</i> <i>k. In order to verify that the wetland meets these exemption conditions, a critical area report for wetlands meeting the requirements in this chapter must be submitted.</i>
Wetland Buffers Tables 19.70.250	<i>Change requested by Dept. of Ecology:</i> Ecology has recommended a few changes to the Wetland buffer tables, this will allow our Land Use Intensity approach to match the Ecology Buffer Recommendations. Options: a. Revert our buffer table back to those shown in the current code in 17.70.340(1), and incorporate the updated habitat score numbers, b. Adopt the buffer tables as currently shown in Draft 2,

AMC Reference	Recommended Change																																																																								
	c. Keep the Land Use Intensity approach but modify the numbers as recommended by Ecology.																																																																								
Staff Recommendation	Staff feels the Land Use Intensity approach is a better method for the City of Anacortes and recommends (option c.) by changing the buffer numbers as such: 1. Buffer Widths for wetlands that have a high level of function for wildlife habitat as indicated by a habitat function score of 8 or 9 points or more on the wetland rating form: Table 19.70.250 (B). <table><tr><th>Wetland Category</th><th colspan="3">Buffer Width (feet)</th></tr><tr><th></th><th>High Intensity</th><th>Moderate Intensity</th><th>Low Intensity</th></tr><tr><td>Category I</td><td>200 300</td><td>190 225</td><td>150 150</td></tr><tr><td>Category II</td><td>200 300</td><td>150 225</td><td>100 150</td></tr><tr><td>Category III</td><td>150</td><td>110</td><td>75</td></tr><tr><td>Category IV</td><td>50</td><td>40</td><td>25</td></tr></table> 2. Buffer Widths for wetlands that have a moderate level of function for wildlife habitat as indicated by a habitat function score of 6 or 7 points or more on the wetland rating form: Table 19.70.250 I. <table><tr><th>Wetland Category</th><th colspan="3">Buffer Width (feet)</th></tr><tr><th></th><th>High Intensity</th><th>Moderate Intensity</th><th>Low Intensity</th></tr><tr><td>Category I</td><td>150</td><td>110</td><td>75</td></tr><tr><td>Category II</td><td>150</td><td>110</td><td>75</td></tr><tr><td>Category III</td><td>150</td><td>100-110</td><td>60-75</td></tr><tr><td>Category IV</td><td>50</td><td>40</td><td>25</td></tr></table> 3. Buffer Widths for wetlands that have a low level of function for wildlife habitat as indicated by a habitat function score of 3 to 5 points or more on the wetland rating form: Table 19.70.250 (D). <table><tr><th>Wetland Category</th><th colspan="3">Buffer Width (feet)</th></tr><tr><th></th><th>High Intensity</th><th>Moderate Intensity</th><th>Low Intensity</th></tr><tr><td>Category I</td><td>100</td><td>75</td><td>50</td></tr><tr><td>Category II</td><td>100</td><td>75</td><td>50</td></tr><tr><td>Category III</td><td>80</td><td>60</td><td>50-40</td></tr><tr><td>Category IV</td><td>50</td><td>40</td><td>25</td></tr></table>	Wetland Category	Buffer Width (feet)				High Intensity	Moderate Intensity	Low Intensity	Category I	200 300	190 225	150 150	Category II	200 300	150 225	100 150	Category III	150	110	75	Category IV	50	40	25	Wetland Category	Buffer Width (feet)				High Intensity	Moderate Intensity	Low Intensity	Category I	150	110	75	Category II	150	110	75	Category III	150	100-110	60-75	Category IV	50	40	25	Wetland Category	Buffer Width (feet)				High Intensity	Moderate Intensity	Low Intensity	Category I	100	75	50	Category II	100	75	50	Category III	80	60	50-40	Category IV	50	40	25
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Wetland Buffers 19.70.250	<i>Change requested by Dept. of Ecology and Public Comment:</i> The public has requested we look at encouraging habitat corridors for wildlife. Ecology: Here is some language regarding buffer reductions that you might want to consider in order to provide more flexibility for applicants and to incentivize low-impact development practices. (see below) Options:																																																																								

AMC Reference	Recommended Change				
	a. Keep Draft 2 buffer tables as proposed. b. Incorporate the recommendation from Ecology to allow smaller buffers for people who install wetland protection measures.				
Staff Recommendation	Staff agrees with Ecology that incentivizing buffer improvements is a good idea. Smaller high functioning buffers are better for critical areas than bigger low functioning buffers. We recommend incorporating Ecology's recommendation to read: 1. For wetlands that score 6 points or more for habitat function, buffer widths for high intensity may be reduced to moderate intensity if both of the following criteria are met: a. A relatively undisturbed, vegetated corridor at least 100 feet wide is protected between the wetland and any other relatively undisturbed area, as defined in the 2014 wetland rating system, or any other Priority Habitat as defined by the Washington State Department of Fish and Wildlife. The latest definitions of Priority Habitats and their locations are available on the WDFW web site at: http://wdfw.wa.gov/hab/phshabs.htm). The corridor must be protected for the entire distance between the wetland and the relatively undisturbed area or Priority Habitat by some type of legal protection such as a conservation easement. Presence or absence of a nearby habitat must be confirmed by a qualified biologist. b. The measures in Table XX are implemented, where applicable, to minimize the impacts of the adjacent land uses. 2. For wetlands that score 3-5 habitat points, only the measures in Table XX are required for the use of moderate intensity buffer widths. 3. If an applicant chooses not to apply the mitigation measures in Table XX, or is unable to provide a protected corridor where available, then high intensity buffer widths must be used. Table XX Required measures to minimize impacts to wetlands (All measures are required if applicable to a specific proposal) <table border="1"> <thead> <tr> <th>Disturbance</th><th>Required Measures to Minimize Impacts</th></tr> </thead> <tbody> <tr> <td>Lights</td><td> - Direct lights away from wetland </td></tr> </tbody> </table>	Disturbance	Required Measures to Minimize Impacts	Lights	Direct lights away from wetland
Disturbance	Required Measures to Minimize Impacts				
Lights	Direct lights away from wetland				

AMC Reference	Recommended Change	
	Noise	• Locate activity that generates noise away from wetland • If warranted, enhance existing buffer with native vegetation plantings adjacent to noise source • For activities that generate relatively continuous, potentially disruptive noise, such as certain heavy industry or mining, establish an additional 10' heavily vegetated buffer strip immediately adjacent to the outer wetland buffer
	Toxic runoff	• Route all new, untreated runoff away from wetland while ensuring wetland is not dewatered • Establish covenants limiting use of pesticides within 150 ft of wetland • Apply integrated pest management
	Stormwater runoff	• Retrofit stormwater detention and treatment for roads and existing adjacent development • Prevent channelized flow from lawns that directly enters the buffer • Use Low Intensity Development techniques (for more information refer to the stormwater manual)
	Change in water regime (increase or decrease in the frequency, duration, timing, extent, depth or variability of water in a wetland)	• Infiltrate or treat, detain, and disperse into buffer new runoff from impervious surfaces and new lawns
	Pets and human disturbance	• Use privacy fencing OR plant dense vegetation to delineate buffer edge and to discourage disturbance using vegetation appropriate for the ecoregion • Place wetland and its buffer in a separate tract or protect with a conservation easement
	Dust	• Use best management practices to control dust
19.70.350, FWHCA - Specific Standards	<i>Change requested by Public Comment:</i> The public has been concerned with the removal of the introduction regarding the ACFL. One public comment received was to add a statement to the code to give some context of the importance of the ACFL: <i>The Anacortes Community Forest Lands include three lakes and their watersheds, numerous wetlands, rock bluffs, old growth forests, grassy knolls, windswept hilltops, sheltered caves, and a variety of other habitats and microclimates that provide a unique and irreplaceable habitat for both imperiled and commonplace species.</i> Options: - Leave the ACFL Language as is in Draft 2, - Replace the Introduction as an appendix in the end of the code section, - Add a purpose statement to the ACFL section to give proper context.	

AMC Reference	Recommended Change
Staff Recommendation	Staff agrees that context would be helpful and recommends (Option c.) by adding a purpose statement to 19.70.350(C)(1) to read: <i>Purpose. The Anacortes Community Forest Lands include three lakes and their watersheds, numerous wetlands, rock bluffs, old growth forests, grassy knolls, windswept hilltops, sheltered caves, and a variety of other habitats and microclimates that provide a unique and irreplaceable habitat for both imperiled and commonplace species. This land has been dedicated by the City for the preservation of forest lands and species, as described in the Conservation Easement documents, the ACFL Comprehensive Plan, and in the newly created Anacortes Municipal Code Title 12.</i>
19.70.350, FWHCA - Specific Standards	<i>Changes requested by Staff and the Skagit Land Trust:</i> To keep formatting consistent we propose adding a purpose statement to (C)(2) of this section, March Point Heronry (using existing language in subsection a.) and revisions to the specific standards as recommended by the Skagit Land Trust based on Best Available Science and local knowledge of the habitat needs. Current Language: <i>C.2. March Point Heronry</i> <i>a. Because Skagit County is home to the greatest concentration of nesting Great Blue Heron in the Salish Sea, March Point being the largest, the City has identified the March Point Heronry as a habitat of local importance.</i> <i>b. Proposed development activities within 1,000 feet, or that is likely to impact the colony, must provide a critical areas assessment report and habitat management plan that follows at a minimum the guidelines provided by WDFW's Management Recommendations for Washington's Priority Species (March 2012). https://wdfw.wa.gov/publications/00026/abbreviated_great_blue_heron.pdf.</i> <i>c. Buffers will be implemented as described in the buffer section below.</i> <i>d. Colony protection is required for minimum 10-years after abandonment.</i> Options: This is a necessary correction
Staff Recommendation	Staff recommends the subsection read as follows: <i>C.2. March Point Heronry</i> <i>Purpose. Because Skagit County is home to the greatest concentration of nesting Great Blue Heron in the Salish Sea, March Point being the largest, the City has identified the March Point Heronry as a habitat of local importance.</i> <i>a. Proposed development activities within the 1,000 foot management zone, or that are likely to impact the colony, must provide a critical areas assessment report and habitat management plan that follows at a minimum the guidelines provided by WDFW's Management Recommendations for Washington's Priority Species (March 2012).</i> <i>b. Buffers will be implemented as described in the buffer section below.</i>

AMC Reference	Recommended Change
	<i>c. Colony protection is required for minimum 10-years after abandonment.</i>
19.70.350	<i>Changes requested by Skagit Land Trust:</i> Because the management recommendations were interpreted incorrectly, and because an error was found in the WDFW Recommendations the Skagit Land Trust requests the following changes to the Heron buffers. Current Language: <i>Great Blue Heron nesting and breeding areas: Development near a verified heron breeding habitat including nesting colony areas, former nesting colonies, pre-nesting staging areas, and breeding season foraging habitat require:</i> <i>i. A year-round urban buffer of 197 feet,</i> <i>ii. For unusually load activities that occur during breeding season (February – September) a seasonal buffer of 656 feet, and a Blasting buffer of 3,280 feet.</i> <i>iii. A management plan developed by a qualified professional to follow, at a minimum, WDFW’s Management Recommendations for Washington’s Priority Species (March 2012).</i> Options: This is a necessary correction
Staff Recommendation	Staff recommends the section read as follows: <i>Great Blue Heron nesting and breeding areas: Development near a verified heron breeding habitat including nesting colony areas, and former nesting colonies:</i> <i>i. A year-round urban buffer of 197 feet,</i> <i>ii. For unusually loud activities that occur during breeding season (February – September) a seasonal buffer of 656 feet, and a Blasting/Extreme noise buffer of 1,320 feet.</i> <i>iv. A management plan developed by a qualified professional to follow, at a minimum, WDFW’s Management Recommendations for Washington’s Priority Species (March 2012) and that identifies the nesting and breeding site as well as pre-nesting staging areas, and breeding season foraging habitat.</i> <i>v. For the March’s Point Colony, given the observed and documented sensitivity of this mega-colony to human intrusion and the fact that the colony is in a rare, isolated but tight location, a year-round buffer of 984 feet.</i>
Title 12.18	<i>Change requested by Public Comment:</i> The community has expressed concern with the loss of Appendix B language describing the history and acquisition of the Anacortes Community Forest Lands. A suggestion to add an additional section or chapter of an ACFL specific municipal code was received during the public comment period. Options: a. Leave Draft 2 as is utilizing the current ACFL provisions, b. Add the Addendum back into Draft 2,

AMC Reference	Recommended Change
	c. Create a new chapter for the ACFL in the Anacortes Municipal Code.
Staff Recommendation	Staff recommends adding a section to Title 12, under AMC 12.19 where detailed information about the Anacortes Community Forest Lands can go with Appendix B.

From: [Bruce Baglien](#)
To: [Cooper, Tess](#)
Subject: Landslide areas along the Guemes Channel trail
Date: Thursday, March 18, 2021 10:56:10 AM

To whom it may concern,

It appears that the known landslide areas along the paved portion of the Guemes Trail have not been noted in the Geological map. Why is it not noted? Clearly, the housing project that was built above the trail has done damage to the stability of the slope that is very unstable. It should also be noted that the city has had to spend enough money on the problems caused by this housing project and the continual cutting of trees holding the cliff back.

The professional geotechnical engineering study noted these problems. It was also noted there were problems along this portion of the trail related to sea-level rise. These issues should be taken into consideration when it has impacted the city budget as it has.

Sincerely,

Bruce Baglien
brucebaglien@msn.com
1303 Seventh Street
Anacortes, WA 98221
USA
M 360 202-0856

From: [tom.flanagan](#)
To: [Cooper, Tess](#)
Subject: Notice of Availability and Open Comment Period
Date: Wednesday, March 17, 2021 8:21:33 PM

In the “Current Draft 3 Documents” published today is the above mentioned Notice. The Notice is dated 3/17/2021 and states that comments must be submitted **on or before 5 PM March 17, 2021**. Likely an inadvertent error as elsewhere it says March 31. The Public Hearing date of April 12 is presumed to be accurate. A response is needed only if the latter date is different. Thanks so much, Kathleen Lorence-Flanagan

From: [Neil O'Hara](#)
To: [Cooper, Tess](#)
Subject: SHIP wetland rating
Date: Friday, April 9, 2021 2:39:41 PM

Dear Tess,

As you may recall from the comments I made on Draft 2 of the CAO, I have a particular interest in SHIP.

In January 2020, I understood that the Department of Ecology had given SHIP a habitat score of 8 and a total score of 23. By that yardstick, SHIP would remain a Category I wetland under the revised CAO and enjoy an enlarged buffer thanks to the high habitat score.

Would you please confirm my understanding? If possible, I would like to see a copy of the Ecology report.

Best regards,

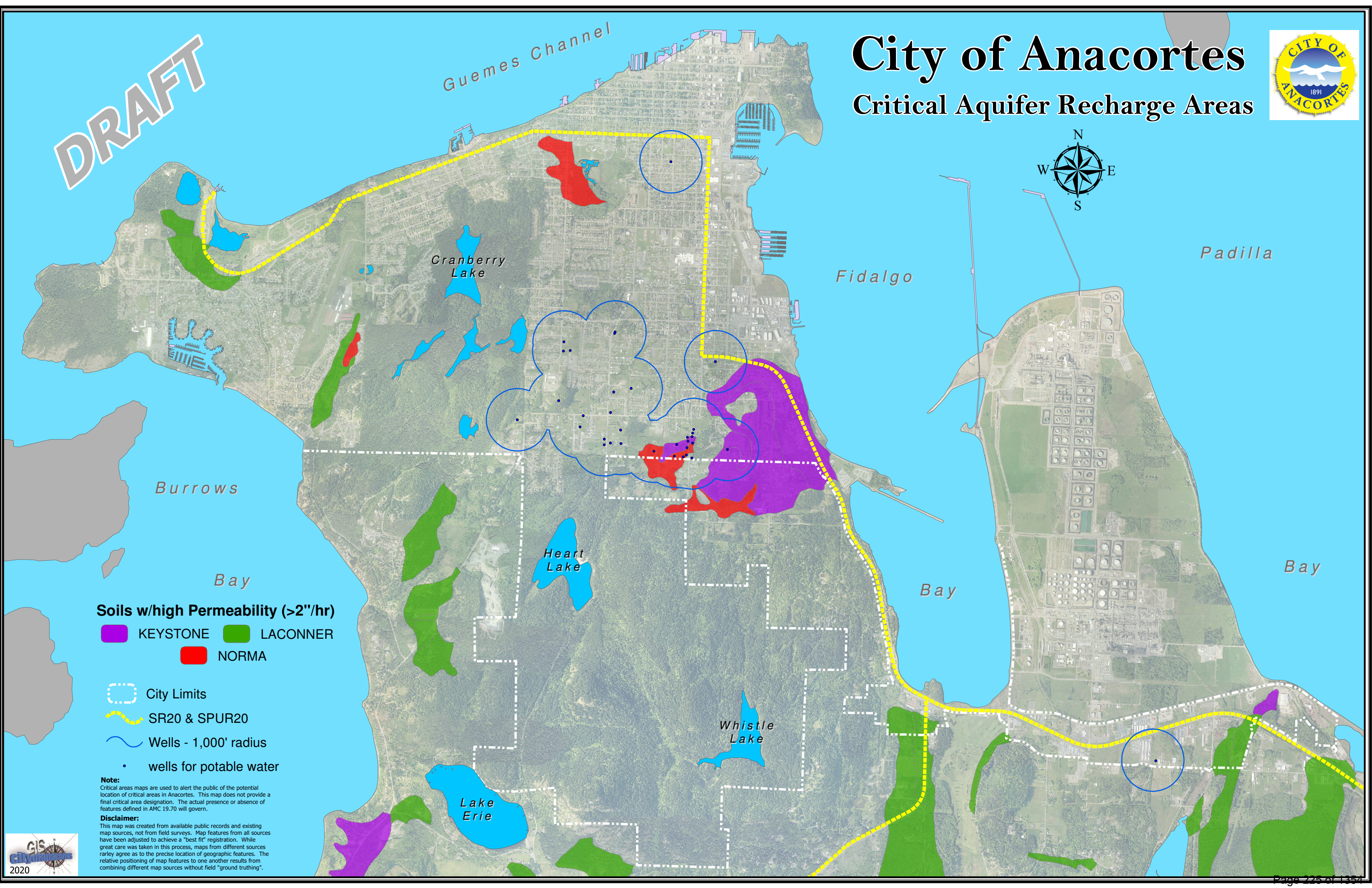
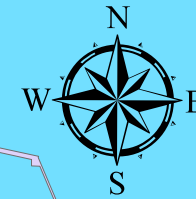
Neil A. O'Hara
4407 Anaco Beach Place
Anacortes, WA 98221-8767

Tel: 781-290-9083

DRAFT

City of Anacortes

Critical Aquifer Recharge Areas



Soils w/high Permeability (>2"/hr)

- KEYSTONE
- LACONNER
- NORMA

City Limits

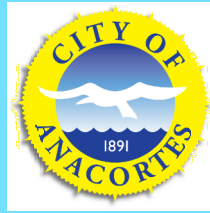
SR20 & SPUR20

Wells - 1,000' radius

wells for potable water

Note:
Critical areas maps are used to alert the public of the potential location of critical areas in Anacortes. This map does not provide a final critical area designation. The actual presence or absence of features defined in AMC 19.70 will govern.

Disclaimer:
This map was created from available public records and existing map sources, not from field surveys. Map features from all sources have been adjusted to achieve a "best fit" registration. While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. The relative positioning of map features to one another results from combining different map sources without field "ground truthing".

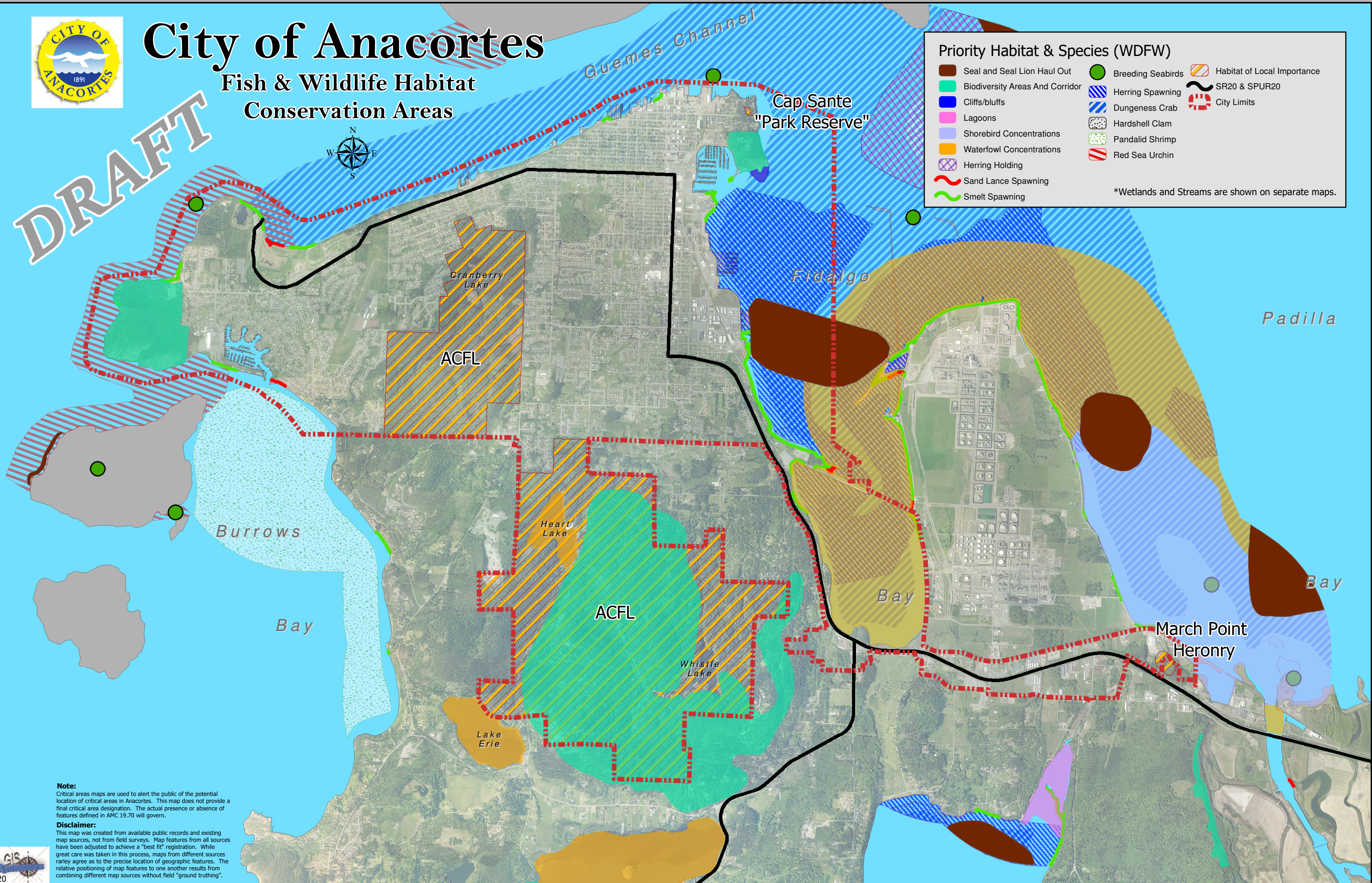


City of Anacortes

Fish & Wildlife Habitat Conservation Areas



DRAFT



Priority Habitat & Species (WDFW)

Seal and Seal Lion Haul Out	Breeding Seabirds	Habitat of Local Importance
Biodiversity Areas And Corridor	Herring Spawning	SR20 & SPUR20
Cliffs/bluffs	Dungeness Crab	City Limits
Lagoons	Hardshell Clam	
Shorebird Concentrations	Pandalid Shrimp	
Waterfowl Concentrations	Red Sea Urchin	
Herring Holding		
Sand Lance Spawning		
Smelt Spawning		

*Wetlands and Streams are shown on separate maps.

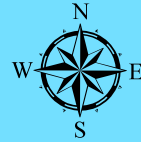
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City of Anacortes

Geologically Hazardous Areas



DRAFT

Guemes Channel

Cranberry Lake

Fidalgo

Padilla

Burrows

Bay

Heart Lake

Bay

Bay

Whistle Lake

Lake Erie

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2020

Shoreline Slope Class	
	Intermediate slope
	Modified
	Unstable slope
	Unstable-old slide
	Unstable-recent slide

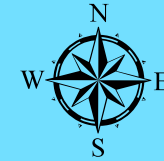
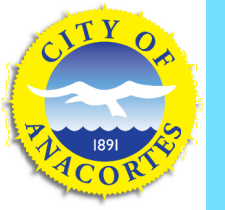
Slopes	
	0 - 15 Percent Slope
	15 - 40 Percent Slope
	Greater than 40 Percent Slope

	Eroding Shoreline
	Erosion Hazard Soils
	Tsunami Hazard Areas
	SR20 & SPUR20
	City Limits

DRAFT

City of Anacortes

Streams



DNR Stream Typing

— F

— N

— Not Classified

— SR20 & SPUR20

--- City Limits

Note:
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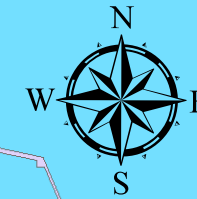


DRAFT

Guemes Channel

City of Anacortes

Wetlands



Padilla

Fidalgo

Burrows

Bay

Bay

Bay

- SR20 & SPUR20
- Delineated Wetlands
- Potential Wetlands
- National Wetland Inventory Wetlands
- City Limits

Note:
Critical areas maps are used to alert the public of the potential location of critical areas in Anacortes. This map does not provide a final critical area designation. The actual presence or absence of features defined in AMC 19.70 will govern.

Disclaimer:
This map was created from available public records and existing map sources, not from field surveys. Map features from all sources have been adjusted to achieve a "best fit" registration. While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. The relative positioning of map features to one another results from combining different map sources without field "ground truthing".

Hunt, Marcia

From: KATHRYN ALEXANDRA <kalexandra@comcast.net>
Sent: Sunday, April 18, 2021 6:22 PM
To: CityClerk
Subject: draft CAO

I am concerned about protecting Anacortes' natural environment. I support Evergreen Islands recommended improvements to the Anacortes CAO, draft three.

sincerely,
Kathryn Alexandra
4311 Ginnett rd
Anacortes, WA 98221

Hunt, Marcia

From: Andrea Doll <andrea.doll@gmail.com>
Sent: Monday, April 19, 2021 2:13 PM
To: CityClerk
Subject: Critical area comments

My name is Andrea Doll
I reside at 1319 8th St.
Anacortes

The intention of the Critical Area Ordinance is to “Protect, maintain and restore healthy, functioning ecosystems through the protection of unique, fragile, and valuable elements of the environment, including, but not limited to wetlands, and fish and wildlife and their habitats, and to conserve the biodiversity of plant and animal species;

But is it?

the draft ordinance offers developers this assurance: “it is not the intent of Chapter to make a parcel of property unusable by denying its owner reasonable economic use of the property..”

The question is: does the ordinance offer EQUAL protection for habitat as it does for property rights?

Through out the CAO draft there are assurances and reassurances: One can skirt environmental restrictions by the use of variances, mitigation and loopholes

Examples:

1. If wetlands are on part of a property the homeowner can encroach on the wetland if it is necessary to add to their residence, i.e. patio, garage
2. If a property has extensive wetlands and streams the developer may build a road through it or relocate a stream in to access a proposed development.
3. A wetland may be filled in for development if a “new wetland” is created elsewhere, the criterion: “no net loss”

People are coming to Anacortes, you can see development every where. It is critical that what we love be protected, not degraded and compromised.

What is YOUR -Anacortes's position. Is it **slogging defense** of the environment or—are you. taking bold steps forward

For example, Are we increasing, not decreasing wet land buffers

Are we inventorying wetlands with an eye to the future

As it stands now:

The CAO as currently written is an invitation to loss, not gain.

I would urge you ,our city council to decide your position, your intent: is it -compromise or bold leadership.

Andrea Doll
1319 8th St.
Anacortes, WA 98221
360 317 4557

Hunt, Marcia

From: Holden, Alexandra
Sent: Monday, April 19, 2021 9:30 AM
To: CityClerk
Cc: Measamer, Don
Subject: Public Comment Mailed to Mayor Gere
Attachments: Munce Critical Areas Public Comment 4.19.pdf

Please see attached for the public comment on the Critical Areas Ordinance mailed to Mayor Gere.



Alexandra Holden, MPA
Executive Assistant to the Mayor
City of Anacortes
904 6th Street & Q Avenue | Anacortes, WA 98221
p: 360-299-1950
alexandrah@cityofanacortes.org | www.anacorteswa.gov

Subject: Critical Area Ordinance Update -Testimony for April 19, 2021 Critical Area Ordinance Public Hearing - Ian S. Munce, AICP

Good day,

1. The City's Comprehensive Plan mandates that the Critical Area Ordinance (CAO) Update "... strengthen regulations to protect sensitive naturel areas..." Attachment A. I respectfully submit that with a few minor edits (that I propose) the CAO Update does just this as to new development projects but takes a major step backward as to property owners who may not want to ever develop but take steps to convert wetland and/or wetland buffer into landscaped areas.

2. The standards that apply to new development projects, in my professional opinion, seem entirely appropriate based on current best available science and best planning practices. I particularly appreciate that the baseline for CAO project review as to wetland category will not include illegal encroachments. However, to ensure that buffer encroachments do not lead to reduced buffer delineations at a later date the CAO needs to explicitly state that a wetlands buffer requirement must be based on the pre-violation habitat condition of the wetland. Attachment B (i).

3. I do think that it is essential that baseline dates are spelled out in 19.70, e.g., for wetlands over 10,000 square feet that baseline date is January 10, 1990 (the effective date of the City's first Wetland Ordinance) and for smaller wetlands is April 14, 1994. I suggest that these dates and other critical area baseline dates are so significant that the opening Goal section should be expanded to read "Goals and Baseline Dates". Attachment B (ii).

4. The wetland map included in the draft ordinance seems to largely track the Wetland District map attached to the 1990 Ordinance. Attachment C. The glaring difference is that the 1990 ordinance applied best availability science and designated, mapped, and protected wetlands over 10,000 square feet and the draft ordinance without explanation recategorizes these as "potential wetlands". The 1990 ordinance quite deliberately placed the onus on the property owner to show that they did not have a wetland and not on the City to pursue complex enforcement actions. The draft CAO simply does not address the structural issue I raised with the City Council last fall (Attachment D) and I thought that staff promised a fix. I do not see such a fix in the draft CAO. The City's use of a 'potential wetland' category and a property owner refusal to allow the City to access their property to determine the category and extent of the wetland and wetland buffers apparently ends the City interest and concern for non-project based wetland protection. Absent a major development proposal, either now or in the future, property owners are placed in a voluntary compliance position. This approach falls far short of what the City Comprehensive Plan, the CAO WAC guidelines, the Growth Management Act mandate.

5. Although the code language of the wetland protection ordinance has been updated since 1990 to the best of my knowledge the 1990 map has never been repealed and is still 'on file' and referenced in the current language of the City Municipal Code. It simply disappears in the proposed new CAO. It should be retained. Attachment B(iii), (iv), and (v). In the alternate the CAO could simply solve the structural problem by specifying that if a property owner denies the

City access for wetland delineation purposes, then the City defaults to Attachment C and takes appropriate enforcement action.

6. Given the Comprehensive plan policies set forth in Attachment A flooding concerns should be expanded to “excess stormwater and/or flooding”, neighbors should be consulted on enforcement actions, and penalties for violations should be mandatory. Attachment B(vi), (vii), and (viii).

7. The recitals in the Ordinance should include key Comprehensive Plan policies cited in Attachment A. Attachment B (ix).

8. Progressive jurisdictions such as Anacortes typically integrate critical area management into their stormwater management programs and this will be essential to achieving the Comprehensive Plan policies set forth in Attachment A. Attachment B (x).

9. Simply assuming that reasonable use variances will be granted and wetlands and wetland buffer will be encroached upon is contrary to the Comprehensive Plan policies set forth in Attachment A. Again, progressive jurisdictions such as Anacortes are putting in place Transfer of Development Rights programs with sufficient incentives to minimize the need for critical area reasonable use variances”. Attachment B (xi).

Ian S. Munce, AICP
1711 Quail Drive
Anacortes, WA 98221
360-333-1646

ATTACHMENT B

PROPOSED EDITS TO JANUARY 2, 2021 DRAFT AMC 19.70 CRITICAL AREA ORDINANCE AND REGULATIONS—Ian Munce, AICP

(i) **Chapter 19.70.235 Wetlands—Required Buffer Areas (A) Buffer Requirements:** Add a #3 “Illegal Modifications. When a violation occurs buffer requirements do not change due to illegal modifications or alterations. A wetlands buffer requirement must be based on the pre-violation habitat condition of the wetland”.

(ii) **Chapter 19.70.010: Expand the heading “Purpose” to “Purpose and Baseline Dates”.**

(iv) **“Wetlands over 10,000 square feet** have been designated, mapped, protected, and regulated since January 15’ 1990 (Ordinance No.2131), geological hazardous areas have been protected and regulated since September 2, 1991 (Ordinance No. 2198), frequently flooded areas protected and regulated since May 19, 2003 (Ordinance No. 2617) and aquifer recharge areas protected and regulated since September 29, 2003 (Ordinance No. 2628). These dates are critical to determinations as to review of new development applications, potential violations, rating categories under 19.70.020, modifications under 19.70.035, exemptions under 19.70.040, and illegal modifications under 19.70.215”.

(iii) **Chapter 19.70.220 Wetlands—Mapping and Delineation (A) Mapping:** Add after the first sentence: “This layer includes the map adopted by Ordinance # 2131, January 15, 1990”. (B) Reference Only: insert at the beginning of the first sentence: “Except for the map adopted by Ordinance # 2131, ... and add at the end of the sentence “through the Annual Development Regulation Amendment process”.

(iv) **Chapter 19.70.020 Identification, classification, and rating of critical areas:** Add after the first sentence “These maps include the map adopted by Ordinance # 2131, January 15, 1990”. Add at the end of the second sentence “except that the map adopted by Ordinance # 2131 actually locates the presence of wetlands over 10,000 square feet”. Add to the final sentence “through the Annual Development Regulation Amendment process”.

(v) **“Chapter 19.70.220 Wetlands—Mapping and Delineation:** Wetlands over 10,000 square feet have been designated, mapped, protected, and regulated since January 15’ 1990 (Ordinance No.2131), geological hazardous areas have been protected and regulated since September 2, 1991 (Ordinance No. 2198), frequently flooded areas protected and regulated since May 19, 2003 (Ordinance No. 2617) and aquifer recharge areas protected and regulated since September 29, 2003 (Ordinance No. 2628). These dates are critical to determinations as to review of new development applications, potential violations, rating categories under 19.70.020, modifications under 19.70.035, exemptions under 19.70.040, and illegal modifications under 19.70.215”.

(vi) **Chapter 19.70.010:** protect not just from “flooding” but from “excess stormwater and/or flooding”.

(vii) **Chapter 19.70.010:** In the current final square remove “or enforcement” from the first sentence and add a second sentence “Neighbors adversely affected by an illegal activity shall be consulted by the City before any final enforcement decision is reached and implemented”.

ATTACHMENT B

(VIII) Chapter 19.70.165 E Penalties: Change the permissive language to mandatory language "...shall be subject" ...".

(IX)) ORDINANCE: Insert Comprehensive Plan Policies from Attachment A.

(x) ORDINANCE: Add a Section 2: "Stormwater Management funds may be used, as appropriate, to implement the Comprehensive Plan critical area policies recited above; this is essential to restoration efforts".

(xi) ORDINANCE: Add a Section 3: "A Transfer of Development Rights program shall be established with sufficient incentives to minimize the need for critical area reasonable use variances".

ATTACHMENT D

From: Ian Munce <ianmunce@gmail.com>

Date: August 20, 2020 at 2:32:09 PM PDT

To: cityclerk@cityofanacortes.org

Cc: Don Measamer <don@cityofanacortes.org>, Tess Cooper <tessc@cityofanacortes.org>

Subject: Public Comment for August 24 Council Meeting Item 5d: "Designating" Critical Areas

Good day, Mayor and City Councilmembers

I apologize for not being clear in my public comments last week.

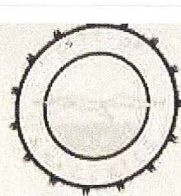
When I said there was a structural problem with the draft ordinance I did not mean a definitional problem as to what constitutes development. I was referring to the practical reality that if a property owner needs a development permit from the City, then they have to meet all ordinance requirements to the satisfaction of City staff. However, if you go forward with a simple "potential wetland" designation then if a property owner asserts that they are just undertaking "pre-1990 maintenance" vegetation removal on a "suspected wetland" and denies City access to the property (pursuant to your current draft section 19.70.170 D) then only an expensive and multi-year court battle can remedy the alleged violation.

This is why I respectfully urge the City Council to retain the current mapped designations for wetlands over 10,000 square feet. This designation was done initially by ordinance in 1990 to give the City immediate enforcement authority over valuable wetlands.

Given this structural problem and the strong environmental protection policies set forth in your Comprehensive Plan you might wish to "designate" key components of other critical areas under consideration on August 24.

Thank you.

Ian Munce, J.D., AICP



CITY OF ANACORTES

WETLAND AREAS



CUENES CHANNEL

FIDALGO

PAGE 1

- BALD EAGLE NEST / HERONY
- PUBLIC LAND / SHORELINE NOT INCLUDED
- SEEP
- STREAMS - 50' BUFFER
- PIPED STREAM

- CATEGORY I WETLAND
 - 225 ft. High level of function for habitat (score for habitat 29 - 36 pts)
 - 110 ft. Moderate level of function for habitat (score for habitat 20 - 28 pts)
 - 75 ft. High level of function for water quality improvement (score 24 - 32 pts) and low for habitat (less than 20 pts)
 - 75 ft. Not meeting above characteristic
- CATEGORY II WETLAND
 - 225 ft. High level of function for habitat (score for habitat 29 - 36 pts)
 - 110 ft. Moderate level of function for habitat (score for habitat 20 - 28 pts)
 - 75 ft. High level of function for water quality improvement (score 24 - 32 pts) and low for habitat (less than 20 pts)
 - 75 ft. Not meeting above characteristic
- CATEGORY III WETLAND
 - 110 ft. Moderate level of function for habitat (score for habitat 20 - 28 pts)
 - 60 ft. Not meeting above characteristic
- CATEGORY IV WETLAND
 - 40 ft. Score for all 3 basic functions is less than 30 pts

BURROWS

BAY

BAY

ACFL

COMPLEX

HOWARD CREEK

COMPLEX

COMPLEX

Hunt, Marcia

From: Rosann Wuebbels <rwuebbels@yahoo.com>
Sent: Monday, April 19, 2021 7:01 AM
To: CityClerk
Subject: Protect anacortes natural enviroment

Dear mayor and city council members,

I support evergreen islands recommended modifications proposal for anacortes critical areas.CAO DRAFT 3

Our natural treasures are our gems and they deserve protection..

Sincerely,

rosann wuebbels and George Reeves

Anacortes wa

[Sent from Yahoo Mail on Android](#)

From: [Ian Munce](#)
To: [Cooper, Tess](#)
Subject: Munce April 19 CAO testimony
Date: Thursday, April 15, 2021 10:22:19 AM
Attachments: [CAO Testimony.docx](#)
[CAO Policies.docx](#)
[19.70.docx](#)
[IMG_0051.pdf](#)
[ATTACHMENT D.docx](#)

Good day, Tess

I mailed hard copies of my CAO testimony for Monday night to the Mayor, individual City Councilmembers, and you (all at the City Hall address).

I now forward an electronic version for your files.

Thank you for your work on this.

Ian

Subject: Critical Area Ordinance Update -Testimony for April 19, 2021 Critical Area Ordinance Public Hearing - Ian S. Munce, AICP

Good day,

1. The City's Comprehensive Plan mandates that the Critical Area Ordinance (CAO) Update "... strengthen regulations to protect sensitive naturel areas..." Attachment A. I respectfully submit that with a few minor edits (that I propose) the CAO Update does just this as to new development projects but takes a major step backward as to property owners who may not want to ever develop but take steps to convert wetland and/or wetland buffer into landscaped areas.

2. The standards that apply to new development projects, in my professional opinion, seem entirely appropriate based on current best available science and best planning practices. I particularly appreciate that the baseline for CAO project review as to wetland category will not include illegal encroachments. However, to ensure that buffer encroachments do not lead to reduced buffer delineations at a later date the CAO needs to explicitly state that a wetlands buffer requirement must be based on the pre-violation habitat condition of the wetland. Attachment B (i).

3. I do think that it is essential that baseline dates are spelled out in 19.70, e.g., for wetlands over 10,000 square feet that baseline date is January 10, 1990 (the effective date of the City's first Wetland Ordinance) and for smaller wetlands is April 14,1994. I suggest that these dates and other critical area baseline dates are so significant that the opening Goal section should be expanded to read "Goals and Baseline Dates". Attachment B (ii).

4. The wetland map included in the draft ordinance seems to largely track the Wetland District map attached to the 1990 Ordinance. Attachment C. The glaring difference is that the 1990 ordinance applied best availability science and designated, mapped, and protected wetlands over 10,000 square feet and the draft ordinance without explanation recategorizes these as "potential wetlands". The 1990 ordinance quite deliberately placed the onus on the property owner to show that they did not have a wetland and not on the City to pursue complex enforcement actions. The draft CAO simply does not address the structural issue I raised with the City Council last fall (Attachment D) and I thought that staff promised a fix. I do not see such a fix in the draft CAO. The City's use of a 'potential wetland' category and a property owner refusal to allow the City to access their property to determine the category and extent of the wetland and wetland buffers apparently ends the City interest and concern for non-project based wetland protection. Absent a major development proposal, either now or in the future, property owners are placed in a voluntary compliance position. This approach falls far short of what the City Comprehensive Plan, the CAO WAC guidelines, the Growth Management Act mandate.

5. Although the code language of the wetland protection ordinance has been updated since 1990 to the best of my knowledge the 1990 map has never been repealed and is still 'on file' and referenced in the current language of the City Municipal Code. It simply disappears in the proposed new CAO. It should be retained. Attachment B(iii), (iv), and (v). In the alternate the CAO could simply solve the structural problem by specifying that if a property owner denies the

City access for wetland delineation purposes, then the City defaults to Attachment C and takes appropriate enforcement action.

6. Given the Comprehensive plan policies set forth in Attachment A flooding concerns should be expanded to “excess stormwater and/or flooding”, neighbors should be consulted on enforcement actions, and penalties for violations should be mandatory. Attachment B(vi), (vii), and (viii).

7. The recitals in the Ordinance should include key Comprehensive Plan policies cited in Attachment A. Attachment B (ix).

8. Progressive jurisdictions such as Anacortes typically integrate critical area management into their stormwater management programs and this will be essential to achieving the Comprehensive Plan policies set forth in Attachment A. Attachment B (x).

9. Simply assuming that reasonable use variances will be granted and wetlands and wetland buffer will be encroached upon is contrary to the Comprehensive Plan policies set forth in Attachment A. Again, progressive jurisdictions such as Anacortes are putting in place Transfer of Development Rights programs with sufficient incentives to minimize the need for critical area reasonable use variances”. Attachment B (xi).

Ian S. Munce, AICP
1711 Quail Drive
Anacortes, WA 98221
360-333-1646

CRITICAL AREA MANDATES

CITY ANACORTES

COMPREHENSIVE PLAN, 2015

ATTACHMENT A

EMPHASIS ADDED IN BOLD

VISION STATEMENT

ANACORTES IS A UNIQUE, CREATIVE, AND CARING MARITIME COMMUNITY THAT ... PROTECTS OUR NATURAL ENVIRONMENT ... FOR FUTURE GENERATIONS

VALUES STATEMENTS/Pursue Environmental Sustainability: embrace a conservation ethic, develop and maintain healthy land and marine ecosystems, and adopt innovative and environmentally sensitive development practices.

Land Use Goal LU-4. Resource protection and sustainable design. Maintain and **strengthen** regulations to protect sensitive natural areas and pursue strategies/actions to **restore** degraded natural areas.

Environment and Conservation Goal EC-1 Environmental protection. Serve as a **leader** in environmental stewardship of the natural environment for current and future generations.

Policy EC-1.2 Work cooperatively with local, state, regional, and federal governments and **community organizations** to protect and **enhance** the environment.

Policy EC-1.8 Use the best available science to preserve or enhance the function and values of critical areas through regulations, programs, and incentives.

Policy EC-3.3 Promote soil stability through **retention of existing vegetation**.

Environment and Conservation Goal EC-4 Water Quality. Protect and **enhance** water quality.

Policy EC-4.1 Work with neighboring jurisdictions, **citizens, and other partners** to maintain and **restore** natural hydrological functions in a drainage basin

Policy EC-4.8 Protect and preserve areas that are critical for aquifer recharge, such as **wetlands**, streams, and water bodies.

Policy EC 4.9 Strive for “no net loss” of wetland acreage, function, and value within each drainage basin over the long term.

Environment and Conservation Goal EC-6. Surface Water. Maintain or improve the functional integrity of watercourses, **wetlands**, bodies of water and their shores.

Policy EC-6.2 Streams and **wetlands should be maintained in their existing natural condition**, or restored where appropriate.

Policy EC-6.5. Place appropriate restrictions on land surface modifications that would cause unnecessarily landscape scarring, hydrology modifications, erosion, or undermining of support of nearby land including, but not limited to, dredging, filling, clearing, paving, and grading.

ATTACHMENT B

PROPOSED EDITS TO JANUARY 2, 2021 DRAFT AMC 19.70 CRITICAL AREA ORDINANCE AND REGULATIONS—Ian Munce, AICP

(i) **Chapter 19.70.235 Wetlands—Required Buffer Areas (A) Buffer Requirements:** Add a #3 “Illegal Modifications. When a violation occurs buffer requirements do not change due to illegal modifications or alterations. A wetlands buffer requirement must be based on the pre-violation habitat condition of the wetland”.

(ii) **Chapter 19.70.010: Expand the heading “Purpose” to “Purpose and Baseline Dates”.**

(iv) **“Wetlands over 10,000 square feet** have been designated, mapped, protected, and regulated since January 15’ 1990 (Ordinance No.2131), geological hazardous areas have been protected and regulated since September 2, 1991 (Ordinance No. 2198), frequently flooded areas protected and regulated since May 19, 2003 (Ordinance No. 2617) and aquifer recharge areas protected and regulated since September 29, 2003 (Ordinance No. 2628). These dates are critical to determinations as to review of new development applications, potential violations, rating categories under 19.70.020, modifications under 19.70.035, exemptions under 19.70.040, and illegal modifications under 19.70.215”.

(iii) **Chapter 19.70.220 Wetlands—Mapping and Delineation (A) Mapping:** Add after the first sentence: “This layer includes the map adopted by Ordinance # 2131, January 15, 1990”. (B) Reference Only: insert at the beginning of the first sentence: “Except for the map adopted by Ordinance # 2131, ... and add at the end of the sentence “through the Annual Development Regulation Amendment process”.

(iv) **Chapter 19.70.020 Identification, classification, and rating of critical areas:** Add after the first sentence “These maps include the map adopted by Ordinance # 2131, January 15, 1990”. Add at the end of the second sentence “except that the map adopted by Ordinance # 2131 actually locates the presence of wetlands over 10,000 square feet”. Add to the final sentence “through the Annual Development Regulation Amendment process”.

(v) **“Chapter 19.70.220 Wetlands—Mapping and Delineation:** Wetlands over 10,000 square feet have been designated, mapped, protected, and regulated since January 15’ 1990 (Ordinance No.2131), geological hazardous areas have been protected and regulated since September 2, 1991 (Ordinance No. 2198), frequently flooded areas protected and regulated since May 19, 2003 (Ordinance No. 2617) and aquifer recharge areas protected and regulated since September 29, 2003 (Ordinance No. 2628). These dates are critical to determinations as to review of new development applications, potential violations, rating categories under 19.70.020, modifications under 19.70.035, exemptions under 19.70.040, and illegal modifications under 19.70.215”.

(vi) **Chapter 19.70.010:** protect not just from “flooding” but from “excess stormwater and/or flooding”.

(vii) **Chapter 19.70.010:** In the current final square remove “or enforcement” from the first sentence and add a second sentence “Neighbors adversely affected by an illegal activity shall be consulted by the City before any final enforcement decision is reached and implemented”.

ATTACHMENT B

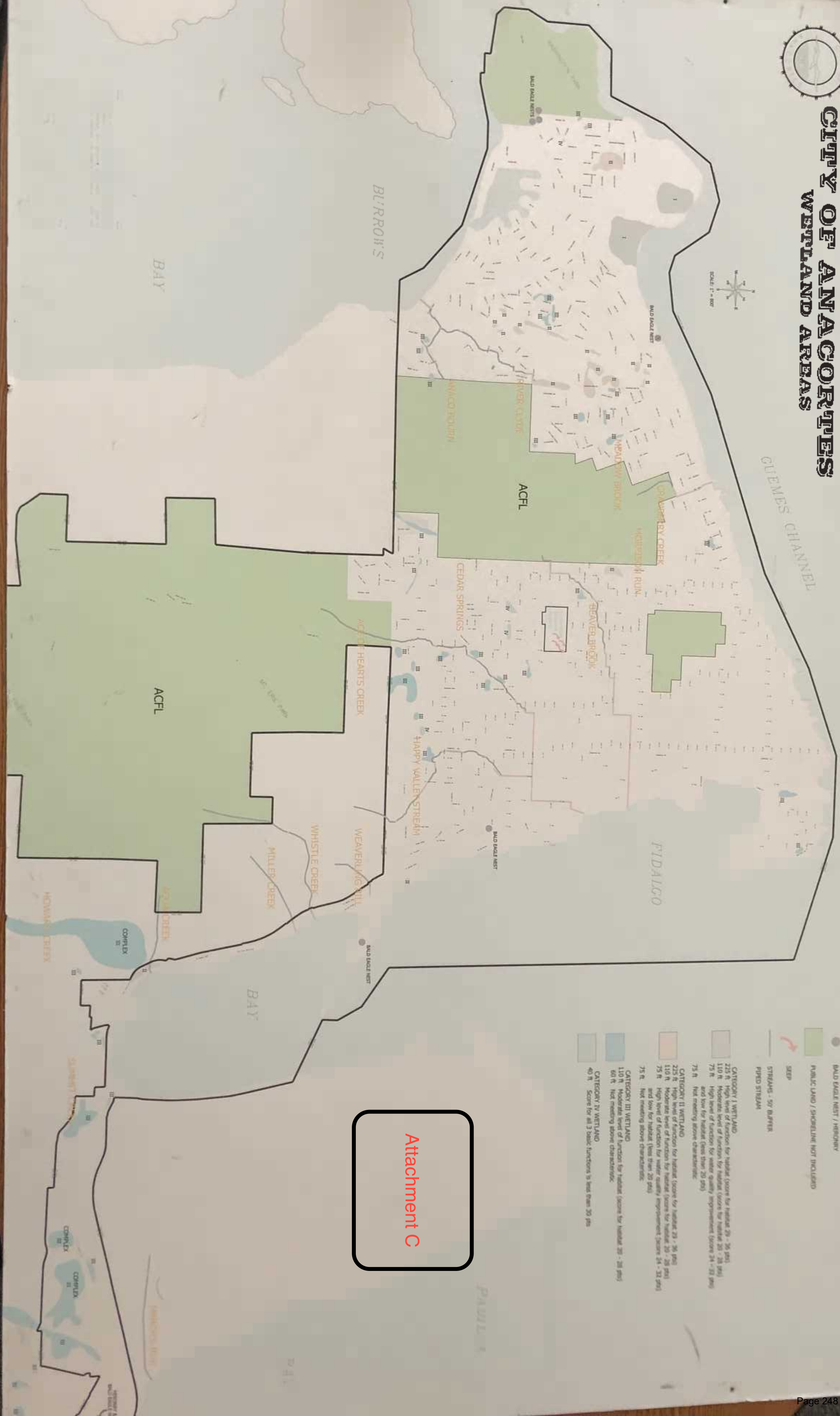
(VIII) Chapter 19.70.165 E Penalties: Change the permissive language to mandatory language "...shall be subject" ...".

(IX)) ORDINANCE: Insert Comprehensive Plan Policies from Attachment A.

(x) ORDINANCE: Add a Section 2: "Stormwater Management funds may be used, as appropriate, to implement the Comprehensive Plan critical area policies recited above; this is essential to restoration efforts".

(xi) ORDINANCE: Add a Section 3: "A Transfer of Development Rights program shall be established with sufficient incentives to minimize the need for critical area reasonable use variances".

CITY OF ANACORES WETLAND AREAS



Attachment C

ATTACHMENT D

From: Ian Munce <ianmunce@gmail.com>
Date: August 20, 2020 at 2:32:09 PM PDT
To: cityclerk@cityofanacortes.org
Cc: Don Measamer <don@cityofanacortes.org>, Tess Cooper <tessc@cityofanacortes.org>
Subject: Public Comment for August 24 Council Meeting Item 5d: "Designating" Critical Areas

Good day, Mayor and City Councilmembers

I apologize for not being clear in my public comments last week.

When I said there was a structural problem with the draft ordinance I did not mean a definitional problem as to what constitutes development. I was referring to the practical reality that if a property owner needs a development permit from the City, then they have to meet all ordinance requirements to the satisfaction of City staff. However, if you go forward with a simple "potential wetland" designation then if a property owner asserts that they are just undertaking "pre-1990 maintenance" vegetation removal on a "suspected wetland" and denies City access to the property (pursuant to your current draft section 19.70.170 D) then only an expensive and multi-year court battle can remedy the alleged violation.

This is why I respectfully urge the City Council to retain the current mapped designations for wetlands over 10,000 square feet. This designation was done initially by ordinance in 1990 to give the City immediate enforcement authority over valuable wetlands.

Given this structural problem and the strong environmental protection policies set forth in your Comprehensive Plan you might wish to "designate" key components of other critical areas under consideration on August 24.

Thank you.

Ian Munce, J.D., AICP

From: [Kyle Loring](#)
To: [Cooper, Tess](#)
Cc: [City Council](#); [Gere, Laurie](#); [Marlene Finley](#)
Subject: Anacortes CAO update -- Evergreen Isls cmts
Date: Friday, April 16, 2021 3:13:53 PM
Attachments: [PLN-2019-0010 -- Evergrn Isls cmts re 3rd draft CAO update.pdf](#)
[PLN-2019-0010 -- 3rd draft Evergreen cmt exhs.pdf](#)

Dear Ms. Cooper,

Please find attached comments on behalf of Evergreen Islands to address the 3rd Draft of the City's CAO update. I have also attached the exhibits to those comments as a separate file.

Sincerely,
Kyle Loring

Kyle A Loring (*he/him*)
LORING ADVISING PLLC
PO Box 3356 | Friday Harbor, WA 98250
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By Email

April 16, 2021

Tess Cooper, Senior Planner
Planning, Community & Economic Development Department
PO Box 547
Anacortes, WA 98221
tessc@cityofanacortes.org

Re: PLN-2019-0010: Evergreen Islands Comments – 3rd Draft of the City of Anacortes
Critical Areas Ordinance Update

Dear Ms. Cooper,

I'm writing this letter on behalf of Evergreen Islands ("Evergreen") to request that the City of Anacortes ("City") revise the 3rd Draft of its Critical Areas Regulations ("3rd Draft") consistent with the Growth Management Act's ("GMA") requirement to protect the functions and values of critical areas and to include the Best Available Science ("BAS"). For decades, Evergreen has dedicated itself to promoting, protecting, and defending Skagit County's unique saltwater island ecosystems, and to ensuring that Anacortes manage the expansion of its built environment protect local ecological treasures. Evergreen provides the comments below to continue to advocate for broadly popular actions like the preservation of regionally important spaces like the Ship Harbor wetland, Anacortes Community Forest Lands, and the many local streams. The group welcomes the opportunity to sit down with City representatives to discuss and address these concerns.

These comments are organized as follows:

Section A – table identifying recommended language changes;

Section B – discussion of the GMA requirement to protect the functions and values of critical areas;

Section C – discussion of the GMA requirement to include the BAS;

Section D – discussion of the myth of mitigation, summarizing studies demonstrating that compensatory mitigation efforts typically are unsuccessful; and

Section E – analysis supporting the revisions recommended in Table A.

A. Table of Recommended Revisions.

The table below shows revisions recommended to satisfy GMA requirements as explained at Section E below. Revisions are identified with redlining, with language to be removed shown in strike-through and language to be added shown in underline.

Section	Page	Draft Text	Recommended Revision
19.70.030.B.3.	8	“Assess the potential impacts to the critical area and determine if they can be avoided or minimized.”	Assess the potential impacts to the critical area and determine if they can be avoided or minimized. <u>In reviewing the impacts and the applicant’s critical area report, the City may engage an independent qualified expert at the applicant’s expense.</u>
19.70.035.C.4	9	“Restoration or replacement of a structure that is damaged by fire, natural disaster or other calamity when:”	Restoration or replacement of a structure that is <u>where up to 75% of its square footage has been</u> damaged by fire, natural disaster or other calamity when:
19.70.040.F Table 19.70.040(A) Exempt Activities (no review)	12	“Provided they do not require structures, grading, filling, draining, or dredging except as provided herein or authorized by a Critical Area Permit: Passive Outdoor Activities, including fishing, birdwatching, hiking, boating, biking, horseback riding, swimming, canoeing, and similar activities with limited environmental impact are exempt activities.”	Provided they do not require structures, grading, filling, draining, or dredging except as provided herein or authorized by a Critical Area Permit: Passive Outdoor Activities, including fishing, birdwatching, hiking, boating, biking , horseback riding, swimming, canoeing, and similar activities with limited environmental impact are exempt activities.
19.70.040.F Table 19.70.040(B) Exempt Activities (Letter of Exemption)	13	“Maintenance, operation, repair, modification, or replacement of existing Non-Motorized trails, and existing facilities within public improved recreation areas....”	Maintenance, operation, repair, modification, or replacement of existing <u>Non-Motorized</u> trails, and existing facilities within public improved recreation areas....

19.70.040	14	<u>“Where trail relocation is the preferred method of repair, trail relocation further away from the Critical Area is not to be considered a new trail but is included in the exemption for operation, maintenance, repair, or replacement.”</u>	<u>Where trail relocation is the preferred method of repair, trail relocation further away from the Critical Area is not to be considered a new trail but is included in the exemption for operation, maintenance, repair, or replacement.</u>
19.70.045.A.	16	“Applicability. An applicant may seek an alteration of a critical area and/or critical area buffer through a permitted alteration when application of the standards renders compliance with these provisions infeasible and the proposed development meets the specific terms of this section and can be considered a reasonable use.”	Applicability. An applicant may seek an alteration of a critical area and/or critical area buffer through a permitted alteration when application of the standards <u>in this chapter would result in the denial of all reasonable and economically viable use of the property</u> renders compliance with these provisions infeasible and the proposed development meets the specific terms of this section and can be considered a reasonable use.
19.70.045.F.	18	“Public services” include, but are not limited to, water supply, sewer and stormwater management facility, electric power, telephone, cable television, gas, and transportation for persons and freight.”	“Public services” include, but are not limited to, water supply, sewer and stormwater management facility, electric power, telephone, cable television, gas, and transportation <u>by city road</u> for persons and freight.
19.70.045.F.	20-21	“New to Table Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes	New to Table Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes

		Comprehensive Plan, the ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and AMC 12.18 ACFL.”	Comprehensive Plan, the ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and AMC 12.18 ACFL.
19.70.230.B.	39	“Category II, III and IV Wetlands. Development activities that result in alteration of Category II, III or IV wetlands may be permitted upon demonstration, through a critical areas report meeting the requirements of this Chapter, that:....”	Category II, III and IV Wetlands. Development activities that result in alteration of Category II, III or IV wetlands may be permitted upon demonstration, through a critical areas report meeting the requirements of this Chapter, that:.... [this subsection B and its paragraphs must be deleted]
19.70.235.C.1.	42	Category IV 50 40 25	Category IV 50 40 25 40
19.70.235.C.2.	42	Category IV 50 40 25	Category IV 50 40 25 40
19.70.235.C.3.	42	Category III 80 60 50 40 Category IV 50 40 25	Category III 80 60 50 40 60 Category IV 50 40 25 40
19.70.235.B	44-45	“Averaging buffer widths... b. The buffer averaging does not reduce the functions or values of the wetland, either through preservation of total buffer area or enhancement of buffer areas... e. The buffer width at its narrowest point is not reduced to less than 75% of the standard width, for Category I and II. No less than 50 percent or 35 feet for Category III and 15 feet for Category IV, whichever is greater.”	Averaging buffer widths... b. The buffer averaging <u>improves</u> does not reduce the functions <u>and</u> or values of the wetland, either through preservation of total buffer area or enhancement of buffer areas... e. The buffer width at its narrowest point is not reduced to less than 75% of the standard width, for Category I and II. No less than 50 percent or 35 feet for Category III and 15 feet for Category IV, whichever is greater.
19.70.235.D.	42-43	Reducing Buffer Widths.	Reducing Buffer Widths. [this subsection D and its

			paragraphs must be deleted]
19.70.235.H.	46	“Setbacks from buffers. Buildings, structures, paving, and other hard surfacing must be set back a minimum distance of 10 feet from the edge of the wetland buffer, or edge of the wetland if no buffer is required, unless otherwise determined by the Decision maker <u>Decision-maker</u> that a smaller distance would meet the intent of this subsection.”	Setbacks from buffers. Buildings, structures, paving, and other hard surfacing must be set back a minimum distance of 10 feet from the edge of the wetland buffer, or edge of the wetland if no buffer is required, unless otherwise determined by the Decision maker <u>Decision-maker</u> that a smaller distance would meet the intent of this subsection.
19.70.235.H.2.	46	“Uncovered decks, roof eaves and overhangs, unroofed stairways and steps;”	Uncovered decks, roof eaves and overhangs, unroofed stairways and steps;
19.70.315	57	“3. Waters of the State, including streams as classified in WAC 222-16-030;”	3. Waters of the State, including streams as classified in WAC 222-16-030, <u>including but not limited to Whistle Creek, Happy Valley Stream, Ace of Hearts Creek, Beaver Brook, Cranberry Creek, Clyde Creek, Anaco Bourn, Morrison Run, Cedar Springs, Weaverling Rill, Miller Creek, Aqua Creek, Howard Creek, Summit Creek, and March’s Run.</u>
19.70.325.A.	60	“FWHCA’s or their buffers may be altered only if the proposed alteration of the habitat or the mitigation proposed does not degrade the functions and values of the habitat.”	<u>Alterations of</u> FWHCA’s or their buffers <u>is prohibited except as otherwise allowed by this chapter and may occur</u> only if the proposed alteration of the habitat or the <u>and any associated</u> mitigation does not degrade the functions and values of the habitat.
19.70.325.F.	61	“Access roads and utilities serving a proposed subdivision may be permitted within the FWHCA and	Access roads and utilities serving a proposed subdivision may be permitted within the FWHCA and

		associated buffers only if the applicant's qualified professional(s) demonstrate, and the Decision-maker determines, that no other feasible alternative exists, all unavoidable impacts are fully mitigated, and the use is consistent with this chapter."	associated buffers only if the applicant's qualified professional(s) demonstrate, and the Decision-maker determines, that no other feasible alternative exists, all unavoidable impacts are fully mitigated, and the use is consistent with this chapter. <u>This paragraph does not authorize new access roads and utilities in FWHCAs and associated buffers for existing subdivisions.</u>
19.70.330.B.2. Stream Buffers	62	Type F 50 feet Type Np 50 feet Type Ns 50 feet	Type F 50 feet <u>1 Site Potential Tree Height</u> Type Np 50 feet <u>1 Site Potential Tree Height</u> Type Ns 50 feet <u>1 Site Potential Tree Height</u> [WDFW's map of Site Potential Tree Heights for Anacortes would apply]
19.70.330.C.	63-64	" Buffer Reduction Standards..... "	Buffer Reduction Standards..... [this subsection C and its paragraphs must be deleted]
19.70.330.D.	64	" Building setbacks from stream buffers. Buildings, structures, paving, and other hard surfacing must be setback a minimum distance of 10 feet from the edge of the stream buffer unless otherwise determined by the Decision-maker <u>Decision-maker</u> that a smaller distance would meet the intent of this subsection."	Building setbacks from stream buffers. Buildings, structures, paving, and other hard surfacing must be setback a minimum distance of 10 feet from the edge of the stream buffer unless otherwise determined by the Decision-maker <u>Decision-maker</u> that a smaller distance would meet the intent of this subsection.
19.70.330.D.2.	64	"Uncovered decks, roof eaves and overhangs, unroofed stairways and	Uncovered decks, roof eaves and overhangs, unroofed stairways and

		steps;”	steps;
19.70.330.F.1, .F.2	64	“Type F and Type Np Streams Relocation....” “Type Ns Streams Relocation....”	“Type F and Type Np Streams Relocation....” “Type Ns Streams Relocation....” [these paragraphs 1 and 2 must be deleted]
19.70.335.B.	66	“B. Other Priority Habitats and Species.”	B. Other Priority Habitats and Species. [this section B and its paragraph 1 must be deleted]
19.70.340.	69	“Fish and wildlife habitat – Buffer Width Averaging for All FWHCA’s. A. Approval Criteria. The Decision makerDecision-maker may allow the averaging of FWHCA buffer widths when the critical areas report demonstrates the following.”	“Fish and wildlife habitat – Buffer Width Averaging for All FWHCA’s <u>Other Than Those Designated by the City as Habitats and Species of Local Importance.</u> A. Approval Criteria. The Decision makerDecision-maker may allow the averaging of FWHCA buffer widths <u>for FWHCAs other than those designated by the City as habitats and species of local importance</u> when the critical areas report demonstrates the following.”
19.70.340.A.1.	69	“In-stream or buffer habitat functions, will be increased or maintained where native buffer vegetation is generally intact, or increased where existing buffer vegetation is inadequate to protect functions and values; and”	In-stream or buffer habitat functions; will be increased or maintained where native buffer vegetation is generally intact, or increased where existing buffer vegetation is inadequate to protect functions and values; and”
19.70.340.A.5.	69	“The buffer width is not reduced in any location to less than 50 percent of the standard width or 35 feet, whichever is greater, on a case-by-case basis as a result of a habitat assessment pursuant to	“The buffer width is not reduced in any location to less than 75 50 percent of the standard width or 35 feet, whichever is greater, on a case-by-case basis as a result of a habitat assessment pursuant to

		AMC 19.70.380 (B)(4); and”	AMC 19.70.380 (B)(4); and”
--	--	----------------------------	----------------------------

B. The GMA Requires Cities to Protect the Functions and Values of Critical Areas.

In 1990, the Legislature adopted the GMA to address uncoordinated and unplanned growth that threatened the environment, sustainable economic development, and the health, safety, and high quality of life enjoyed by Washington residents.¹ A keystone of the GMA structure is the mandate to protect critical areas. The Legislature emphasized the fundamental importance of protecting CAs by requiring cities to designate and protect critical areas before addressing any other GMA mandate.² The Board has noted that “[i]t is significant that the [GMA] required cities and counties to identify and conserve resource lands and to identify and protect CAs before the date that [interim Urban Growth Areas] had to be adopted. This sequence illustrates the fundamental axiom of growth management: ‘the land speaks first.’”³ This primacy “underscores the paramount importance that [the legislature] intended for this statutory mandate.”⁴ In Pilchuck, the Board recognized the “higher order of directiveness” and “higher order of urgency” that the legislature placed on CAs, and that “[e]ven the legislature’s choice of the term ‘critical’ to describe these areas conveys an importance greater than, for example, ‘natural systems’ or ‘environmentally sensitive’ areas.”⁵

The GMA’s planning goals and express requirements reflect this substantial concern for protecting CAs. Planning goals 9 and 10 set forth goals to: “retain open space, enhance recreational opportunities, conserve fish and wildlife habitat, increase access to natural resource lands and water, and develop parks and recreation facilities” and “[p]rotect the environment and enhance the state’s high quality of life, including air and water quality, and the availability of water.”⁶ The GMA then directs cities to designate CAs, adopt development regulations that protect them, and update those regulations regularly.⁷

The GMA requires the protection of all functions and values of critical areas.⁸ Protection means the “preservation of the functions and values of the natural environment or safeguarding the public from hazards to health and safety.”⁹ Hence, the court in WEAN struck

¹ RCW 36.70A.010.

² RCW 36.70A.040(3), .060(2-3), .070(5)(c)(iv), .130(1), .170.

³ Bremerton v. Kitsap County, CPSGMHB No. 95-3-0039, FDO, 28 (Oct. 6, 1995).

⁴ See Pilchuck v. Snohomish County, CPSGMHB No. 95-3-0047, FDO, 16-17 (Dec. 6, 1995).

⁵ See id. at 16.

⁶ RCW 36.70A.020(9), (10).

⁷ RCW 36.70A.060(2); .070(5)(c)(iv); .170(1).

⁸ Whidbey Envtl. Action Network v. Island County, 122 Wn. App. 156, 175, 93 P.3d 885 (2004) (“WEAN”).

⁹ WAC 365-196-830(3).

stream buffers sized solely for water quality, rather than the “entirety of functions attributed to stream buffers,” because the regulations had not protected “all functions and values” of CAs.¹⁰ And although a city need not maintain all individuals of all species at all times, the “goal of fish and wildlife habitat conservation is to manage land so as to maintain species in suitable habitats within their natural geographic distribution” and avoid creating isolated subpopulations.¹¹ Thus, “local governments must either be certain that their critical areas regulations will prevent harm or be prepared to recognize and respond effectively to any unforeseen harm that arises.”¹²

C. BAS Must Be Included.

In 1995, the Legislature added the requirement that counties “include the best available science in developing policies and development regulations to protect the function and values of critical areas.”¹³ Counties must also “give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries.”¹⁴ The purpose of the BAS requirement is to ensure that CA regulations are based on meaningful, reliable, and relevant evidence, rather than speculation or surmise.¹⁵

To include BAS, a city must both: (1) gather or develop valid scientific information produced by a scientific methodology; and (2) analyze that information in a reasoned process.¹⁶ Valid scientific information typically bears the following hallmarks: (1) peer review; (2) replicable methods that reach logical conclusions; and (3) appropriate statistical or quantitative methods.¹⁷

A city includes BAS by identifying: (1) the specific regulations adopted to protect the CA; (2) the relevant sources of BAS included in the decision-making; and (3) any nonscientific information in the record used to justify a departure from BAS recommendations, as well as the rationale, potential risks, and measures to limit risks associated with that departure.¹⁸ A city’s record must show that it considered the BAS substantively in designating and protecting critical

¹⁰ WEAN, 122 Wn. App. at 175 (emphasis added).

¹¹ Stevens County, 146 Wn. App. at 511.

¹² Swinomish Indian Tribal Cmty., 161 Wn.2d at 436.

¹³ RCW 36.70A.172(1).

¹⁴ *Id.*

¹⁵ Honesty in Envtl. Analysis and Legislation v. Cent. Puget Sound Growth Mgmt. Hearings Bd., 96 Wn. App. 522, 531, 979 P.2d 864 (1999) (hereafter “HEAL”).

¹⁶ WAC 365-195-900--925; Ferry County v. Concerned Friends of Ferry County, 155 Wn.2d 824, 834-39, 123 P.3d 102 (2005).

¹⁷ WAC 365-195-905(5)(a)(1)-(3).

¹⁸ WAC 365-195-915.

areas.¹⁹ Although a city may balance the BAS with GMA goals, it ultimately must protect critical areas.²⁰

BAS plays a central role in adopting provisions that protect CAs.²¹ In HEAL, the court stated that

[w]hile the balancing of the many factors and goals could mean the scientific evidence does not play a major role in the final policy in some GMA contexts, it is hard to imagine in the context of critical areas. The policies at issue here deal with critical areas, which are deemed “critical” because they may be more susceptible to damage from development. The nature and extent of this susceptibility is a uniquely scientific inquiry. It is one in which the best available science is essential to an accurate decision about what policies and regulations are necessary to mitigate and will in fact mitigate the environmental effects of new development.²²

Regulations that seek to apply a jurisdiction’s unique view of the science typically contravene the GMA. For example, in Ferry County, the county’s CAO violated the GMA when the county relied on advice from a consultant who did not visit the county and who cited only a 1997 birding manual and a discussion with a wildlife biologist about pygmy rabbits.²³ The county had not vetted the information provided by the consultant or compared it to science from state, federal, and Tribal agencies.²⁴ The court noted that “a ‘[c]ounty cannot choose its own science over all other science and cannot use outdated science to supports its choice.’”²⁵ Similarly, in Department of Ecology v. City of Kent, Kent failed to conduct a reasoned analysis when it declined Ecology’s science-based wetlands rating system in favor of an outdated, 1979 wetland classification system that relied upon wetland size and number of vegetation classes without determining wetland functions.²⁶

Lastly, when scientific evidence is unavailable, a city should adopt a precautionary or no risk approach.²⁷ In Yakima County, the court held that Yakima County failed to use a no-risk approach when it responded to scientific uncertainty with minimal stream buffers.²⁸ Similarly,

¹⁹ Whidbey Envtl. Action Network v. GMHB, 471 P.3d 960, 967 (Wa. Ct. App. Sept. 1, 2020) (“WEAN 2020”).

²⁰ RCW 36.70A.060(2); HEAL, 96 Wn. App. at 532-33.

²¹ See HEAL, 96 Wn. App. at 532-33.

²² Id. (emphasis added).

²³ 155 Wn.2d at 837-38.

²⁴ Id. at 838.

²⁵ Id. (quoting Island County Citizens’ Growth Mgmt. Coalition v. Island County, No. 98-2-0023c, 2000 WL 268939, at *7 (WWGMHB March 6, 2000) (“ICCGMC”)).

²⁶ CPSGMHB No. 05-3-0034, FDO, 14-16, 43 (April 19, 2006).

²⁷ Yakima County v. E. Wash. Growth Mgmt. Hearings Bd., 168 Wn. App. 680, 693, 279 P.3d 434 (2012) (citing WAC 365-195-920(1)).

²⁸ 168 Wn. App. at 693.

in Swinomish Indian Tribal Community, the court declared that “local governments must either be certain that their critical area regulations will prevent harm or be prepared to recognize and respond effectively to any unforeseen harm that arises.”²⁹

As explained at Section E below, the City has failed to include the BAS in proposing several provisions in its CAO update, including the undersized wetland and stream buffers and the authorization to entirely relocate streams.

D. Alterations of Critical Areas and Buffers Must Be Strictly Limited Because Compensatory Mitigation Typically Fails to Replace Lost Critical Area Functions.

The BAS demonstrates that mitigation projects rarely replace lost critical area functions and values and that the best approach to protecting them is to prevent their alteration. Twenty-five years ago, Race and Fonseca synthesized surveys of mitigation projects and found significantly flawed mitigation projects that: (1) did not adhere to established mitigation policies; (2) were frequently unsuccessful; and (3) often missed the deadline.³⁰ Race and Fonseca stated that “[t]here is need to acknowledge the extent to which non-scientific, real-world complications plague current policies and practices.”³¹ Another broad survey of structural and functional loss in restored wetlands found that after 100 years, 621 wetland sites continued to suffer biological structure and biogeochemical functioning 26% and 23% below reference sites.³² And a 2008 study of 23 wetland mitigation projects found similarly that: (1) 67% of the projects did not meet permit requirements for wetland areas; (2) open-water/emergent wetlands were exchanged for scrub/shrub forested wetlands; (3) wetlands decreased in number from 134 to 65; and (4) smaller wetlands were lost.³³

Last, a 2009 paper examined the reasons that biodiversity trading programs like critical areas compensatory mitigation provisions fail to achieve no-net-loss and found that such programs can succeed where the trade involves a simple, relatively measurable commodity, like sulfur dioxide in the air, but that they fail when attempting to trade biodiversity like wetland or riparian ecosystems because of their complexity, difficulty in measuring their functions, and

²⁹ 161 Wn.2d at 436.

³⁰ Margaret S. Race and Mark S. Fonseca, *Fixing Compensatory Mitigation: What Will It Take?*, 6 Ecological Applications 1, 94-101 (1996) (stating at page 97 that “[b]ased on over a decade of survey results, the cumulative record of past mitigation projects remains undeniably poor overall, with disappointingly few examples of success,” and noting that exemptions virtually guarantee incremental loss of wetlands) (attached hereto as Exhibit A).

³¹ Race and Fonseca, at 1.

³² Moreno-Mateos, et al., *Structural and Functional Loss in Restored Wetland Ecosystems*, 10 PLoS Biology 1 (Jan. 2012) (attached hereto as Exhibit B).

³³ Kettlewell, et al., *An Assessment of Wetland Impacts and Compensatory Mitigation in the Cuyahoga River Watershed, Ohio, USA*, 28 Wetlands 1, 57 (3/2008) (attached hereto as Exhibit C).

lack of directly interchangeable parts.³⁴ Particularly pertinent here, the authors conclude that,

given the option of saying to developers ‘yes, with conditions’ rather than ‘no,’ officials will prefer ‘yes, with conditions’ – particularly where compliance with conditions cannot be credibly measured and officials can avoid accountability for outcomes. Legitimized bartering can thus create a policy situation ‘obscure enough to please all parties...and so ill-defined that failures...will be difficult to detect and impossible to litigate.’ ...In sum, while compensation and no net loss are worthy goals, and bartering biodiversity might appear more promising than simple and weakly enforced prohibitions, this article suggests policies that enable biodiversity trading may perversely yield worse biodiversity outcomes.³⁵

This inability to ensure the replacement of complex ecosystems impacted by development warrants a greater emphasis on preventing development that would harm critical areas.

E. Several Provisions Must Be Revised to Protects the Functions and Values of Critical Areas.

In order to organize specific comments around the Best Available Science, the sections below address specific CAO provisions by topic, including: (1) undersized wetland and stream buffers; (2) buffer reductions and averaging; (3) stream relocation; (4) elimination of smaller wetlands; (5) broadly authorized alterations to critical areas; (6) exceptions for activities in critical areas or buffers; and (7) final points. The sections below explain how the BAS supports the text revisions identified in the table at Section A above.

1. Undersized wetland and stream buffers.

The CAO would set buffers for some wetlands and all streams below the size recommended by the BAS. The City’s consultant and Ecology recommend buffers of a minimum size of 60 feet for Category III wetlands and 40 feet for Category IV wetlands even if required measures are implemented to minimize impacts on wetlands.³⁶ Yet Table 19.70.235(C) at page 42 of the CAO would establish a 25-foot buffer for Category IV wetlands near low intensity development.³⁷ Table 19.70.235(D) would set Category III buffers for low intensity development at 40 feet and Category IV buffers at 25 feet for low intensity development.³⁸ In addition, Ecology’s BAS recommends that Category III wetlands have the same buffer size as Category I and II

³⁴ Walker, *et al.*, *Why bartering biodiversity fails*, Conserv. Ltrs 2 (2009) (attached hereto as Exhibit D).

³⁵ *Id.* at 155 (quoting Walker *et al.* 2008:226; Winter 1985).

³⁶ Wash. Dept. of Ecology, *Wetland Guidance for CAO Updates, Western Washington Version*, Pub. No. 16-06-001, 28 (June 2016) (hereafter “ECY Guidance”) (attached hereto as Exhibit E); Aqua-Terr Systems, Inc., *City of Anacortes, Critical Areas Ordinance Revision/Update, Best Available Science updates recommendations report*, 10 (Nov. 1, 2016).

³⁷ CAO Draft 3, at 42.

³⁸ CAO Draft 3, at 42.

wetlands if they score 5 or more on the habitat score.³⁹ And Ecology recommends that wetlands with a habitat score of 5 receive a buffer width greater than those that score 3-4, but the City applies the same lower buffer size to wetlands with a score of 5 as it does to wetlands with scores of 3-4.⁴⁰ The 3rd Draft's widths should be amended consistent with the BAS for protecting wetlands, which already represent a moderate risk approach that has a medium chance of harming wetlands. In addition to the revisions identified in the table at Section A above, the 3rd Draft should be revised with a table for wetlands with a score of 5 points consistent with Ecology's BAS at pages 28-30 of its Guidance.⁴¹

With regard to streams, the BAS from the Washington Department of Fish and Wildlife ("WDFW") identifies a need to protect a zone larger than the 50 feet on either side of streams that the CAO proposes.⁴² Based on BAS, WDFW categorizes an area called a riparian management zone ("RMZ") as a Priority Habitat and thus recommends that local jurisdictions designate it as a Fish and Wildlife Habitat Conservation Area in their critical areas ordinances.⁴³ The RMZ is the "area that provides full ecological function for bank stability, shade, pollution removal, contributions of detrital nutrients, and recruitment of large woody debris, and can also provide habitat for terrestrial wildlife species."⁴⁴ As indicated by WDFW's recommendation to designate the RMZ as a critical area, it is distinct from a buffer or setback. To protect RMZs, WDFW notes that the BAS contemplates that a CAO will: (1) designate riparian ecosystems as critical areas within an area called the riparian management zone ("RMZ"); (2) include watershed-scale management considerations; (3) establish the width of an RMZ as one site-potential tree height in forested ecoregions like that in which Anacortes is found; (4) consider the needs of relevant terrestrial species; and (5) apply the same RMZ area to all streams, whether or not they are fish-bearing.⁴⁵

WDFW recommends applying the same RMZ protection to all streams because they "found no evidence that full riparian ecosystem functions along non-fish-bearing streams are less important to aquatic ecosystems than full riparian ecosystem functions along fish-bearing streams."⁴⁶ In addition, WDFW found that non-fish-bearing streams: (1) support a unique community of aquatic and riparian-obligate wildlife; (2) provide movement corridors for wildlife, particularly in the face of changing climate conditions; (3) provision fish-bearing streams with

³⁹ ECY Guidance, at 28-30.

⁴⁰ Id.

⁴¹ Id.

⁴² WDFW, *Riparian Ecosystems, Volume 2: Management Recommendations* (Dec. 2020) (hereafter "Riparian Recommendations") (attached hereto as Exhibit F). The associated Volume 1 is attached hereto as Exhibit G.

⁴³ Riparian Recommendations, at 11.

⁴⁴ Riparian Recommendations, at 11.

⁴⁵ Riparian Recommendations, at 6-8.

⁴⁶ Riparian Recommendations, at 7-8.

matter and energy; and (4) provide cool water to downstream reaches.⁴⁷

Based on the map of site-potential tree height that WDFW has created, the RMZ for streams in Anacortes would extend from approximately 127 feet to 171 feet, consistent with the tree heights there.⁴⁸ Within that zone, WDFW recommends avoiding: (1) clearing, grading, and filling; (2) new development that would require bank hardening; (3) on-site sewage systems without habitat monitoring plans; or (4) removal of hazard trees without proper evaluation and avoidance and minimization of impacts.⁴⁹ In addition, WDFW notes that its recommendations for RMZs apply to urban areas as well as non-urban areas.⁵⁰

WDFW's recommendations are consistent with the earlier science referenced by the October 21, 2019 document that the City's consultant, GeoEngineers, provided regarding stream buffers (though not with GeoEngineers' ultimate recommendation for 50-foot buffers).⁵¹ Although that document suggests that "a 50-foot buffer is the minimum required to provide a basic level of functions," it overlooks the fact that the studies it references find significantly larger buffers necessary to remove significant amounts of pollutants or to provide habitat.⁵² Thus, as acknowledged by that paper, Mayer et al. projected that a 90-foot buffer was needed to remove 75% of nitrogen and a 370-foot buffer for 90% nitrogen removal.⁵³ Likewise, "[m]ost studies report a range of 200 to 300 feet necessary to provide essential habitat for most wildlife species (Keller et al., 1993)."⁵⁴

The 3rd Draft should be revised consistent with the Ecology and WDFW BAS, including increased wetland buffers and stream RMZs with widths consistent with site-potential tree height, as well as development proscriptions within the RMZs.

2. Buffer reductions and averaging.

The BAS does not support the City's proposed buffer reductions, or its buffer averaging that would unnecessarily reduce portions of a buffer below 75% of its standard width. Section 19.70.235.D of the 3rd draft, at page 43, proposes to reduce wetland buffers based largely on implementing basic recommendations that already apply for the City's buffer sizes, and Section

⁴⁷ Riparian Recommendations, at 8.

⁴⁸ WDFW Priority Habitats and Species: Riparian Ecosystems and the Online SPTH Map Tool, *available at*: <https://wdfw.maps.arcgis.com/apps/MapJournal/index.html?appid=35b39e40a2af447b9556ef1314a5622d>

⁴⁹ Riparian Recommendations, at 25-27.

⁵⁰ Riparian Recommendations, at 29-30.

⁵¹ GeoEngineers, Stream Buffer Best Available Science Review and Buffer Recommendations (Oct. 21, 2019).

⁵² GeoEngineers, at 12.

⁵³ GeoEngineers, at 8.

⁵⁴ GeoEngineers, at 10.

19.70.330.C, at pages 63-64, proposes to reduce buffers to 25 or 35 feet if a developer decides they want to reduce buffers and designs a site plan to do so. These sections should be revised consistent with BAS.

In describing the importance of buffers, Ecology's most recent version of its wetlands guidance states that, "[t]he scientific literature is unequivocal that **buffers are necessary to protect wetland functions** and values."⁵⁵ As noted above, Ecology's buffer approach are based on a moderate-risk approach with a medium likelihood of causing impacts. Nonetheless, "**Ecology's buffer recommendations are also based on the assumption that the buffer is well vegetated with native species appropriate to the ecoregion.**"⁵⁶ Where the buffer does not contain vegetation adequate to protect the wetland functions, it should either be planted or increased in size.⁵⁷

Against this backdrop, Ecology's BAS contemplates buffer averaging in those limited instances where it "will improve the protection of wetland functions, or if it is the only way to allow for reasonable use of a parcel."⁵⁸ In addition "[t]he width of the buffer at any given point after averaging should be no smaller than 75% of the standard buffer."⁵⁹

Consequently, the averaging provisions that allow a buffer just 50% should be revised to 75% and averaging where habitat functions will be maintained must be revised to require an improvement.

The extensive buffer reduction allowed through averaging is also inconsistent with the Growth Board's decision in ReSources, Inc. v. City of Blaine, where it rejected buffer averaging that allowed reductions of 40% and 60%, even where "all anticipated impacts to the critical area and its required buffer have been mitigated and, for averaging, the total buffer area is not reduced below the area that would result from use of the standard buffer."⁶⁰ The Board noted the lack of BAS to justify the buffer reductions, and quoted with approval Ecology recommendations that

[t]he widths of buffers may be averaged if this will improve the protection of wetland functions, or if it is the only way to allow for reasonable use of a parcel. There is no scientific information available to determine if averaging the widths of buffers actually protects functions of wetlands."⁶¹

⁵⁵ ECY Guidance, at 11 (emphasis in original).

⁵⁶ ECY Guidance, at 13.

⁵⁷ Id.

⁵⁸ Id. (emphasis added).

⁵⁹ Id. (emphasis added).

⁶⁰ WWGMHB No. 09-2-0015, FDO, 17 (March 29, 2010).

⁶¹ Id. (emphasis in original)

In addition, no BAS supports merely reducing buffers. For example, there is no support for the proposal to reduce stream buffers to 35 feet or 25 feet where a developer creates a site design that would require such a buffer reduction, as proposed by Section 19.70.330.C on page 63. Nor does the BAS support the proposed wetland buffer reductions based on the implementation of basic minimization measures like addressing lights, noise, toxic runoff, stormwater runoff, change in water regime, pets and human disturbance, and dust, unless the buffer sizes proposed by the City match those recommended by Ecology. The wetland buffer sizes established at Tables 19.70.235(C) and (D) set buffers smaller than Ecology's recommended buffers at Table XX.1 for wetlands that have a habitat score of 5 or 6-7.⁶² The 3rd draft CAO chart should be revised for consistency with Ecology recommendations or the buffer reductions must be removed.

3. Stream relocation.

There is no BAS to support the relocation of streams, either as part of a mitigation or rehabilitation/restoration plan or for other purposes. As discussed above, WDFW's Riparian Recommendations demonstrate that riparian corridors must be protected, not moved. Nor is there any BAS that suggests that streams can be moved while protecting their functions and values. On the contrary, WDFW's Riparian Recommendations state that "[t]he use of the precautionary principle and adaptive management are particularly appropriate when dealing with complex and dynamic systems, and when we have uncertainty related to exactly how management activities affect functioning of wetlands and riparian ecosystems."⁶³ And "[r]iparian areas and surrounding watersheds are complex and dynamic systems comprised of many interacting components."⁶⁴ Consequently, the permission to physically relocate streams granted by proposed Section 19.70.330.F. must be removed.

4. Elimination of smaller wetlands.

It is not possible to protect the functions and values of a wetland by allowing it to be destroyed, yet the 3rd Draft would allow the "alteration" of Category IV wetlands up to 1,000 square feet in size at Section 19.70.230.B.3. While one of the conditions contemplates the application of the mitigation sequence, the BAS identified above demonstrates that wetlands are sufficiently complex ecosystems that attempts to mitigate for impacts to them regularly fail. Consequently, this exemption allowing impacts must be repealed.

Further, Growth Board decisions have repeatedly recognized the importance of

⁶² ECY Guidance, at 26.

⁶³ Riparian Recommendations, at 5.

⁶⁴ Id.

wetlands of all sizes in striking provisions that allow development of wetlands.⁶⁵ In Hood Canal, the Board rejected an exemption for even very small, truly isolated and poorly functioning wetlands where there was no evidence of the likely number of exempt wetlands, or of the potential cumulative impacts to those wetlands, adaptive management, or monitoring to assure no net loss.⁶⁶ Similarly, in Larson Beach Neighbors v. Stevens County, the Board held that exemptions for certain wetland sizes did not comply with the GMA in the absence of BAS showing that such actions would protect their functions and values.⁶⁷ And in Pilchuck, the Board held that the structure, value, and functions of CAs are inviolate and that a county's discretion to craft regulations that might result in some localized impacts or even loss should be "wielded sparingly and carefully for good cause" and that no circumstances would allow "the net loss of the structure, value and functions of such natural systems within a watershed or other functional catchment area."⁶⁸

The exemption to develop smaller wetlands also conflicts with the BAS. The development of smaller wetlands would impact each of the four basic functions and values they perform: (1) water purification;⁶⁹ (2) maintenance of hydrologic functions and soil stability;⁷⁰ (3) providing habitat;⁷¹ and (4) landscape beautification. Development adversely impacts these functions by altering hydrology with impervious surfaces, removing vegetation, constructing ponds, grading, and disturbing soil. Wetlands also can lose their capacity to filter pollutants once overloaded.⁷²

The BAS strongly supports protecting wetlands of all sizes, and emphasizes the importance of smaller wetlands. Ecology's wetlands guidance states that "[t]he scientific literature does not support exempting wetlands that are below a certain size."⁷³ Earlier Ecology literature noted that "the loss of small wetlands is one of the most common cumulative impacts on wetlands and wildlife in Washington."

⁶⁵ E.g., Hood Canal Envtl. Council, et al., v. Kitsap County, CPSGMHB No. 06-3-0023c, FDO, 19-20 (Aug. 28, 2006).

⁶⁶ CPSGMHB No. 06-3-0012c, FDO, 19-20 (Aug. 28, 2006).

⁶⁷ EWGMHB No. 03-1-0003, FDO at 20-22 (Feb. 10, 2004).

⁶⁸ See CPSGMHB Case No. 95-3-0047, FDO, at 16.

⁶⁹ Wash. Dept. of Ecology, *Wetlands in Washington State, Vol. 1: A Synthesis of the Science*, 2-29 – 2-31 (2005) (wetlands improve water quality by: (1) decreasing contaminant loads; (2) removing excess nutrients like nitrogen and phosphorous; (3) retaining or killing harmful bacteria and viruses; (4) maintaining stream temperature; and (5) filtering out and stabilizing fine sediments suspended) (hereafter "Wetlands Synthesis") (attached hereto as Exhibit H).

⁷⁰ Id. (wetlands: (1) promote infiltration of runoff into aquifers; (2) decrease erosion in gullies and small channels; (3) store water; (4) help sustain summer flow in small streams; and (5) maintain elevated humidity in uplands).

⁷¹ Id.

⁷² E.g., Wetlands Synthesis, at 2-39 (discussing phosphorous saturation).

⁷³ ECY Guidance, at 8.

The exception for developing smaller wetlands must be removed, particularly in the absence of any understanding of the amount of impacts it would cause.

5. Alterations to critical areas broadly authorized.

As explained above, alterations of wetlands do not protect their functions and values and conflict with the BAS. Consequently, the City must remove its broad authorization to permit development activities that result in alteration of Category II, III, or IV wetlands at Section 19.70.230.B. on page 39 of the 3rd draft. This is particularly critical given the need to apply a precautionary approach for such a complex ecosystem as a wetland and in light of the substantially likely failure of efforts to compensate for functions lost to development.

Likewise, language about altering FWHCAs should be revised to clarify that alterations are allowed only as identified in the critical areas ordinance. As written, the text on page 60 (Section 19.70.325.A.) states that, “FWHCA’s or their buffers may be altered only if the proposed alteration of the habitat or the mitigation proposed does not degrade the functions and values of the habitat.” That language should be revised as identified in the table at Section A above to clarify that only those alterations specified elsewhere in the ordinance are authorized.

6. Exceptions for activities in critical areas or buffers.

The 3rd Draft proposes to allow a significant amount of development in critical areas or their buffers through exemptions at Table 19.70.040(A) and (B) or permitted alterations at Table 19.70.045. The following bullets identify some of these exemptions and recommend revisions (the page numbers refer to the page in the electronic document):

- (page 12) -- Passive Outdoor Activities. City staff testified to the Anacortes Hearing Examiner during an appeal of the SEPA review of the CAO that the City had removed the reference to cycling as a passive outdoor activity. However, in conflict with that testimony, the City has proposed to expressly identify biking as a passive outdoor activity. This reference should be removed.
- (page 13) -- the 3rd Draft removes "non-motorized" before trails in the exemption for maintenance, operation, repair, modification, or replacement of recreation areas in critical areas and buffers. Because motorized equipment typically causes more impact in critical areas and buffers, this exemption should apply to only non-motorized trails and facilities and that term should be reinserted into the ordinance.
- (page 14) – the 3rd Draft adds a new provision that allows for new trails to be developed in critical areas and buffers if an existing trail is already located in that critical area or

buffer. Particularly in the absence of a provision requiring the restoration of an existing trail in the event of construction of a new trail, this provision should be removed because it does not protect the functions and values of critical areas by doubling the amount of trail in that critical area or buffer. The old trail would otherwise continue to have impacts unless it were fully restored, and the new trail would add new impacts.

- (page 18) – Although the Public Services permitted alteration has been renamed the "Public Roads and Utilities" permitted alteration, it continues to allow development of critical areas and buffers for new transportation facilities, which according to City documents includes the Guemes Channel Trail. The text should be revised as identified in the table at Section A above to clarify that it applies to only automobile roads and not to other forms of transportation, as suggested by the change to the title.

- (pages 20-21) -- the 3rd draft includes a new provision that expressly allows new development in critical areas within the Anacortes Community Forest Lands ("ACFL"). This provision must be removed to ensure that the wetlands and FWHCAs in the ACFL are not impacted. To the extent that the purpose of this text is to allow some recreational development in portions of the ACFL that do not qualify as wetland or FWHCA, then the language could be revised to ensure that the CAO does not provide blanket approval to develop wetlands and streams in the ACFL.

7. Final Points.

The following bullets identify several other necessary clarifications for the CAO (the page numbers refer to the page in the electronic document):

- (page 8) -- in the Project Evaluation section, 19.70.030, consistent with what has become the standard approach, the City should indicate that they may seek independent review of a project's impacts through a consultant funded by the applicant.

- (page 9) – Section 19.70.035.C.4. allows a complete rebuild of nonconforming structures damaged by fire/etc. To better implement the City's land use planning goals and for consistency with modern approaches and for fairness to other property owners, the text should be revised to clarify that if a building is destroyed more than 75% of its value, a rebuild will be consistent with current rules.

- (page 16) – On its face, Section 19.70.045.A. appears to broadly allow alterations to critical areas and their buffers. We recommend that the language be revised per the table at Section A above to ensure that it does not authorize unintended development in critical areas and buffers.

- (page 37) – The ordinance deletes the Ship Harbor wetland, Cannery Pond, and wetlands within the watersheds of Little Cranberry Lake, Whistle Lake, and Heart Lake from categorization as regionally significant wetlands. While we appreciate that these areas have been designated as Fish and Wildlife Habitat Conservation Areas, they continue to receive strong support for designation as regionally significant wetlands and should remain so designated.

- (pages 46 and 64) – Setbacks are intended to prevent buffer development or alteration. Yet the decks, roofs, overhangs, and stairways and steps that Sections 19.70.235.H and 19.70.330.D authorize would encourage the removal of buffer vegetation to avoid frequent maintenance of those areas from limbs or litter fall. Therefore, those items should be precluded in setbacks and that text removed. In addition, there is no scientific rationale for reducing the setbacks, and the provision for doing so should be removed.

- (page 57. **Stream names**) – the 3rd draft of the CAO would eliminate the CAO's existing reference by name to fifteen local streams. Evergreen asks that you reinstate those stream names as shown in the table above. In addition to honoring important community spaces, this action will demonstrate that the City has not unintentionally dedesignated those places currently designated as FWHCAs.

- (page 61) – Section 19.70.325.F. authorizes access roads through FWHCAs and buffers for subdivisions if a consultant reports that no other feasible alternative exists and impacts will be mitigated. Since new subdivisions will be able to design parcels to avoid the need for developing access roads in FWHCAs, that language should be revised to ensure that only subdivisions established prior to the critical areas ordinance update can take advantage of that exception.

Thank you for your consideration of these comments. We urge you to protect the functions and values of critical areas and to include the Best Available Science in doing so.

Sincerely,



Kyle A. Loring
Attorney for Evergreen Islands

Attchs

Cc: Anacortes City Council, Anacortes Mayor, Marlene Finley

EXHIBIT A



Fixing Compensatory Mitigation: What Will it Take?

Author(s): Margaret S. Race and Mark S. Fonseca

Source: *Ecological Applications*, Vol. 6, No. 1 (Feb., 1996), pp. 94-101

Published by: Ecological Society of America

Stable URL: <http://www.jstor.org/stable/2269556>

Accessed: 08/04/2009 17:35

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FIXING COMPENSATORY MITIGATION: WHAT WILL IT TAKE?^{1,2}

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Abstract. This study was undertaken to review the current status of permit-linked mitigation policies and practices in order to determine implications of the continued use of mitigation as a wetlands management tool within the United States. Based on reviews of both published literature and agency reports, our survey of past mitigation projects nationwide indicates that the success rate of permit-linked mitigation projects remains low overall. In addition, there is continuing difficulty in translating mitigation concepts into legal principles, regulatory standards, and permit conditions that are scientifically defensible and sound. Based on the record of past poor performance, we assert that continued piecemeal revision efforts focused on technical or scientific details are not likely to make compensatory mitigation more effective. There is need to acknowledge the extent to which non-scientific, real-world complications plague current policies and practices. To prevent continued loss of wetlands under compensatory mitigation, decisive action must be taken by placing emphasis on improving compliance, generating desired acreages, and maintaining a true baseline. Without selective changes in the status quo, current policies and poor implementation are likely to lead to further wetland losses.

Key words: *compensatory mitigation; habitat mitigation; habitat replacement; man-made wetlands; mitigation failures; mitigation policies; permit compliance; restoration of aquatic ecosystems; wetlands management; wetlands mitigation; wetlands restoration.*

It's deja vu all over again.
(attributed to Yogi Berra)

INTRODUCTION

In the space of two decades, mitigation has evolved from a seldom-used dictionary term to a heavily applied wetlands management practice that has become firmly entrenched with agency managers who are charged with the dual responsibilities of safeguarding the nation's wetlands and approving proposals for development. Questions about the advisability and success of mitigation projects surfaced over a decade ago (Race and Christie 1982), and persist in lively debates that continue to the present, bolstered by expanded scientific research and increased practical experience (e.g., Race 1985, Harvey and Josselyn 1986, Race 1986, Batha and Pendleton 1987, Zedler 1987, O'Donnell 1988, Redmond 1992). At the heart of the current debate is the practice of permit-linked compensatory mitigation: required actions that are intended to compensate for environmental damage or loss of habitat through replacement of functions, values, or acreage of wetlands proposed for destruction. Very often compensatory mitigation involves creation of new wetlands or enhancement of existing wetlands.

According to current federal policy, explicit trades

between permitted impacts and mitigation requirements should not be allowed, and mitigation efforts should be "sequenced," with a preference for avoiding and minimizing wetland impacts before resorting to compensatory mitigation. However, with so much at stake in the permit process, the unfortunate reality is that discussions often focus heavily on compensatory mitigation as a means of offsetting habitat damage or loss. Although hardly responsible for the majority of national wetland losses, the practice of compensatory mitigation remains a serious concern because it is a bartering scheme that trades permission to damage a known quantity of wetland area for the promise of some kind of replacement, sometimes at locations away from the impacted area. The manner in which this bartering is pursued varies widely under local, state, and federal agencies whose jurisdictions overlap in wetlands. Thus, the process of planning and permitting compensatory mitigation projects is not at all consistent.

In this paper we take a renewed look at mitigation in a broad context and ask once again whether mitigation—as currently conceived in policy and applied in practice—is a useful wetlands management tool or, rather, an option that inevitably contributes to further incremental loss of habitats regionally and nationally in response to persistent demands for development permits.

¹ Manuscript received 14 July 1994; revised 3 March 1995; accepted 8 March 1995.

² For reprints of this group of papers on wetland mitigation, see footnote 2, page 33.

BACKGROUND

In reviewing the literature, it became clear we can add little that has not already been said in the mitigation debate. Every year, there are conferences in the United States with mitigation or restoration as a theme (e.g., Annual Symposium on the Restoration and Creation of Wetlands, Hillsborough Community College, Tampa, Florida). Moreover, several texts have addressed the full spectrum of mitigation issues (Kusler and Kentula 1990, NRC 1992, Thayer 1992). Each volume provides summaries of definitions, analyses of scientific advances, and discussion of protocols and guidelines for a variety of wetland mitigation, restoration, and creation options. It is clear that the field has progressed considerably since a time when there "was no consistent definition of what [mitigation] was nor any consensus as to how it should be applied" (Race and Christie 1982).

While the proliferation of studies about mitigation is both encouraging and helpful, it is interesting to note that much of the work on mitigation remains outside the peer-reviewed literature. A computer search using BIOSIS revealed only 44 citations since 1987 for mitigation when the word was combined with the terms habitat, or wetland, or ecosystem. In addition, many of these entries were abstracts. In our opinion, this lack of peer review represents a serious flaw in the evolution of mitigation technology and philosophy.

If there is so much scientific and practical information about mitigation, why is there a lingering undercurrent of doubt about compensatory mitigation (Roberts 1993)? Part of the reason may come from its continuing close association with, and reliance on, restoration ecology. The National Academy of Sciences report on aquatic ecosystem restoration (NRC 1992) emphasizes the tremendous potential of restoration techniques for replicating lost functions and values as well as former plant and animal communities. In fact, the report advocates a goal of "restoring 10 million wetland acres" (4.05×10^6 ha) over the next 18 yr throughout the nation. However, as noted by Nicholas (1992):

one of the report's major contributions is an honest picture of the present state of wetland restoration—rudimentary, at best; criminally inept, at worst. The lack of knowledge about wetland functions and values and the lack of a larger planning context in which restorations are carried out are identified as serious limitations in ongoing efforts.

According to the NRC (1992) report, mitigation efforts cannot yet claim to have duplicated lost wetland functional values; nor has it been shown that restored wetlands maintain regional biodiversity or recreate functional ecosystems.

Further doubts about compensatory mitigation are raised from reviewing the outcome of actual mitigation

projects in the field. Despite evolving sophistication by the research and management community, the results are not encouraging, and the success of mitigation remains in serious doubt.

SURVEYS OF MITIGATION PROJECTS

Race (1985) contended that premature extrapolation of experimental results led to institutionalization of mitigation as a policy with little to suggest that it fulfilled expectations of restored ecosystem function. She based this conclusion on a review of 6 yr of permit history and surveys of 33 restoration projects located in San Francisco Bay. In general, noncompliance with permit conditions was the norm. Unfortunately, these findings were not unique.

Eliot (1985) reviewed 58 mitigation projects in San Francisco Bay that had been permitted over a 6-yr period. She found they did not adhere to established mitigation policies, they were frequently unsuccessful, and almost half of the projects had not been accomplished by the specified permit completion date. She advocated effective enforcement as the key to mitigation project completion, noting that its absence accounted for much of the noncompliance among permits in her study. She also noted that mitigation ratios (ratio of habitat replaced to habitat lost) varied widely among projects and were not consistently used to determine the acreage of compensating projects. This kind of arbitrariness all but guarantees opposition and legal challenges from developers, who generally feel that current wetlands policies are unfair and inequitable anyway (Wilmar 1986, Wilms 1990).

Quammen (1986a) reviewed studies of mitigation projects in various parts of the country, including Virginia, New England, New Jersey, Florida, and San Francisco Bay. She concluded that on the whole:

compliance with permit conditions is low and that effectiveness of restoration to compensate for wetland losses cannot yet be determined. Only when the project objectives and design criteria are clearly stated as part of the permit conditions, and monitoring is conducted and reported, will we be able to evaluate whether created wetlands are able to compensate for the losses in natural wetlands.

A New Jersey field survey and qualitative evaluation of 30 artificial salt-marsh projects (wetland permit and violation cases) revealed an array of problems including wave damage, sedimentation problems, deteriorating bulkheads, and unplanned shifts in species composition (Shisler and Charette 1986). Additional detailed quantitative sampling at eight of the sites indicated significant differences in nearly all sediment characteristics, vegetational parameters, and macroinvertebrate measures when compared to adjacent natural marshes. The authors concluded that the "restoration and creation of artificial marshes is in an early state of development . . . and their long-term success under var-

ious environmental conditions still needs to be experimentally tested.”

R. A. Cobb³ conducted surveys of a wide variety of wetland mitigation sites in Texas and concluded that permitted activities led to a 0.6:1 ratio of habitat replacement to loss. He concluded that conflicting goals among agencies, lack of customized plans, lack of performance bonds, inexperience, and absence of a structure to assure long-term accountability for the maintenance of a site all conspired to produce meager results.

A report by the Staff of the Bay Conservation and Development Commission (BCDC 1988) evaluated the success of 14 permit-associated mitigation programs involving tideland restoration in San Francisco Bay. They reported that “mitigation programs can and, in most cases where work has been adequately performed, have successfully created and enhanced Bay resources.” However, their criteria for success were based on whether a completed project met the permit’s specific mitigation requirements, rather than how well it replaced or offset the specific, adverse Bay-related impacts of that project (compliance vs. functional success as described by Quammen 1986b). They noted (BCDC 1988) that “while many of the mitigation projects were successful, some well-designed projects have yet to create the desired resources,” suggesting the need for mitigation areas “that are larger in size and greater in resource value than the area disturbed by the . . . project.” Five of the 14 projects experienced some delay in completing all or a portion of their mitigation requirements as a direct result of being unable to either find and/or acquire a suitable restoration site. The report recommended a number of ways to increase overall success including increased attention to enforcing mitigation requirements, greater specificity in prescribed mitigation plans, and requiring that mitigation work begin prior to undertaking the actual permitted project.

In a comprehensive Florida study, the Florida Department of Environmental Regulation (FDER) revisited 119 habitat-creation, enhancement, or preservation sites covered under 63 permits (*unpublished report* submitted to Governor L. Chiles [5 March 1991]).⁴ The survey found that only 6% of the permits were in full compliance, and that in 34% of the permits no mitigation had even been attempted—although losses of natural habitat had gone forward. Interestingly, permits for tidal areas fared better than freshwater sites, with 27% vs. 12% “ecological effectiveness.” To counter these losses, the report suggested that more staff, greater upfront mitigation, filing-fee assessments, and administrative fines for noncompliance were needed to counter habitat losses.

Lewis (1992) combined the FDER study findings with data from two other Florida studies of mitigation projects (D. W. Crewz, *unpublished report* [Mid-project, 1990];⁵ K. L. Erwin, *unpublished report* [1991]⁶) and reported: “Taken as a whole, these three studies looked at 174 regulatory agency-permitted mitigation projects and concluded that only eight achieved compliance with all permit requirements. That’s only a 4.6% success rate . . .”

A detailed audit by the Florida Department of Environmental Regulation reviewed the specifics of >1300 permits, representing ≈10% of all dredge-and-fill mitigation permits during a 5-yr period (FDER, *unpublished report* [1991; Audit Report number AR-249]) (see footnote 4). Their reviews included subsamples of permit files and compliance records as well as inspection of actual mitigation sites and interviews with applicable personnel. The audit reported inadequate record keeping and poor tracking of wetlands mitigation data, a high rate of noncompliance with permit conditions by permittees, inconsistencies in permit conditions within and among Department offices, and inadequate inspections and enforcement. For example, the audit found that 43% of the mitigated permits did not have conditions considered to be adequate and readily enforceable. Only 39% of the permittees had fully complied with the permit conditions in the required time; many projects had not even been started, while others were found to be in noncompliance for reasons including improper elevations, incorrect amounts or types of vegetation, inadequate monitoring or maintenance, and inadequate size or configuration. Only 8% of the freshwater sites and none of the tidal sites were evaluated as being *ecologically* successful, and 28% were so unsuccessful that major remedial action was recommended. The auditors concluded that “the wetlands mitigation program has generally been ineffective,” and that despite some recent improvements, many problems remain.

Mager (1990) documented the existence of at least 763 permitted projects and echoed concern about the lopsided, upfront attention given to mitigation proposals as compared to follow-up: “There is virtually no follow-up once a permit is issued and the ultimate fate of thousands of acres of wetlands is unknown.” These concerns are especially serious when one considers national trends. As noted by Zedler (1996a), a U.S. Environmental Protection Agency (EPA) review of permit records for eight states over the past two decades documented 724 permits in the cumulative record, with 898 wetlands impacted and 745 compensatory wetlands required.

The serious shortcomings of mitigative activities

³ *Unpublished report* (1987) to U.S. Fish and Wildlife Service, Corpus Christie, Texas, USA.

⁴ Available from Florida Department of Environmental Regulation, Tallahassee, Florida, USA.

⁵ Available from Mana-Sota-88, 5314 Bay State Road, Palmetto, Florida 34211 USA.

⁶ Available from South Florida Water Management District, 3301 Gun Club Road, P.O. Box 24680, West Palm Beach, Florida 33416-4680 USA.

have also been expressed by others (Newman 1986). Recently, the Committee on Restoration of Aquatic Ecosystems advised against the use of wetland restoration to offset or justify the destruction of other wetlands until wetland restoration science has moved from a trial-and-error process to a more predictive science (NRC 1992). Subsequently, a review article in *Science* noted the sober reality that under present mitigation policies and practices "losses are likely to be uncompensated for and that what we call mitigation has a high chance of failure" (Roberts 1993). Experts interviewed for that article expressed the consensus that "compensatory mitigation should be the last resort, and must be based on the best available science, with strict, agreed-upon standards to judge success, perhaps by a government agency or private groups, and a commitment by developers to make mid-courses corrections when needed—what Zedler calls 'adaptive management' of the ecosystem." Furthermore, the article concludes with the suggestion that regulatory agencies should require, whenever feasible, that the replacement wetland be completed up front, before the natural one is destroyed.

DISCUSSION

Based on over a decade of survey results, the cumulative record of past mitigation projects remains undeniably poor overall, with disappointingly few examples of success. With hindsight, there are undoubtedly many persuasive explanations for poor performances or partial successes—including inadequate design, poor hydrology, improper location, wrong contours, incorrect elevation, small size, poor sediment characteristics, lack of skill by constructors, invasion of exotic species, exposure to severe storms, vagaries of nature, or surveys performed too early in the developmental stage to demonstrate success. It is not our intention to reanalyze past projects with the goal of identifying and systematically ranking the reasons for poor performance. In our opinion, such a task would be both unnecessarily costly and unproductive. Rather, it is time to admit the limitations in both our knowledge and our ability to gain additional information in a timely fashion. As discussed by Ludwig (1993), there comes a time when it is advisable to seek resolution to resource management issues outside the traditional scientific realm. While there is certainly need for continued scientific and on-site research, it is *doubtful whether additional scientific information will be sufficient to resolve the current problems of compensatory mitigation* or make it more effective. In the face of escalating political attacks on wetlands protection efforts and the apparent necessity of continuing to use mitigation as a wetlands management tool, it is arguably more important to explore ways to improve overall mitigative performance as soon as possible. It is also important to acknowledge a number of real-world com-

plications that are likely to frustrate attempts to improve compensatory mitigation policies and practices.

Tensions between a landscape approach and existing permit policies

Over the years the conceptual view of environmental impacts has evolved significantly, from an early perspective that assessed mainly direct project impacts, to a later view that focused on cumulative impacts, and most recently to a landscape approach. This evolution in perspective has not been accompanied by corresponding shifts in the wetlands permit process. For example, there is considerable debate about the correct scale over which to evaluate wetland functions and impacts to them. Bedford and Preston (1988) and Zedler (1996b) argue persuasively that the inability to document cumulative impacts has resulted in a continued focus on impacts bounded by the arbitrary definitions of a given project, without proper consideration of the linkages between communities and ecosystems. This disparity between landscape planning goals and individual projects often conflicts with individual property rights, thereby setting severe limits on the use of landscape approaches with compensatory mitigation.

The problem is largely a social one; we are a society that has not progressed past the frontier economics that initially categorized wetlands as a resource to be reclaimed, and that emphasizes private-sector goals over public concerns (M. E. Colby, *unpublished report*).⁷ How, in the absence of strict environmental oversight, can a landscape approach be utilized in compensatory mitigation? Barring significant erosion of private property rights, we submit that it cannot. Depending on the scale chosen, landscape management may encompass literally thousands or millions of individual property owners. Taking a large-scale, ecosystem approach to wetlands management is a significant change in natural resource management policies, one representing a major paradigm shift that will require radical revision in values, management practices, and institutional structures in order to succeed (Cortner and Moote 1994).

Maintaining consistency in the permit process is critical if we wish to avoid problems caused by conflicts with private ownership and questions over legal "taking" of land or inequitable government compensation for land in question. Thus, integrating ecologically relevant concepts such as landscape-scale decision criteria need more than good science; it will also require conscious redesign of the entire permitting infrastructure to avoid legal challenges. If developers are not offered what they perceive as rational alternatives, we should not be surprised to see them respond by litigating against compensatory mitigation (Wilmar 1986).

⁷ Policy planning and research working paper series, publication number WPS 313. Available from Strategic Planning and Review Department, The World Bank, New York, New York, USA.

Currently, review of mitigation requests is on a case-by-case basis (and will likely remain so for a long time), a process that explicitly recognizes private ownership of land and presumably treats all projects with the same set of guidelines or requirements. Adopting a landscape approach to compensatory mitigation may generate unanticipated legal complications. For example, later permittees might face more stringent controls or requirements because of cumulative impacts to the regional ecosystem caused, in part, by earlier permittees. For the landscape approach to guide compensatory mitigation projects, there must be an acceptable mechanism to justify changes in permitting criteria while balancing individual property rights. The practice of adaptive management—utilizing post-approval monitoring, changes in performance standards, revisions of compliance criteria, and repeated corrective measures—could result in charges of inconsistency or capriciousness if regulators repeatedly change the rules and requirements for permit holders.

Exemptions, small cumulative losses, and continued erosion of the wetlands baseline

Gladwin and Roelle (1992) noted that exemptions under the Corps of Engineers Nationwide Permit 26 program (authorizing discharges in “<10 acres” (4.1 ha) of wetlands)⁸ cause significant unrecorded wetlands losses from many small impacts. The current structure of permit and exemption processes virtually guarantees incremental, cumulative loss of wetlands. This means that failed mitigation projects or other small losses will not be detectable until their cumulative impact is seen on a very large scale. When detectable, these cumulative losses would indicate an alarming state of decline where remedial action is bound to be prohibitively expensive.

In some quarters there is optimism that remote-sensing technology can be brought to bear upon cumulative impact problems and landscape-scale wetlands management. In order to guide compensatory mitigation planning, the resolution of the landscape assessments must be consistent with the physical size of the compensatory mitigation projects. Rivera et al. (1992) determined that, depending on the sensing technology, 36–68% of the projects being approved for wetland alterations occurred below the detection limit of the technologies at hand. Although new technologies can provide resolution at <1-m scales, such as those being used in San Diego Bay (J. Zedler, *personal communication*), it may be some time before these are used nationwide. The sheer mass of data that would be processed for watershed-scale maps with 1-m resolution

seems sufficiently costly at present to inhibit regional planning processes. Further, expecting routine high-resolution mapping of individual mitigation projects seems unrealistic given the widespread lack of follow-up and monitoring. At least for the foreseeable future, remote sensing will probably not provide oversight data for small mitigation projects nor aid in quantitative assessment of their cumulative impacts. Without accurate information on acreages of historical and current losses, it is difficult to address questions such as “what is the baseline level of habitat?” and “to what standard do we compare the extant acreage?”.

Many resource managers argue that mitigation is better than getting nothing at all in return for coastal development projects that would otherwise proceed with no recompense for environmental degradation. We disagree. In the short term, mitigation projects that do not meet the no-net-loss criteria become a liability in the effort to sustain local ecosystem functions. Over the long run, wetland management policies that allow development before the delivery of prescribed mitigative compensation contribute to the downward spiral of cumulative habitat loss. These losses may have to be offset by other projects that must provide higher ratios of replacement acreage to lost acreage for compensation. Without overcompensation through other projects, the “better something than nothing” approach constitutes a tacit approval of accepting net loss of habitat.

RECOMMENDATIONS

As described above, vexing problems continue to plague the policies and practices of compensatory mitigation. There is great difficulty in translating mitigation concepts into legal principles, regulatory standards, and permit conditions that are scientifically defensible and fair. Despite the dedicated efforts of researchers, practitioners, and regulatory officials nationwide over the past decade, there remains no universally accepted standard for required compensation—a situation that, in our opinion, is likely to persist for some time, even in the face of expanding research in restoration ecology.

While we agree there are many ways to reduce the risks of failure in wetlands restoration projects (e.g., NRC 1992: Chapter 6), it is important not to be overly optimistic that either more research, more time, more highly trained consultants, or more money will necessarily mean reduced failure rates. Even when wetland restoration experts have adequate budgets, ample time, extensive on-site experimental data, and the ability to take an adaptive management approach, functional success cannot be guaranteed (Zedler 1996b).

The permit process is still significantly ahead of the scientific debate regarding issues such as functional equivalency, biological diversity, and reconstruction of landscape patterns. Questions about substitute wetlands will no doubt continue even as additional permits are issued. Until we begin to approach at least rudimentary

⁸ The Clean Water Act (1972) authorized the Corps of Engineers to issue permits for discharges of dredge or fill materials in the waters of the U.S. Also, the Corps was given additional permit authority in 1984 under the Nationwide Permit 26 Program (NWP 26) which allows fill of <10 acres in non-tidal wetlands.

compliance on a regular basis (such as actually initiating the work), no one will be able to determine whether these habitat exchanges can be justified on scientific grounds. Getting to compliance is the key. There is ample reason to believe that compensatory mitigation can still work—but only if we act decisively to implement some of the many insightful recommendations that have already been put forth in the literature.

Activities aimed at improving compliance

A stronger emphasis on permit compliance and enforcement is needed to improve the overall success rate of mitigation projects (Redmond 1992). Up-front completion of mitigation projects will help the situation, but only if there is some way to monitor, verify, and enforce actual compliance *prior* to commencement of the development project. Even if compliance levels eventually approach 100%, we must continue to monitor and evaluate functional equivalency of the mitigated habitat vs. the natural area that it replaces.

As noted by Lewis (1992), mitigation programs currently lack the tools necessary to enforce and ensure success of wetlands creation and restoration projects or even to see that they get done. Several factors combine to deter agencies from vigorous enforcement including the actual dollar costs of enforcement, the political costs of added staff, and the political costs of prohibiting development (Jensen 1987). Despite these problems, agencies must reconsider the issue of enforcement and monitoring, exploring ways to increase effective oversight of mitigation projects and ensure their compliance with permit conditions. Unless enforcement and monitoring are emphasized, noncompliance will likely continue as the norm, because there are no penalties or incentives for a permit holder to adhere to permit conditions.

In seeking to address the problems of noncompliance and lack of enforcement, there is need to plan carefully and avoid pitfalls associated with proposed solutions. For example, Wold (1990) described the problem caused by disparity of fine assessments for NOAA's [National Oceanic and Atmospheric Administration] civil penalty policy for overfishing. He concluded that the fines were so low in contrast to the benefits of overexploiting the resource as to not be a deterrent, and that inconsistent application of fines led to litigation because of perceived unfairness. Proposed penalties or incentives that seek to improve compliance must be considered in light of the beneficial services of functional wetlands (e.g., erosion control, primary and secondary production, aesthetics, etc.). With wetlands, various approaches that either penalize or provide incentive to a permit holder can be found, including performance bonds, civil fines and penalties, mitigation banking, and in lieu fees. Because none of these approaches, especially mitigation banking, is without problems (King 1992, Lewis 1992, King and Bohlen 1994), resource managers should review how

these alternatives contribute to overall compliance and no-net-loss-of-wetlands goals.

We strongly advocate that restoration and/or mitigation be *on site* and *in kind* as it has the greatest potential to minimize disruption of remaining ecological functions (by recognizing the importance of position in the landscape as opposed to simply quantities of habitat). This tactic should be especially emphasized in areas where significant ecological linkages and functions still exist. However, in highly disturbed settings such as urbanized areas where substantial habitat fragmentation has already occurred and ecological functions may be further impaired by the very act of mitigation (e.g., mobilization of hazardous materials during recontouring), alternatives such as mitigation banks may be a more realistic solution, albeit not without problems. Clinging to a landscape perspective in extremely fragmented or polluted settings makes little ecological sense in locations where the landscape has essentially vanished. Whatever actions are taken to increase compliance with permit conditions, they must truly lead to effective prohibition of wetlands degradation.

Clearly, alternative approaches must be executable in the face of tight budgets and conflicting agency mandates. One suggestion to improve compliance might be implementation of an approach similar to that used by the U.S. Internal Revenue Service (the tax-collection branch of the U.S. federal government), with audits, fines, and civil penalties. Such an approach may be tractable for agencies, both politically and economically. The idea is not to survey every permitted project after the fact, but to randomly choose projects and hold them to the strict criteria put forth in the permit conditions. The uncertainty of such an *audit* may well provoke much-needed attention to detail in mitigation projects. In addition, any fines that were generated for noncompliance could be used for actual habitat restoration purposes if they are so earmarked. By establishing expectations of audits for performance and compliance, repeated mistakes by unqualified practitioners would eventually be discouraged.

Budget reallocations

We recognize that any recommendation to increase monitoring, enforcement, and compliance-related activities will necessarily require a reexamination of how agency dollars are allocated. In general, agency dollars have been divided among tasks such as damage assessment; permit reviews and negotiations; inventory and resource surveys; research and development; and, to a lesser extent, enforcement and compliance. Assuming that increased funding will not be available, it may be necessary and advisable to reallocate funding in ways that emphasize permit compliance, even if this means de-emphasizing some research and inventory tasks, especially coarse-scale, dated inventories.

*Focus on generated acreage and establish
a true baseline of acreage*

Many researchers have commented on the lack of information comparing important biological functions of human-made and natural wetlands. However, in our view, concerns about function are eclipsed by concerns about generating habitat in the first place. The main priority should be on actually generating the acreage of habitat for which permits have been written. Once acreage is assured, only then does it make sense to emphasize the debate over how to measure wetland quality, function, natural equivalency, or persistence. If required acreage is not being delivered on a regular basis, then permit conditions must be strengthened.

Conclusions

As we noted at the outset, the issues in the debate over mitigation are not new, and neither are our recommendations. In fact, much of what we have discussed echoes the collective wisdom of researchers, practitioners, and agency managers, who for years have been making individual recommendations about their particular situations. The time has come to act deliberately on these collected recommendations with the aim of improving overall mitigation success. Certainly, this means applying technical skills and scientific knowledge; but it also requires an appreciation of the socio-political context of that work.

In this spirit, we suggest the need to plan strategically and prioritize actions selectively in order to realize a true no-net-loss of wetlands. We must avoid continued piecemeal revision efforts focused on technical or scientific details that are not likely to make compensatory mitigation a more effective management tool. The time has come to refocus compensatory mitigation efforts in a way that acknowledges underlying problems linked with unavoidable cultural, political, development, economic, and institutional constraints. This in no way undermines the importance of scientists or restorationists in the process; everyone must take a larger view of the mitigation process, translating and implementing their findings where appropriate. But to prevent continued losses of wetlands under compensatory mitigation, we must reorder our priorities, putting emphasis on improving compliance, generating desired acreage, and maintaining a true baseline. Unless we change the status quo of compensatory mitigation, we fear that the baseline of wetlands acreage will continue to erode in the face of faulty policies and poor implementation. We think the system is fixable, but only with deliberate, selective changes. In our optimistic moments we look forward to a time when review papers like this are not a decadal event.

ACKNOWLEDGMENTS

The authors extend special thanks to Joy Zedler for her many helpful suggestions and extreme patience during the preparation of this manuscript. Thanks also to two reviewers,

Curtis Bohlen and Jon Kusler, for their comments and suggestions for revision.

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EXHIBIT B

Structural and Functional Loss in Restored Wetland Ecosystems

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Abstract

Wetlands are among the most productive and economically valuable ecosystems in the world. However, because of human activities, over half of the wetland ecosystems existing in North America, Europe, Australia, and China in the early 20th century have been lost. Ecological restoration to recover critical ecosystem services has been widely attempted, but the degree of actual recovery of ecosystem functioning and structure from these efforts remains uncertain. Our results from a meta-analysis of 621 wetland sites from throughout the world show that even a century after restoration efforts, biological structure (driven mostly by plant assemblages), and biogeochemical functioning (driven primarily by the storage of carbon in wetland soils), remained on average 26% and 23% lower, respectively, than in reference sites. Either recovery has been very slow, or postdisturbance systems have moved towards alternative states that differ from reference conditions. We also found significant effects of environmental settings on the rate and degree of recovery. Large wetland areas (>100 ha) and wetlands restored in warm (temperate and tropical) climates recovered more rapidly than smaller wetlands and wetlands restored in cold climates. Also, wetlands experiencing more (riverine and tidal) hydrologic exchange recovered more rapidly than depressional wetlands. Restoration performance is limited: current restoration practice fails to recover original levels of wetland ecosystem functions, even after many decades. If restoration as currently practiced is used to justify further degradation, global loss of wetland ecosystem function and structure will spread.

Citation: Moreno-Mateos D, Power ME, Comín FA, Yockteng R (2012) Structural and Functional Loss in Restored Wetland Ecosystems. *PLoS Biol* 10(1): e1001247. doi:10.1371/journal.pbio.1001247

Academic Editor: Michel Loreau, McGill University, Canada

Received: May 27, 2011; **Accepted:** December 8, 2011; **Published:** January 24, 2012

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Funding: Support for this research came from Spanish Ministry for Innovation and Science (www.micinn.es) and Spanish Foundation for Science and Technology through the postdoctoral mobility grants program, and from the National Centre for Earth Surface Dynamics (nced.umn.edu), an NSF Science and Technology Center. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

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Introduction

From tropical mangroves to boreal peatlands, wetlands are amongst the most productive and economically valuable ecosystems in the world [1]. They provide critical ecosystem goods and services, including carbon storage, biodiversity conservation, fish production, fuel production, water purification, flood and shoreline surge protection and erosion control, and recreation [1–3]. However, owing to human activities, over half of the wetland ecosystems existing in the early 20th century have been lost in North America, Europe, Australia, and China [2]. Over the last century, restoration of degraded wetlands and creation of new ones have been attempted, in efforts to recover physical, chemical, and biological processes and entities lost because of wetland destruction or degradation [4]. Frequently, however, this approach does not restore ecosystem structure and functions to preimpact levels [5–8]. In North America (including Canada, United States, and Mexico) alone, over US\$70 billion have been spent attempting to restore more than 3,000,000 ha of wetlands in the last 20 y (see Text S1) [9], but the recovery trajectories of structure and functions in restored wetlands have not yet been globally assessed [10,11].

After degradation or natural perturbation, ecosystem structure and functions recover towards reference levels [7,12], but recovery

rates might be affected by the physical characteristics of the ecosystem, the degrading activity, or the environmental setting [7,12]. Abiotic factors, such as size of restored ecosystems and climate, might affect recovery rates. It could be expected that intensely engineered small (few hectares) wetlands might recover faster than less manipulated, large wetlands (hundreds of hectares) to their original characteristics, but this prediction remains unconfirmed. Higher recovery rates could also be expected in warmer climates than in cold ones, because of accelerated ecosystem processes [7,13]. Restoration efforts during the recovery process may lead ecosystems to reference states or redirect them towards alternative states [14–16] that could also be initiated by prerecovery disturbance itself. If recovery is slow, it could be difficult to distinguish between these alternatives. We surveyed long-term (up to 100 y, available for some but not all of the studied variables) chronosequences of restored wetland ecosystems from 621 restored and created wetlands relative to 556 reference wetlands (Figure S1). Following Article 1.1 of the Ramsar Convention of Wetlands [17], we considered wetlands to be marshes, peatlands, floodplains, mangroves, depressional wetlands, and lacustrine wetlands—submerged permanently or periodically under flowing or still fresh, salty, or brackish water. We compared structure and function of 401 wetlands restored on sites where they had been previously degraded and 220 newly

Author Summary

Wetlands, which include tropical mangroves and boreal peatlands, are among the most valuable ecosystems in the world because they provide critical ecosystem goods and services, such as carbon storage, biodiversity conservation, fish production, water purification, and erosion control. As global change accelerates the loss of wetlands, attempts are increasing to restore this fragile habitat and its associated functioning. There has been no global evaluation, however, of how effective such restoration efforts have been. Here, we present a meta-analysis of the biological structure (driven mostly by plant communities) and biogeochemical functioning (driven primarily by the storage of carbon in wetland soils) of 621 wetland sites. Our analysis suggests that even a century after restoration efforts, these parameters remained on average 26% and 23% (respectively) lower in restored or created wetlands than in reference wetlands. Our results also indicate that ecosystem size and the environmental setting significantly affect the rate of recovery. Recovery may be more likely and more rapid if more than 100 contiguous hectares of habitat are restored. In warm climates, and in settings linked to riverine or tidal flows, recovery can also proceed more rapidly. In general, however, once disturbed, wetlands either recover very slowly or move towards alternative states that differ from reference conditions. Thus, current restoration practice and wetland mitigation policies will maintain and likely accelerate the global loss of wetland ecosystem functions.

created wetlands (wetland creation *de novo* is currently accepted for environmental mitigation [4]). We also examined how size of ecosystem and its environmental setting (climate regime and hydrologic connectivity) affected recovery. Using a standardized method (see Materials and Methods), we selected 124 studies (see Text S2) in which ecological responses were measured at known time intervals since restoration. From the selected studies, we extracted 1,501 data points (Tables 1, S1, and S2) comparing hydrologic, biological, and biogeochemical variables in restored or created and reference wetlands. Response ratios (see Materials and Methods) were calculated for each data point. Variables selected

from the same studies were not necessarily independent (see Materials and Methods), so statistical inferences must be interpreted cautiously.

We compared recovery trajectories of hydrologic, biological, and biogeochemical variables of restored and created wetlands to address three questions: (a) How fast are biological and biogeochemical components of restored ecosystems changing relative to less perturbed reference ecosystems?; (b) Do these changes trend towards or away from the predisturbed ecosystem or parallel control ecosystems?; and (c) Does wetland size or environmental setting (regional climate, hydrologic connectivity) affect recovery?

Results/Discussion

Hydrologic and Biological Recovery

Some hydrologic features can often be restored by manipulating local topography, soil permeability, surface and ground water flows—physical features that are usually engineered in wetland restoration projects. Hydrological features defined for these analyses (Table 1) appeared to be recovered immediately after restoration (Figure 1A), but see Cole [18], Hunt et al. [19], Ahn and Dee [20], and Kumar and Zhao [21] for deeper considerations of challenges to hydrologic restoration in wetlands (from factors like climate variation [20] or complex flow paths of water through heterogeneous vegetation and soils [21]). In addition, all hydrologic variables reported in studies we reviewed were followed only for 10 y to 15 y, so longer-term changes remain unknown.

In contrast to reported hydrologic performance, biological structure (as defined in Table 1) in restored or created wetlands, recovered to only 77% (on average) of reference values (Figure 1A and 1B; Table S3), even 100 y after restoration, when data on 14 taxa from two studies of three wetland sites are available [22,23]. Abundance, species richness, and diversity of native animals and plants in wetlands were severely reduced following degradation. After restoration, recovery proceeded at different rates, and trajectories plateaued at different levels. Vertebrate assemblages reached similar structural values to those in reference wetlands within 5 y (Figure 1B). Vertebrate richness recovered more slowly than abundance ($p=0.021$; Figure 2A), possibly reflecting responses by a few highly mobile vertebrate species [24,25] once

Table 1. Variables measured simultaneously in restored or created and reference wetlands to estimate wetland restoration performance over time.

Wetland Structure and Functions	<i>n</i> ^a	Variables Measured
Hydrology	32	Water level, flooding regime, water storage
Biological components	809	
Vertebrates	166	Abundance, density, species richness, occupancy
Macroinvertebrates	161	Density, abundance, species richness
Plants	439	Plant cover, species richness, biomass, abundance
Biogeochemistry	692	
Carbon storage and cycling	103	Soil total and organic carbon, respiration rate, mineralization rate
Nitrogen storage and cycling	102	Soil total and organic nitrogen, denitrification, and nitrification
Phosphorus storage	103	Soil total and organic phosphorus, Ca-Fe-Al bounded phosphorus
Other elements storage	106	Salinity, soil Fe, Al, Ca, K, Mn, Mg, water dissolved oxygen
Organic matter accumulation	177	Soil organic matter, bulk density, soil texture, soil moisture

Only the most frequently measured variables were included (see Tables S1 and S2, for full description of the variables measuring restoration performance).

^a*n* = number of variables used to plot each chronosequence.

doi:10.1371/journal.pbio.1001247.t001

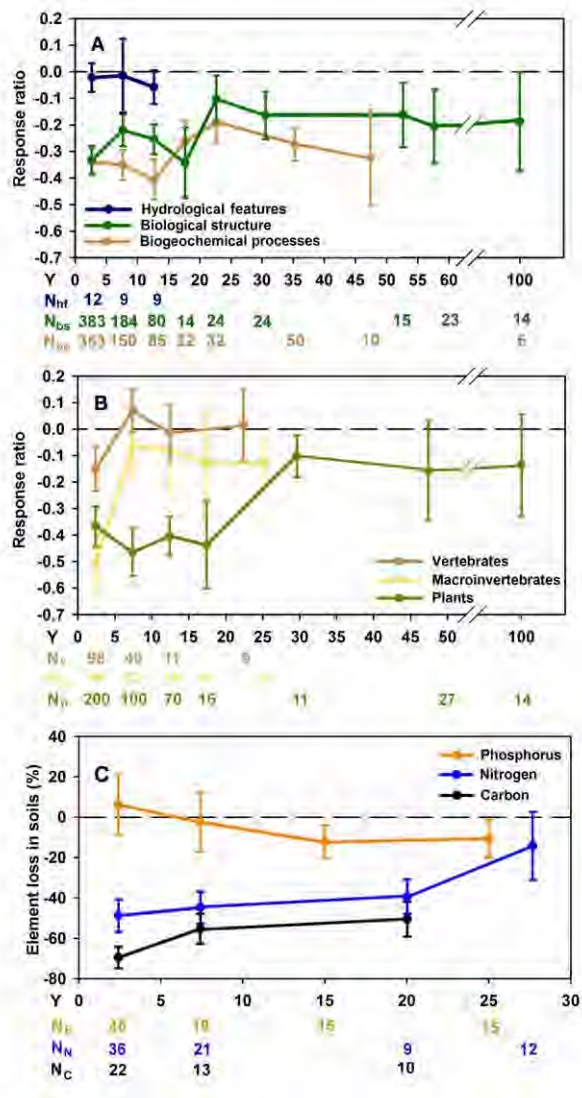


Figure 1. Recovery trajectories of created and restored wetlands. Chronosequences of the means ($\pm$ standard error [SE]) of the response ratios (see Materials and Methods) of restored and created wetlands at successive age classes of 5 y or 10 consecutive y for hydrology, biological structure, and biogeochemical functions (A) and for the main biological structural components (B). Chronosequences of the means ($\pm$ SE) of the element loss in soils of restored or created wetlands at successive age classes of 5 y or 10 consecutive y (C). The zero value dashed line represents reference wetlands. Only trend lines for those variables for which we had enough data points (see Materials and Methods) were plotted (N, number of data points used to calculate the mean [$\pm$ SE] per age class; Y, years after restoration. Subscripts are as follows: bp, biogeochemical processes; bs, biological structure; C, carbon; hf, hydrological features; m, macroinvertebrates; N, nitrogen; p, plants; P, phosphorus; v, vertebrates). doi:10.1371/journal.pbio.1001247.g001

hydrological connectivity was restored. Macroinvertebrates (64% noninsects) took 5 y to 10 y to statistically converge with reference assemblages in restored and created wetlands (Figure 1B), and average values never reached absolute reference levels. Many macroinvertebrates cannot recolonize new or restored wetlands by themselves, but are carried in by flowing water or other organisms [26,27]; however, their short life cycles (often annual or semi-

annual) could accelerate population recovery after they arrive [28,29].

Plant assemblages in restored and created wetlands were slowest to recover. Plants took on average 30 y to converge statistically with reference states; although again, absolute average values of structural features of plant assemblages remained lower than reference levels even after 100 y following restoration (Figures 1B and 2B). The slow and incomplete recovery of plant assemblage might be due to dispersal limitation, vulnerable early life history stages, or sensitivity of any life stage to altered conditions (e.g., reduced organic content of soils, discussed below) during early succession following disturbance [30,31]. Other factors, such as exotic colonists, subsequent disturbance or altered disturbance regimes, priority effects (historical legacies), and nonlinear interactions may also lead to delayed recovery or persistent differences between restored biota and those in reference wetlands [6,31,32].

Biogeochemical Recovery

Four biogeochemical responses were sufficiently well documented in some studies we reviewed to examine trends over time: these were the storage of carbon, nitrogen, and phosphorus (Figure 1C) (see also storage and cycling combined for carbon and nitrogen in Figure S2A), and the accumulation of organic matter in soil (Figure S2B). The storage and cycling of carbon and nitrogen were drastically reduced from preimpact levels after degradation. In contrast, phosphorus storage seemed unaffected. After restoration, responses were variable. Initially, carbon storage increased slightly but then plateaued below reference levels; nitrogen storage and cycling increased slowly but continuously; and phosphorus storage remained unaffected. Wetland degradation notoriously oxidizes stores of accumulated organic carbon and releases CO₂ to the atmosphere, as aerobic conditions accelerate microbial respiration [2,33]. After wetland hydrologic regimes are recovered, more anaerobic conditions allow stores of organic carbon to slowly reaccumulate in the soil. After 20 y, however, carbon storage in restored and created wetland soils was still significantly lower (by 50%; $p = 0.008$) than in reference wetlands (Figure 1C; Table S3; Text S1; data from six studies of 21 wetlands) Organic matter accumulated slowly [34,35], so that average values remained only 62% of the value at the reference wetlands 20–30 y following restoration (Figure S2B; data from seven studies of 21 wetlands).

Aerobic conditions in degraded wetlands also perturb nitrogen storage and cycling, allowing mineralization of organic N and transformation of ammonium to nitrate [2]. Nitrate is quickly processed by microorganisms and plants, leaving the original pool of nitrogen in the soil depleted or unavailable. Nitrogen storage remained significantly lower in restored wetlands for 30 y after the wetlands were restored or created (Figure 1C; Table S3). Depleted or unavailable soil nitrogen can limit wetland productivity, retarding carbon storage [33,36]. In contrast, total phosphorus decreased only slightly in restored or created wetlands and did not show significant differences with reference wetlands (Figure 1C). Although, phosphorus chemical fractions could change in representation, the amount of total phosphorus did not change significantly [37]. This lack of variation in phosphorus might be explained because of the more conservative cycling by phosphorus (lack of exchange with the atmosphere) [38]. In addition, without extrinsic inputs, phosphorus levels would be geologically determined.

After 50 y to 100 y, restored wetlands recovered only to an average of 74% of their biogeochemical functioning relative to reference wetlands (Figure 1A; data from two studies of seven wetlands; data of wetlands recovering for more than 50 y after

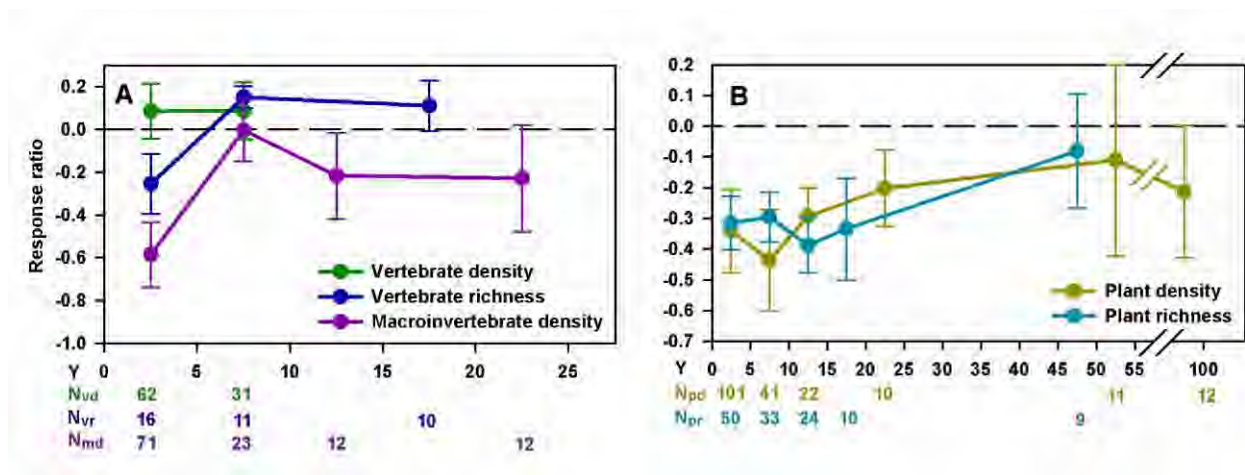


Figure 2. Recovery trajectories of animal and plant richness and density. Chronosequences of the means ($\pm$ standard error [SE]) of the response ratios (see Materials and Methods) of restored or created wetlands at successive age classes of 5 y or 10 consecutive y for vertebrates and macroinvertebrates density and richness (A) and for plant density and richness (B). Insufficient data points meeting our plotting criteria (see Materials and Methods) were available to plot for macroinvertebrate richness. The zero value dashed line represents reference wetlands (N, number of data points used to calculate the mean ($\pm$ SE) per age class; Y, years after restoration. Subscripts are as follows: md, macroinvertebrates density; pd, plant density; pr, plant richness; vd, vertebrate density; vr, vertebrates richness). doi:10.1371/journal.pbio.1001247.g002

restoration were not plotted in Figure 1A because the sample size did not meet our criteria for average points, see Materials and Methods section, on this graph). Since phosphorus storage appeared only slightly changed, the overall lack of recovery of biogeochemical functioning may have been driven largely by the low recovery of the carbon storage and the low accumulation of soil organic matter (see Text S1).

Effects of Size and Environmental Setting

Comparing wetland recovery trajectories under different conditions may shed light on factors that impede or facilitate recovery. Although biogeochemical responses in both restored and created wetlands were similar, biological structure in created wetlands approached reference conditions more quickly (Figure S3A and S3B; Table S5). Created wetlands may have been engineered to force the initial system towards defined reference conditions [39].

Ecosystem size and local and regional context affect wetland recovery. Large wetlands (>100 ha) appeared to recover their biological structure and biogeochemical functions sooner after restoration or creation than smaller wetlands (Figures 3 and S4; Table S4; data from 13 studies of 25 wetlands). This differential recovery suggests that small wetlands may not provide adequate local resources or connectivity for local biota to restore preimpact functioning. Restored and created wetlands, particularly if small, may have become more isolated and surrounded by more fragmented landscapes than they had been before impact [40]. Also, small wetlands would only be able to support a limited number of individuals, and thus, will not be able to support all the species, particularly taxa with large body sizes, formerly capable of occupying the area [41].

Regional climate had a strong effect on the sequence and rate of wetland recovery following restoration. As expected, warm temperatures accelerate ecosystem processes [7,13,42], including those mediating biological and biogeochemical recovery after wetland restoration or creation. In tropical and summer-warm temperate climates, wetlands approached reference conditions relatively rapidly, while wetlands restored in cold climates had not recovered to reference conditions after 50 y (Figure 4A and 4B; Tables S3 and S5). In tropical climates only, biogeochemical

variables recovered to reference levels before biological structure did (data from eight studies of eight wetlands). Whether this difference in recovery sequence is a real aspect of tropical wetlands, or an artifact of small sample size, remains to be seen. In a much larger sample of studies from temperate climates this sequence was reversed, and biogeochemical recovery was slower. Biological structural variables appeared recovered 5 y after restoration, while even 30 y after restoration, biogeochemical functions had only recovered to 79% of reference levels (data from 83 studies of 302 wetlands). In cold climates, corresponding biogeochemical recovery was only 53% 50 y after restoration; both biogeochemical functions and biological structure variables

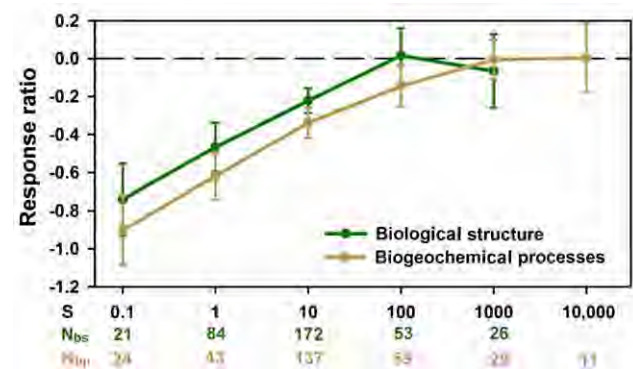


Figure 3. Effect of size on wetland recovery. Evolution of the mean ($\pm$ standard error [SE]) of the response ratios (see Materials and Methods) of restored or created wetlands at successive size categories for wetlands between 0 y to 5 y after restoration or creation. The zero value dashed line represents reference wetlands. Mean ($\pm$ SE) at 0.1 ha was estimated for wetlands with sizes $\leq$ 0.1 ha. Means ($\pm$ SE) at 1 ha were estimated for wetlands in which sizes ranged between 0.1 ha and 1 ha. The same approach was used to estimate the means ($\pm$ SE) at 10, 100, 1,000, and 10,000 ha (N, number of data points used to calculate the mean ($\pm$ SE) per age class; size, size in hectares of the restored wetlands. Subscripts are as follows: bp, biogeochemical processes; bs, biological structure). doi:10.1371/journal.pbio.1001247.g003

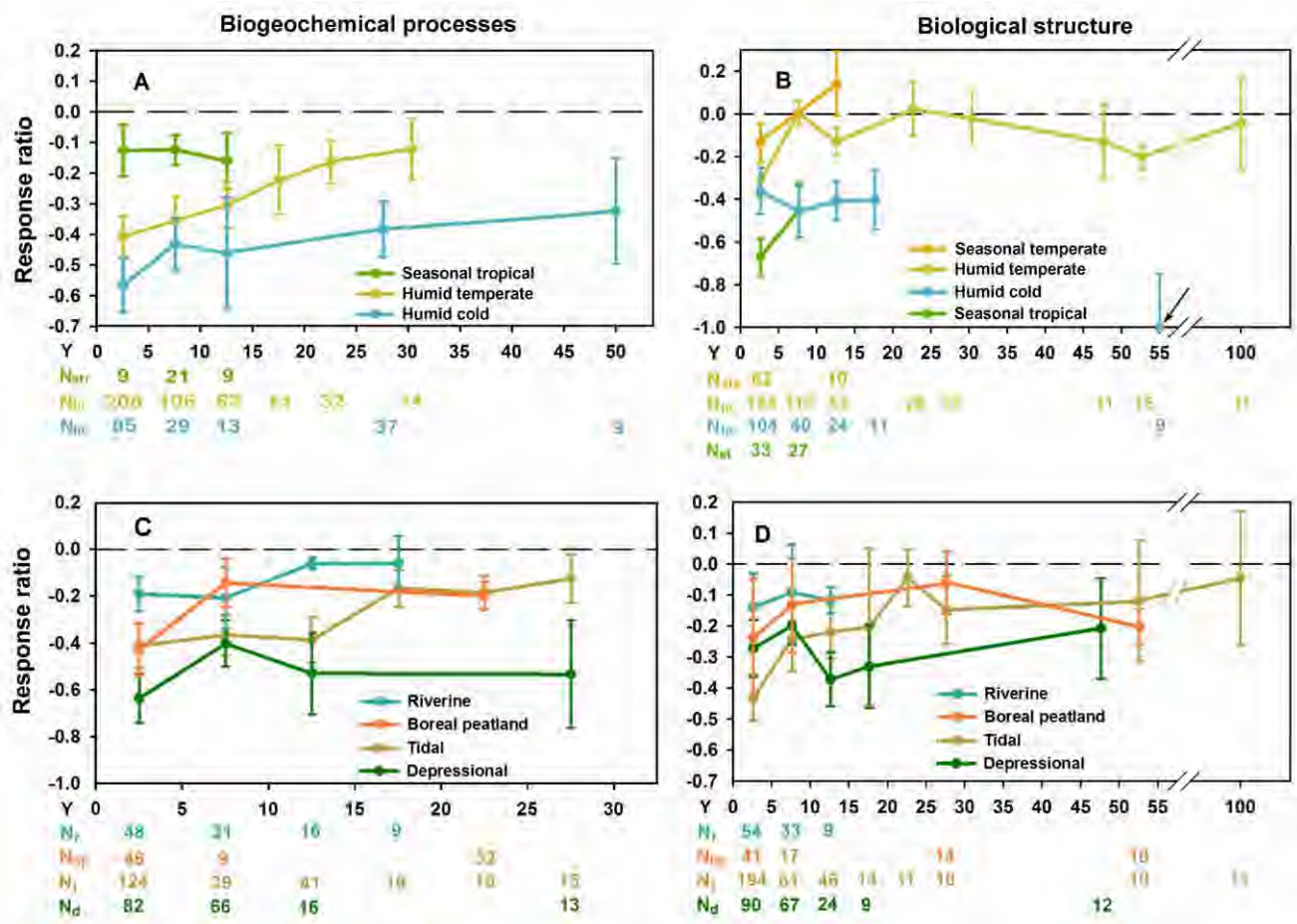


Figure 4. Effects of climate and hydrology on wetland recovery trajectories. Chronosequences of the means ($\pm$ standard error [SE]) of the response ratios (see Materials and Methods) of restored and created wetlands at successive age classes of 5 y or 10 consecutive y for biogeochemical functions and for biological structures under contrasting climates (A and B), and under different hydrologic connectivity (C and D) [31]. The zero value dashed line represents reference wetlands. The arrow (B) indicates the outlier mean value of two restoration studies with extremely low recovery rates (N, number of data points used to calculate the mean ($\pm$ SE) per age class; Y, years after restoration. Subscripts are as follows: bp, boreal peatland; d, depressional; hc, humid cold; ht, humid temperate; r, riverine; str, seasonal tropical; ste, seasonal temperate; t, tidal). doi:10.1371/journal.pbio.1001247.g004

remained statistically distinct from reference conditions for the entire (50-y) chronosequence (Figure 4A and 4B; Tables S3 and S5; data from 33 studies of 311 wetlands).

Hydrologic setting [43] also affected recovery (Figure 4C and 4D; Tables S3 and S5). Riverine and tidal wetlands, linked to larger hydrologic regimes by natural flow variation, recovered biogeochemical functions and biological structure after 20 y and 30 y, respectively (data from 73 studies of 210 wetlands). These results are similar to those (15 y to 25 y to recover the original biotic composition and diversity) found by Borja et al. [8] in 51 globally distributed estuarine and coastal ecosystems. In contrast, wetlands in inland depressions that were watered by precipitation or groundwater flow had not recovered to reference conditions even after 50 y following restoration (data from 36 studies of 358 wetlands). Peatlands (usually only the upper layer [<1 m] of peat was removed) recovered biological structure immediately, but 30 y after restoration, biogeochemical functioning in peatlands remained statistically lower than in reference wetlands (data from 11 studies of 18 wetlands).

Slow Recovery or Alternative States?

Two hypotheses could explain the lag in biological and biogeochemical recovery of the biological structure and biogeo-

chemical functioning. First, the chronosequences we examined may be too short (<30 y) for full recovery, especially of carbon and nitrogen storage [44]. Second, restored wetlands may have shifted to alternative states, different from their condition before degradation [14,15]. The subreference plateaus of soil organic accumulation, carbon storage, and general biogeochemical functioning could support the second hypothesis of alternative states in restored systems. Slow recovery of plant density and richness might be linked to lags in carbon storage. Mutualist symbionts critical for plant productivity (e.g., N-fixing bacteria [2] or mycorrhizal fungi [45]) may be absent in recently (<50 y) restored wetland soils. Alternatively, fast-growing, early successional terrestrial plants, and potentially also wetland plants, usually allocate most of their carbon to photosynthetically active structures of low density and high nutrient content, which are easily grazed or rapidly decomposed, retarding local storage of carbon [46,47].

Comparison with Other Findings

Two other studies have assessed recovery rates of large scale natural ecosystems following disturbance or perturbations [7,12]. Both of these studies examined a broad range of ecosystem types (terrestrial, freshwater, and marine), including wetlands. Jones and

Schmitz [12] found that across ecosystems and perturbation types (natural and human-caused), about half of the tracked response variables were considered by original authors to have recovered to preimpact states. Jones and Schmitz computed averaged recovery times for the subsamples of variables and cases that primary authors considered to have recovered over the course of their studies. These recovery times ranged from about 10 y to 40 y, and were longer for forests, and following human-caused, rather than natural perturbations. To assess whether systems had recovered or not, Jones and Schmitz used authors' expert opinion, return to historic initial conditions, or approach to parallel reference states (our study evaluated recovery only for studies using the last of these criteria). Given the narrower scope of our study (assessing wetlands only), and our different analysis approach, estimated recovery times from these two reviews are surprisingly similar. Rey Benayas et al. [7] studied recovery across a wide range of human-perturbed ecosystems, including wetlands. Using (as we did) the response ratio of restored to reference ecosystems, Benayas et al. found biodiversity and selected ecosystem services to be 86% and 80% recovered in a sample of 89 cases pooled over all age categories since perturbation. Interestingly, they reported slightly (6%) higher recovery in biological variables compared to ecosystem services (nutrient cycling; primary production; provisioning of timber, fish, and food crops; and regulation of climate, water supply, and soil). These ecosystem services overlap in part with categories of biogeochemical variables in our study (e.g., carbon and nutrient storage and cycling). The similarity between their results and our finding (that biological variables were 9% more recovered than these biogeochemical responses) suggests that structural recovery might often be necessary to achieve functional recovery.

Conclusions

Our meta-analysis suggests that recovery of wetlands following restoration as currently practiced is often slow and incomplete. In warm climates, and in settings linked to riverine or tidal flows, recovery may proceed more rapidly. Recovery may also be more likely and more rapid if >100 contiguous ha are restored. In many wetlands, however, ecosystem services may not be fully recovered even when wetlands appear to be biologically restored. If markets for ecosystem services and mitigation offsets from restored or created wetlands are used to justify further wetland degradation, net loss of global wetland services will continue and likely accelerate (see also Race and Fonseca [48]). We join other wetland ecologists and restoration scientists in calling for better scientific understanding of biotic and abiotic factors that constrain ecosystem restoration. For our common future, we need more realistic, long-term evaluations to find better ways to alleviate constraints limiting the recovery of wetland ecosystems.

Materials and Methods

Literature Search

On the 22nd of December 2010 a reference search was done in the scientific database ISI Web of Science – SCI-Expanded. The terms used were “(wetland* or floodplain* or peatland* or marsh* or mangrove*) same (restor* or creat* or re-creat* or rehabilit*)”. We used these terms to cover a wide variety of wetlands as defined in the Article 1.1 of the Ramsar Convention text [7]. For this analysis, we considered restored wetlands to be wetlands recreated on sites where wetlands had formerly existed but been drained or otherwise severely degraded. Created wetlands were described by authors as wetlands built on sites that lacked previous wetland history. We selected studies of wetlands under natural hydrological regimes, planted with native species, and in which no allochthonous

substrates were imported during the restoration or creation activities. For this reason, the term “construct*” was not included in the search terms, because we found in an independent search that >99% of the studies of constructed wetlands were of highly artificial systems not maintained under natural conditions. The search produced 2,959 selected articles. We applied the general selection criterion: “Articles must compare measurements of structural components and biogeochemical processes in restored or created and reference wetlands at a known age.” Under this criterion we selected 172 articles. These articles were read, and those in which data were averaged over time intervals larger than 5 y, those in which sizes differing by more than one order of magnitude were averaged, and those lacking reliable measurements or comparable restored and reference conditions were discarded, leaving 124 articles (see Text S2). Reference wetlands were usually adjacent to restored or created wetlands, although in some cases they were separated by several kilometers (maximum distance found was ~100 km). In all cases, restored or created wetlands were of the same wetland hydrogeomorphic type [17] as reference wetlands with which they were compared. From the selected articles, six were carried out on experimental wetlands, the rest were carried out on wetland restoration or creation projects. Studies either described measurements at a known age after wetlands were restored or created, or a chronosequence of the progression during the wetland restoration process. Restored and created wetlands were located in 12 countries and totaled >21,294 ha in area and reference wetlands >19,694 ha. The exact total area is not known because it was not reported in 23 out of the 124 selected studies.

Data Extraction

Measurements of structural components and biogeochemical processes were extracted from the main text, tables, and figures of the articles. When abundance of one species was measured at different life stages, only the adult abundance of each species was selected. Variables describing hydrological structure, biological structure, element storage and cycling, and organic matter accumulation were classified as structural components or biogeochemical processes according to wetland functions described by Smith et al. [42], and as ecosystem services described in the Millennium Ecosystem Assessment (MEA) (organic matter accumulation was sometimes designated as “soil formation” in the MEA but not in other soil science references) [49].

Element storage and cycling variables measured processes (mineralization or denitrification) and concentration of elements in different pools (total content in soil, organic content in soil, or content in roots), which suggest how nutrients are moving between pools through biotic and abiotic processes (Tables S1 and S2). The studies presented enough data points to plot recovery of storage of carbon, nitrogen, and phosphorus.

Response Ratio Calculation

To standardize and compare data, we used standard response ratios used in meta-analysis, $\ln(X_{rest}+1/X_{ref}+1)$ [3], where X_{rest} is the value of the measured variable in the restored or created wetland and X_{ref} is the value of the measured variable in the reference wetland. To avoid the value “0” in the natural logarithm of the equation, “1” was added to both values in restored or created and reference wetlands. The effect of adding “1” to the values in the response ratio equation has been demonstrated to have little effect on conclusions [50]. The effect size was not weighted because variance was reported for only 64% of the variables. Differences between weighted and unweighted meta-analysis statistics are generally small [7].

As variables depicting structural components and biogeochemical processes in restored or created wetlands converged to values in the reference wetlands, recovery of function was generally enhanced. But for some variables, such as soil bulk density [51,52], or proportions of exotic species [53,54], higher values are associated with lower levels of wetland recovery. In some cases, the specific context of a study made variables negative for recovery of a particular restored wetland, e.g., the presence of woody species where none had occurred in the reference wetlands [55,56]. In these cases (11% of the collected variables), we changed the sign to reverse the value of the response ratio.

Data Classification

For each variable we recorded the age of the restored or created wetland, the wetland hydrogeomorphic type, the number of restored or created and reference wetlands considered in a given study, the size (ha) of the restored or created and reference wetlands, the initial condition (restored or created), the geographic location, and the climate. Most data (49%) were from wetlands that had been restored or created for less than 5 y (Figure S1). If data from several wetlands of different sizes were averaged in the study, then we also averaged the sizes for our analysis. The geographic location was registered as the latitude and longitude in degrees of the center of the wetland or group of wetlands. The climate was classified according to the last revision of the Köppen-Geiger climate classification [57]. We used the name humid temperate climate for Cf climate, humid cold climate for Df climate, seasonal temperate climate for Cs climate (with dry summer), and seasonal tropical for A climates. Two of our sampled studies were done in seasonal temperate climate with dry winter (Köppen-Geiger climate classification Cw), and were not considered in our climate study. Wetland hydrogeomorphic type was classified according to Brinson [58] and Smith et al. [42] as depressional, riverine, tidal, peatland, lacustrine, and seeping slope. Only three studies were on lacustrine wetlands and one on seeping slope wetlands, so these types were not considered in our study of differences among wetland types.

In studies where more than one wetland was studied and data were available for each individual wetland, data were collected for each wetland. In 27 studies, more than one wetland was compared with the same reference wetland, and in 11 studies, restored or created wetlands were compared with more than one reference wetland. All studies where more reference rather than restored or created wetlands were studied provided only averaged data for both groups of wetlands. We calculated contingency tables between the wetland size, the initial conditions (created versus restored), and the covariates included in the environmental setting section (climate and wetland hydrogeomorphic type), using contingency coefficients (C), to test for independence between them. Wetland type showed relevant degrees of association with the climate ($C=0.63$) and wetland size ($C=0.58$), the rest of variables had coefficients below 0.5, indicating low degree of association. These associations may be explained by the influence of the climate on wetland types, e.g., peatlands are usually associated to cold climates, and mangroves to tropical climates. Also, peatlands usually extend over vast surfaces (hundreds or thousands of hectares) and depressional wetlands are usually small basins (less than 10 ha or few tens of hectares).

Statistical Analysis

Because data were non-normally distributed (according to the Kolmogorov-Smirnoff test for normality), we used Wilcoxon signed rank tests to test for significant deviations from zero (no

difference from reference conditions) for each estimated mean of the response ratios for variables at each age interval of a restored or created wetland. To test for differences between the same variable measured under two different environmental settings at a given recovery time, we used Kruskal-Wallis tests.

Chronosequences Plotting

To plot the temporal trends, the mean values and the standard error of each variable with every age class of 5 y (0–4.9, 5–9.9, etc) were used. The criterion for a mean for a certain age class to be used in the plot was that it must have been derived from at least nine different data points obtained from at least two different studies. When this criterion was not fulfilled, the mean values and standard error of age classes of 10 y (e.g., 10–19.9, or 20–30) were used. Temporal trend lines were fitted when enough data to calculate means for two or more age classes were available.

Supporting Information

Figure S1 Distribution of wetland sizes across wetland ages for the 654 restored and created wetlands considered in the study.

(TIF)

Figure S2 Chronosequences for the storage and cycling of carbon and nitrogen (A), and for the accumulation of organic matter in soils (B).

(TIF)

Figure S3 Chronosequences for biogeochemical processes (A) and for biological structures (B) under contrasting initial conditions (restored wetlands versus wetlands created de novo in dry lands).

(TIF)

Figure S4 Evolution of the response ratios of restored or created wetlands at successive size categories for wetlands between 5 y to 15 y after restoration or creation.

(TIF)

Table S1 Variables measuring structural components.

(DOC)

Table S2 Variables measuring biogeochemical processes.

(DOC)

Table S3 Statistical significance of differences between the means of the response ratios in restored or created versus reference wetlands.

(DOC)

Table S4 Statistical significance of differences between the means of the response ratios in restored or created versus reference wetlands at each size interval.

(DOC)

Table S5 Statistical significance of differences between the response ratios in restored or created wetlands under different environmental settings.

(DOC)

Text S1 Wetland restoration investment and carbon storage calculation.

(DOC)

Text S2 References used in the meta-analysis.

(DOC)

Acknowledgments

We acknowledge the comments from Joy B. Zedler, Oswald Schmidt, J.M. Rey Benayas, William E. Dietrich, Andrea Swei, and one anonymous reviewer on earlier versions of the manuscript, and the collaboration of Maribel Vara Rodriguez.

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Author Contributions

The author(s) have made the following declarations about their contributions: Conceived and designed the experiments: DMM MEP. Analyzed the data: DMM. Wrote the paper: DMM MEP. Performed the meta-analysis: DMM RY. Interpreted and discussed results from the meta-analysis: DMM MEP FAC.

EXHIBIT C

AN ASSESSMENT OF WETLAND IMPACTS AND COMPENSATORY MITIGATION IN THE CUYAHOGA RIVER WATERSHED, OHIO, USA

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Abstract: A watershed-based assessment of wetland impacts and compensatory mitigation was conducted for the Cuyahoga River Watershed (CRW) in northeastern Ohio, USA, to explore the effectiveness of wetland mitigation regulations and any resulting cumulative changes to wetland and landscape structure. Mitigation projects from 23 Section 401 certifications and Ohio Isolated Wetland permits were evaluated for permit compliance, wetland structure, and landscape context. Although there was a net gain in wetland area as a result of the 23 permits, the CRW experienced a net loss of wetland acreage due to the exportation to mitigation banks located outside the watershed. The majority of projects (67%) that restored or created wetlands independently (not at a mitigation bank) were not successful at meeting permit requirements in terms of wetland area. The comparison of impacted and mitigation wetland vegetation types revealed an increase in open-water/emergent wetland area and a decrease in area of scrub/shrub and forested wetlands, along with a decrease in the number of wetlands from 134 impacted wetlands to 65 mitigation wetlands. Impacted wetlands were significantly smaller than replacement wetlands. Landscape composition surrounding the wetlands was highly variable, varying from 17%–75% natural land uses and from 18%–82% human land uses. We suggest that an improvement in compliance with permit requirements is necessary. Current wetland policy allows for the exportation of wetlands for mitigation purposes, which can result in the loss of wetlands from some hydrologic units. The consideration of wetland structure needs to be incorporated into the regulatory process to avoid a shift in wetland types that are present. Finally, instead of reviewing projects on a site-by-site basis, a landscape approach should be taken in order to avoid the loss of upland-wetland heterogeneity and the placement of mitigation wetlands in degraded landscapes.

Key Words: land use, mitigation, permit compliance, watershed approach

INTRODUCTION

In the United States, under Sections 401 and 404 of the Clean Water Act (CWA), unavoidable

impacts to wetlands must be mitigated through creation, restoration, enhancement, or preservation of wetlands. Section 404 general permits are issued

by the United States Army Corps of Engineers (U.S. ACOE) for activities considered to have minimal impacts upon waters of the United States. Activities that meet the U.S. ACOE definition of minimal impacts are specific to and described within each general permit, which are reviewed and issued every five years. For those activities that have more than minimal impacts upon waters of the United States, an individual Section 401 State Water Quality Certification is also required. In the state of Ohio, the Ohio Environmental Protection Agency (OEPA) is responsible for issuing Section 401 certifications. The OEPA also issues Ohio Isolated Wetland permits for impacts to those wetlands that do not fall under federal jurisdiction. This program supports the principle of no-net-loss, committed to maintain and eventually increase the area of wetlands in the United States (USEPA-USACE 1990).

After a few decades of implementation, it remains uncertain whether Sections 404 and 401 of the CWA are successful in establishing fully functioning wetlands. Mitigation success is frequently measured by comparing mitigation wetlands to natural "reference" wetlands. These studies often assess changes in the type of wetlands and the plant community being constructed (e.g., marsh, floodplain, scrub/shrub) (Craft et al. 2002, Balcombe et al. 2005c), while others characterize bird communities (Darnell and Smith 2004, Balcombe et al. 2005a, Keagy et al. 2005), aquatic fauna (West et al. 2000, Balcombe et al. 2005b), and biogeochemical processes (West et al. 2000, Craft et al. 2002, Brooks et al. 2005). In diverse locations of the United States, information has also been compiled to assess permit compliance (Texas and Arkansas: Sifneos et al. 1992; Oregon and Washington: Kentula et al. 1992; central Pennsylvania: Cole and Shafer, 2002; Tennessee: Morgan and Roberts 2003; San Francisco Bay region, California: Breaux et al. 2005).

Few assessments have compared the wetlands that were impacted with the mitigation wetlands that replaced them (but see Cole and Shafer 2002, Minkin and Ladd 2003). Such direct comparison is the ideal approach to understanding whether or not mitigation policy is effective (Zedler 1996) but is often challenging because of the lack of records kept on the impacted wetlands (Sifneos et al. 1992). One difficulty in this type of assessment is the analysis of wetland function, especially for impacted wetlands that have already been eliminated for development. Instead, we have to rely upon information that has been collected for these wetlands prior to their destruction. Such information is often limited and lies mostly within assessment reports submitted for Section 401/404 application. Despite these limitations, to understand

the impact of mitigation practices within a region, we must make an effort to compare what is being lost to what is being produced.

The need for a watershed-based approach has also been raised (Bedford and Preston 1988, Zedler 1996, Environmental Law Institute 2004). Watershed and landscape based approaches are recommended because many wetland functions rely upon conditions in the surrounding landscape (Amezaga et al. 2002). Despite this understanding, few studies of wetland mitigation have taken this large-scale approach (but see Kelly 2001, Johnson et al. 2002), probably because many mitigation projects are conducted on a site-by-site basis without considering the broader landscape (Bedford and Preston 1988, Race and Fonseca 1996, Zedler 1996). Wetland impacts and mitigation efforts might result in a spatial re-configuration of wetlands within the landscape (Bedford 1996, Kelly 2001). This re-configuration could include changes in 1) the spatial extent of wetlands including size, number, and location, 2) wetland characteristics such as hydrogeomorphic class or vegetation type, and 3) land uses surrounding wetlands. These re-configurations can be expected to have an impact upon the functions that wetlands are able to provide (Tilton 1995, Faulkner 2004, Houlahan et al. 2006).

In this study, we conducted a watershed-based assessment of wetland mitigation using information from Section 401/404 applications. The lack of data on impacted wetlands limited the comparison of impacted and mitigation wetlands to strictly structural metrics. The objectives of the study were to: 1) assess the level of compliance with permit requirements and net gain/loss of wetland area overall and on a watershed basis; 2) determine whether any changes in wetland structure have occurred as a result of wetland impacts and mitigation efforts; 3) quantify whether the mitigation practice altered the number, size, and density of wetlands; and 4) describe the land uses surrounding mitigation wetlands.

METHODS

Permits Assessment

We reviewed the Section 401 certifications and Ohio Isolated Wetland permits issued by the Ohio Environmental Protection Agency (OEPA) for impacts to surface waters within the Cuyahoga River Watershed (CRW). The CRW is located in northeastern Ohio (USA) (Figure 1). The CRW covers an area of 2,106 km² of both urban and rural land uses, including a portion of the Cuyahoga Valley National Park. Twenty-three permits issued between January 1, 1995 and January 1, 2003 and

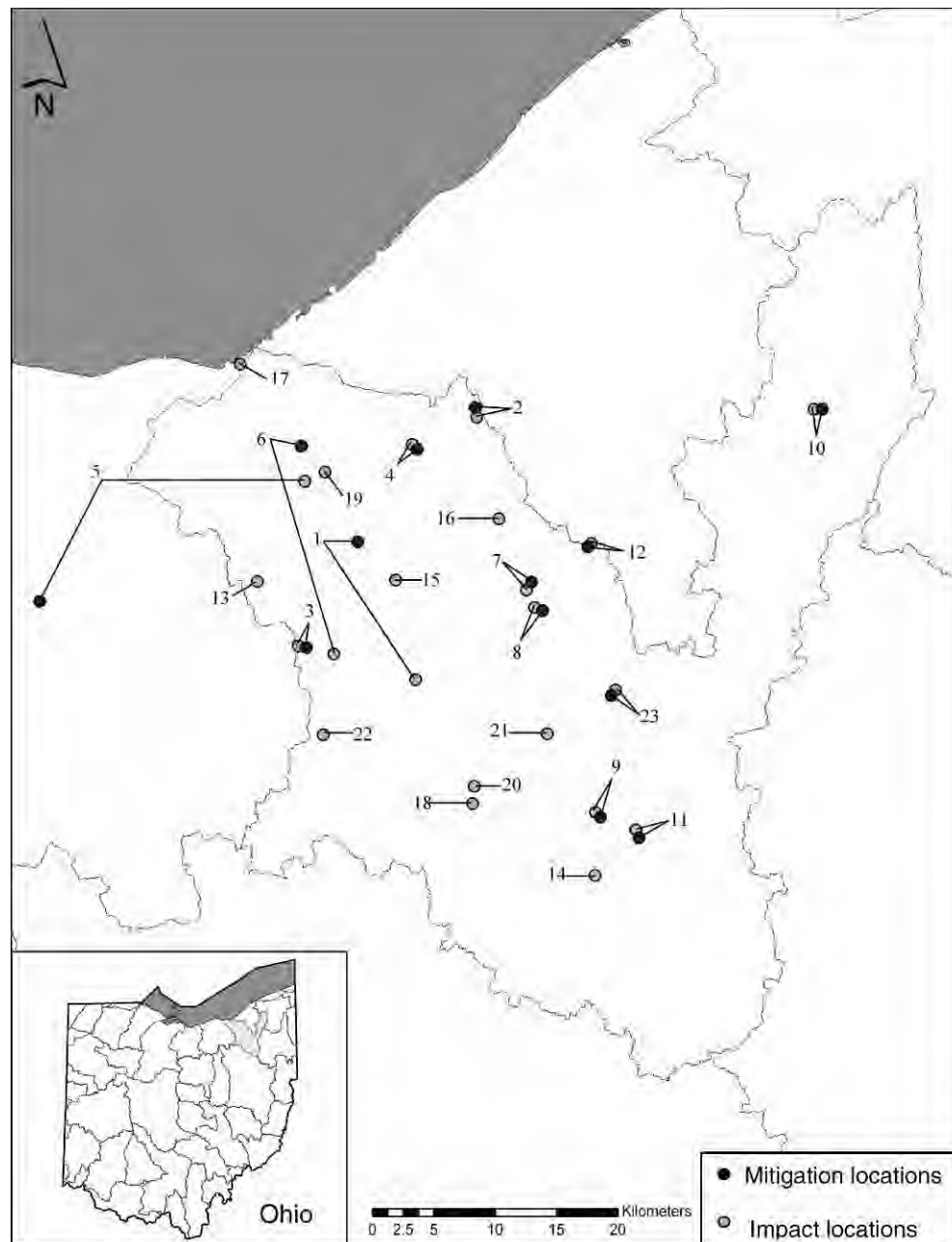


Figure 1. Map of the Cuyahoga River Watershed and locations of impacted and mitigation wetlands associated with the 23 Section 401 and Ohio Isolated Wetland permits issued during the 1995–2003 period.

requiring compensatory mitigation provided the basis for this study (Figure 1). Permits for which wetland were created after January 1, 2003 were excluded to allow sufficient time for wetland characteristics to develop, while permits issued prior to 1995 were not available.

Information regarding the area, location, and type of vegetation of the impacted wetlands, as well as the required wetland area for mitigation, were taken from permit files. Material provided by the applicant in the permit files was used to determine the area of

four vegetation types for each impacted wetland [open-water/submergent vegetation, emergent vegetation, scrub/shrub vegetation, and forested vegetation]. Because many applicants failed to discriminate between open-water/submergent vegetation and emergent vegetation, these two categories were combined for the analysis. Merging the two vegetation types limited our ability to describe certain changes in plant structure and, in particular, to determine whether mitigation practices created deeper/wetter wetlands in the landscape.

On-Site Mitigation Wetland Survey

Field work was conducted between June 1, 2004 and October 1, 2004. Mitigation wetlands were delineated using the United States Army Corps of Engineers 1987 wetland delineation procedure (U.S. ACOE 1987). Wetland boundaries were mapped using a Trimble GeoXT handheld Global Positioning System (GPS). To standardize coordinate data collection, a point was taken at each location where the wetland boundary turned 10° or more. Point data were later processed and differential correction was conducted using stationary files from the nearest base station. Data were imported into ArcGIS software (ESRI) to calculate wetland area. Percentages of vegetation types (open-water/submergent, emergent, scrub/shrub, and forest) were visually estimated in the field for each wetland.

During the delineation of the mitigation wetlands, two problems were encountered that resulted in an over-estimation of wetland area: 1) presence of deep open-water habitat and 2) existence of wetlands on site pre construction. Two mitigation sites contained deep open-water habitat that was fringed by emergent and submergent vegetation wetland. Given time and methodological constraints, we did not delineate the open-water-wetland boundary. Although the deep open-water areas would not normally be counted for wetland mitigation credit by OEPA, they were included in this study. Additionally, at three other sites, project maps revealed wetlands that were located adjacent to and within mitigation wetland boundaries. Essentially, existing wetlands were expanded during the mitigation construction process. It was not possible to delineate the precise boundary between the natural wetlands and mitigation wetlands, so these areas of natural wetland were included with mitigation area. The information collected at the mitigation sites was compared with the data available on the impacted wetlands in the permit files. This comparison allowed us to calculate net change of wetland area, to determine compliance with permit requirements, and to assess any changes in vegetation types. We also calculated the mandated mitigation ratio (defined as the area of mitigation wetland requested to be built divided by the area of impacted wetland), and the actual mitigation ratio (defined as the area of mitigation wetland actually built divided by the area of impacted wetland).

Number, Size, and Density of Wetlands

The number and size of impacted wetlands were compared to the number and size of mitigation

wetlands using information from permit files (for impacted wetlands) and GPS data (for mitigation wetlands) for all 23 projects. We assumed that wetland area created at a mitigation bank was located within a single wetland. This analysis was conducted for all projects combined, as well as on a per-project basis. Additionally, for each independent project ($n = 12$), the density of impacted wetlands was compared to the density of mitigation wetlands on a per-project basis using the patch density (i.e., number of wetlands/100 ha) metric in the software FRAGSTATS Spatial Pattern Analysis Program, Version 3.3 (McGarigal et al. 2002; see Kettlewell 2005 for complete description of the method). Impacted wetland polygons were created by scanning and geo-referencing projects maps supplied by the permit holder. Mitigation wetland polygons were created using GPS data collected in the field. For each impacted and mitigation site of all 12 independent projects, landscapes (with only impacted and mitigation wetland land uses) were created with the buffer tool within ArcGIS (ESRI, Inc.) using a buffer of 1,000 m from wetland edges. Mitigation wetlands were created at two different locations for Project #5, resulting in Project #5a and 5b. Wetland density for the two mitigation locations associated with this project was combined.

Land Use Setting

The availability of high resolution aerial photographs proved to be the limiting resource for assessing land uses around each wetland. Quality aerial photos were only available for recent years, making it impossible to estimate land uses around the impacted wetlands with certainty. Therefore, we focused on describing land use surrounding the mitigation wetlands. Six inch (15.24 cm) resolution, county-level aerial photos taken between years 2000 and 2002 were used to digitize land uses into 13 different classes: agriculture, construction, forest, industrial, mitigation wetland, mowed, oldfield, park, pond, residential, road, waterway, and wetland. Land use classes were eventually grouped into human (i.e., agriculture, construction, industrial, mowed grass, residential, and road), natural (i.e., forest, old field, and park), and surface water (i.e., mitigation wetland, pond, and wetland) categories. Out of the 12 independent projects, eight projects were included in this land use analysis. For this analysis, the two mitigation locations for Project #5 were kept separate, providing a total number of nine projects. Land uses were digitized using ArcGIS (ESRI, Inc.) at a map scale of 1:2000–1:4000 (see Kettlewell 2005 for complete description of the

method). Landscapes were analyzed within the 300-m and the 1,000-m buffers from the edge of mitigation wetlands. The number of wetlands located in 300-m and 1,000-m buffers (excluding and including mitigation wetlands) was also assessed. These two buffers size, while somewhat arbitrary, were selected because they represent local and larger-scale processes that may be critical in maintaining wetland structure and function. The 300-m buffer adjacent to a wetland affects wetland plant diversity (Houlahan *et al.* 2006) and serves as critical terrestrial habitat for reptiles and amphibians (Semlitsch and Bodie 2003, Colburn 2004; Porej *et al.* 2004). For some amphibian species, a 1,000-m buffer is optimum to maintain metapopulations (Vos and Stumpel 1995, Knutson *et al.* 1999; Porej *et al.* 2004).

Statistical Analysis

Minitab statistical software Version 12.23 was used for all statistical analysis. The significance level was set at $\alpha = 0.05$ for all statistical tests. Pearson's correlations were used to select landscape indices for various portions of land use analysis and to test whether variance in landscape area affected metric values. A Pearson's coefficient of $r > 0.700$ or $r < -0.700$ was used to indicate metrics that were significantly correlated. Two sample t-tests were used to compare impacted and mitigation wetland characteristics when all projects were combined. Paired t-tests were used to compare impacted and mitigation characteristics on a per-project basis. Outliers were identified using the Box and Whisker Plot procedure. The data were log-transformed when necessary to meet the assumptions of the analysis (normality and homoscedasticity).

RESULTS

Permit Compliance

Of the 23 projects evaluated, eight were mitigated for wetland losses by purchasing "wetland credits" at various mitigation banks within the Ohio portion of the Lake Erie basin, outside the CRW. One project was mitigated at a bank owned by the applicant within the watershed. Two projects that impacted wetlands within the watershed were mitigated entirely through wetland preservation. Twelve projects relied upon independent creation or restoration efforts to mitigate for wetland losses (*i.e.*, not at a bank). Of these 12 projects, 11 were located within the CRW. Nine of the 12 independent mitigation projects were constructed "on-site," while

three sites were constructed at a location other than the impact site. Sixty-five wetlands were created as mitigation for 134 impacted wetlands. Because several wetlands can be impacted or created for each permit, the number of projects does not reflect the number of wetlands.

For the 23 permits, 14.95 ha of wetlands were lost, 27.78 ha of created wetlands were required, and 26.27 ha of mitigation wetlands were created. The 26.27 ha of mitigation wetlands assumes that requirements for the eight mitigation bank projects were adequately met. The result is a net gain of 11.32 ha of wetlands at an actual mitigation ratio of 1.76:1, while the mandated mitigation ratio was 1.85:1. A total of 5.24 ha (10 projects) of wetlands were purchased from a pooled mitigation bank and 0.77 ha (one project) of wetlands were created within a private mitigation bank. Another 20.26 ha (12 projects) of wetlands were either created or restored by the applicant independently. An additional 2.11 ha of wetland enhancement and 21.30 ha of wetland preservation were proposed, although these areas were not evaluated for compliance. Of the 12 independent projects, the mandated mitigation ratio averaged 3.96:1 and ranged from 1.00:1 to 25.50:1. If one outlier was removed, this ratio decreased to 2.00:1 (ranging from 1.00:1 to 3.54:1). The actual mitigation ratio averaged 3.11:1 and ranged from 0.87:1 to 14.00:1. Once again, if one outlier was removed, this ratio dropped to 2.12:1 (ranging from 0.95:1 to 4.88:1).

Within the CRW, 14.58 ha of wetlands were lost and 11.36 ha of mitigation were created. The remaining 14.91 ha of wetland mitigation were exported from the watershed. Two projects were responsible for 9.67 ha of exported wetland area and 5.24 ha of exported wetland area were the result of purchasing mitigation bank credits. While the mandated mitigation ratio was not significantly different from the actual mitigation ratio on average ($p > 0.05$, $df = 11$, $t = 0.83$), the majority of the 12 independent projects ($n = 8$) did not achieve the required wetland area (Figure 2).

Vegetation Types

The majority of mitigation wetlands were comprised of open-water/emergent vegetation (82.8%), followed by scrub/shrub vegetation (14.7%) and forested vegetation (2.5%) (Figure 3). Based on information contained in permit files, impacted wetlands were also dominated by open-water/emergent vegetation (42.5%), followed by scrub/shrub (41.0%) and forested vegetation (16.5%). Emergent wetlands were replaced at a ratio of

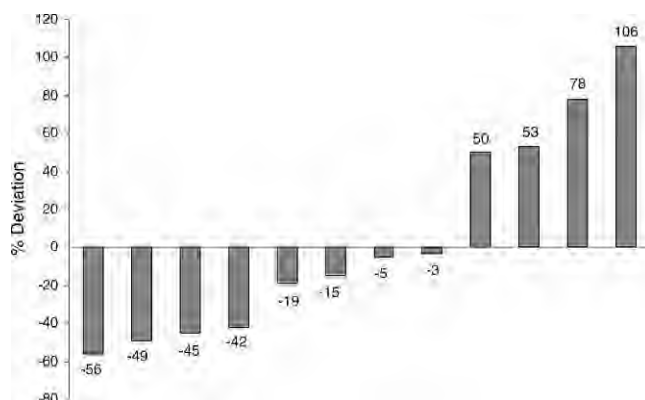


Figure 2. Percent deviation from the required mitigation wetland area for the 12 independent projects (i.e., projects that did not use a mitigation bank). Projects with bars above the zero line constructed more wetland area than necessary, while those below the zero line failed to meet mitigation requirements.

3.6:1, scrub/shrub wetlands were replaced at a ratio of 0.65:1, and forested wetlands were replaced at a ratio of 0.28:1. If only the mitigation wetland created in the CRW are considered, emergent wetlands were replaced at a ratio of 2.3:1 and scrub/shrub wetlands were replaced at a ratio of 0.03:1 (i.e., all forested wetland impacts were mitigated within the CRW).

Mitigation associated with the 12 independent projects led to an increase in open-water/emergent wetland area per project ($p = 0.014$, $df = 11$, $t = -2.91$) and a decrease in scrub/shrub wetland area ($p = 0.019$, $df = 11$, $t = 2.75$) (Table 1). The change in forested wetland area was not significant. However, an analysis of presence/absence of vege-

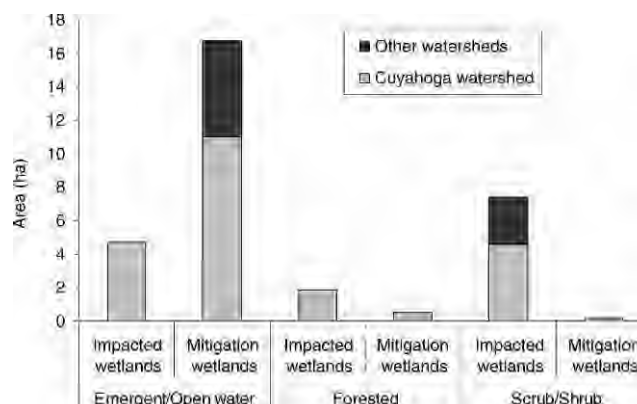


Figure 3. Vegetation types of impacted and mitigation wetlands for the 12 independent projects (i.e., projects that did not use a mitigation bank). The wetland areas shown in dark grey were exported to other watersheds.

tation types indicated that forested vegetation was present more often in impacted wetlands than mitigation wetlands ($p = 0.017$, $df = 11$, $t = 2.80$). Changes in the presence/absence of open-water/emergent and scrub/shrub wetlands were not significant.

Number, Size, and Density of Wetlands

During this mitigation process, 134 wetlands were destroyed in the CRW, while 50 were created. The decrease in number of wetlands on a per-project basis was not significant; however, when one outlier was removed (Project #12), the decrease became significant ($p = 0.004$, $df = 21$, $t = 3.26$). Project #12 led to the creation of 25 of the 65 mitigation wetlands. Mitigation wetlands ($n = 65$) for all

Table 1. Vegetation types by wetland area for impacted and mitigation wetlands for the 12 independent projects (i.e., projects that did not use a mitigation bank).

Project #	Impacted Wetlands			Mitigation Wetlands		
	Emergent Open-water	Forested	Scrub Shrub	Emergent Open-water	Forested	Scrub Shrub
	Ha					
1	1.125	0.313	0	1.372	0	0
2	0	0.567	0	0.931	0.052	0.052
3	0.291	0.101	0.170	1.424	0	0
4	0	0	0.371	1.587	0	0.084
5	1.576	0.310	3.096	5.780	0	2.847
6	0.121	0.134	0.178	0.617	0.154	0
7	0.295	0.202	0	2.440	0	0
8	0.745	0.146	0	0.771	0	0
9	0.069	0	0	0.108	0	0
10	0.024	0	0	0.277	0	0
11	0	0	0.231	0.243	0	0
12	0.437	0.045	0.473	1.216	0.304	0
Totals	4.684	1.818	4.519	16.766	0.510	2.982

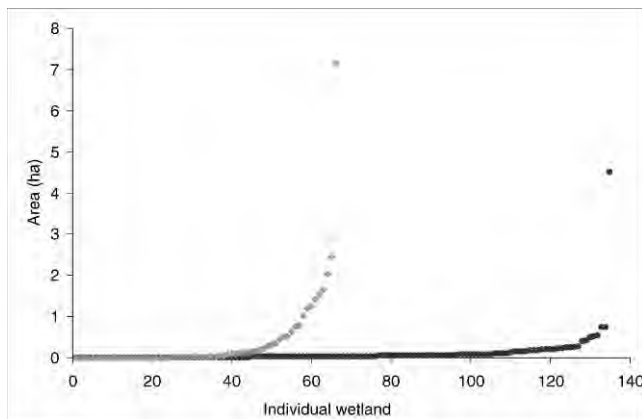


Figure 4. Size-ranked display of all impacted (dark circles) and mitigation (gray diamonds) wetlands for the 12 independent projects (i.e., projects that did not use a mitigation bank). The y-axis shows the area of each wetland. The x-axis ranks each wetland by size showing 65 mitigation points and 134 impacted points. Note that many of the wetlands were very small, with an area close to zero.

projects were significantly larger in area than impacted wetlands ($n = 134$) ($p = 0.027$, $df = 74$, $t = 2.26$; Figure 4). The average size of impacted wetlands was 0.11 ha, and the average size of CRW replacement wetlands was 0.23 ha. If two outliers were removed, the significance became greater ($p = 0.002$, $df = 66$, $t = 3.21$). No difference in wetland density (i.e., number of wetlands/100 ha) was noticed as the result of the mitigation process.

Land Use Setting

There was considerable variation in land uses surrounding the nine mitigation projects studied (Table 2). Within the 300-m buffers, natural and human land uses occupied 33% to 75% and 18% to 65% of total landscape area, respectively. At the 300-m level, three projects (Projects #2, 3, and 4) were dominated by human land uses, while five (Projects #1, 5a, 5b, 6, 7, and 8) were dominated by natural land uses. Natural land uses within the 1,000-m landscapes occupied 17% to 59% of the total landscape area and human land uses represented 31% to 82% of the area. At the 1,000-m level, five projects (Projects #2, 3, 4, 5a, and 6) were dominated by human land uses and four (Projects #1, 5b, 7, and 8) were dominated by natural land uses. More specifically, forest was the dominant land use within 300-m and 1,000-m buffers surrounding six of the nine mitigation projects. The second and third most common land uses were residential and oldfield for the 300-m buffers, and residential and industrial for the

1,000-m buffers. Within the 300-m buffers, the number of wetlands ranged from 0 (Projects #3, 4, and 8) to 8, while at the 1,000-m level, the number of wetlands ranged from 0 (Project #4) to 19. When mitigation wetlands were included, the number of wetlands ranged from 1–10 at the 300-m level and from 1–20 at the 1,000-m level.

DISCUSSION

Recent studies of wetland permit compliance have re-enforced uncertainties about our abilities to create wetland ecosystems. Some reports highlight that most permit-holders are in compliance with permit conditions (e.g., Cole and Shafer 2002, Minkin and Ladd 2003), while others stress that the majority of permit-holders are unable to successfully meet permit requirements (e.g., Johnson *et al.* 2000, Brown and Veneman 2001). Both net-gains and a net-loss of wetland area have been reported. Our study suggests that, overall, the mitigation process resulted in a net-gain of wetland area. However, the majority of the projects that we reviewed did not meet wetland area requirements, and the CRW experienced a net loss of wetland area. Only 78% of the area of all the wetlands impacted is now present as mitigation wetlands within the watershed, highlighting one of the problems associated with “off-site” mitigation. Because our analysis led to an over-estimation of wetland area (i.e., inclusion of deep open water and of natural wetlands in some mitigation wetlands), the net change of wetland area could have been even more detrimental.

Eight of the 23 projects mitigated for impacts by purchasing wetland credits at a mitigation bank outside of the CRW. Mitigation banks have been designed to allow permit-holders who are impacting small areas of wetland to mitigate for impacts by purchasing “wetland credits” instead of creating or restoring wetlands “on-site” (Reppert 1992). The question then, is to what extent we should allow wetland functions to be trans-located geographically. In Ohio, permit-holders are restricted to using mitigation banks that are located within the same ACOE district (i.e., Buffalo or Huntington) where the impacts occur. Mitigation banks are generally restricted to service areas of one or two 8-digit hydrologic unit code watersheds. However, applicants are permitted to purchase mitigation credits for impacts to lower quality wetlands at banks elsewhere within the same ACOE district (Ohio Administrative Code 3745-1-54). Such authorization of wetland exportation should consider the function and context of the impacted wetlands and the

Table 2. Percentage of human, natural, and water land uses around each wetland mitigation project. Bold numbers indicate the dominant land use for each project. Ag = Agriculture, Const = Construction, Ind = Industrial, Mow = Mowed grass, Res = Residential, For = Forest, Old = Oldfield, Mit = Mitigation wetland, Wway = Waterway, Wet = Wetland.

Project #	Human land uses						Natural land uses				Water land uses		
	Ag	Const	Ind	Mow	Res	Road	For	Old	Park	Pond	Mit	Wway	Wet
Land uses in the 1000-m buffer around each mitigation project													
1	0	4.0	1.7	6.2	15.0	4.3	44.8	14.3	0	0	0.4	4.2	5.0
2	5.4	3.6	0	7.7	30.3	4.2	40.9	5.8	0	0.3	0.3	0	1.6
3	0	6.4	23.1	7.9	15.2	14.1	19.9	12.6	0	0.3	0.4	0	0.1
4	0	2.3	20.3	2.6	41.4	15.3	12.5	0.5	4.1	0	0.6	0.3	0
5a	15.8	0.7	0	3.0	27.8	1.5	37.7	9.2	0	1.1	0.4	2.3	0.4
5b	14.4	1.7	4.0	2.4	16.7	1.5	33.6	15.1	4.7	2.0	1.6	1.4	0.9
6	3.4	15.2	32.7	4.8	0	2.9	16.8	15.0	3.9	1.0	0.2	3.9	0.1
7	0.9	5.7	3.9	4.4	24.4	2.8	48.1	4.1	2.0	0.5	0.6	1.4	1.1
8	0	5.1	12.6	11.0	10.6	5.3	40.7	11.2	0.7	0.9	0.2	1.2	0.5
Land uses in the 300-m buffer around each mitigation project													
1	0	1.9	0	9.3	1.6	5.8	36.1	31.9	0	0	2.7	0	10.8
2	0	4.0	0	7.9	46.0	4.3	34.0	1.3	0	0.1	1.9	0	0.3
3	0	4.4	4.9	20.0	0	35.3	7.9	24.9	0	0	2.7	0	0
4	0	13.7	3.2	5.3	25.7	11.7	35.7	0	0	0	4.0	0.6	0
5a	26.7	0	0	0.5	12.5	1.2	45.8	2.8	0	0.1	2.4	6.0	2.0
5b	9.4	2.0	5.4	1.9	15.5	1.1	11.5	29.2	5.7	6.0	10.2	0	2.1
6	0	9.3	1.8	6.7	0	2.9	26.3	23.4	19.0	0	1.9	7.6	1.2
7	0	2.0	0	2.5	11.0	2.2	59.0	12.2	4.4	0.4	4.4	0.1	1.8
8	0	12.0	14.5	8.6	5.5	2.1	43.3	9.2	0	0.1	1.7	3.2	0

mitigation bank. If the impacted wetlands are functionally inferior and located within a degraded landscape, then their replacement with a higher quality mitigation wetland may be justified. Specific to the watershed we studied, it is worth noticing that a portion of the lower Cuyahoga River has been declared by the International Joint Commission in 1988 as an area of concern. Areas of concern are designed to focus efforts to clean up the most polluted areas of the Great Lakes region. As wetlands ecosystems are well-known to contribute to improving water quality, the net loss of wetland from the CRW is therefore counter-productive to the goal set by the International Joint Commission (1988).

In this study, impacted and mitigation wetlands were both dominated by emergent vegetation and open-water. The percentage of wetlands that were emergent/open-water nearly doubled as a result of mitigation efforts, while the amount of forested and scrub/shrub wetlands both decreased in area. Our classification scheme did not separate between emergent vegetation and open-water, principally because applicants to 401/404 permits did not make this distinction. To provide more detailed information about the impacted wetlands, permit applicants should be encouraged to make a clear distinction

between open water and emergent vegetation. The lumping of open water with emergent vegetation prevents us to conclude on whether mitigation wetlands surveyed in the CRW have more open water than the impacted wetlands. A trend in creating open water systems as mitigation for emergent wetlands has been observed in other areas (Bedford 1996, Gwin et al. 1999, Hoeltje and Cole 2007). Other wetland mitigation studies also have reported a shift from forested and scrub/shrub wetlands to emergent/open-water dominated systems (e.g., Brown and Veneman 2001, Cole and Shafer 2002, Minkin and Ladd 2003). It has been suggested that this shift is occurring because emergent/open-water wetlands are easier to construct than forested or scrub/shrub wetlands (Cole and Shafer 2002, Porej 2003). Construction of a deep open-water/emergent depression also seems to be the most reliable way (Porej 2003, Hoeltje and Cole 2007) to meet the hydrology, soil, and vegetation requirements set forth by the ACOE wetland definition (U.S. ACOE 1987). Such a shift in wetland types is likely to cause a regional shift in biodiversity (Gwin et al. 1999) and probably will be associated with a shift in wetland function (Minkin and Ladd 2003). Despite these concerns, it is worth noting that forested and scrub/shrub wetlands will

take longer to get established than emergent wetlands. In other words, we could hypothesize that the dominance of emergent wetlands over forested and scrub/shrub wetlands might decrease as we allow successional processes to occur.

In addition to change in wetland type, the mitigation process altered the spatial configuration of wetlands in the CRW. Essentially, the landscape is experiencing a consolidation of many small wetlands into fewer, larger ecosystems. The maintenance of a rich distribution of wetlands in the landscape is certainly just as important as maintaining high quality wetlands (Kelly 2001, Amezaga *et al.* 2002). The loss of many small wetlands has consequences upon landscape heterogeneity and metapopulation dynamics (Semlitsch and Bodie 1998) and possibly upon nutrient and water cycles (Kelly 2001). In addition, many of the mitigation wetlands we studied had few wetlands in their surrounding area. This disconnectedness from other wetlands and water bodies in the landscape can have effects on many ecological functions (Amezaga *et al.* 2002).

Our landscape analysis further indicates that there was considerable variation in the type of land uses surrounding mitigation wetlands. A few projects were located in landscapes dominated by human land use. One mitigation wetland, for example, was an open-water wetland located within a suburban housing development. Another mitigation wetland was a fringe wetland surrounding a storm-water retention basin within a very urban area. In contrast, other mitigation wetlands were surrounded with natural land uses, often because of their location within parks. The land use surrounding wetlands can be critical to maintain wetland structure and function, and urban development in many watersheds is a threat to the integrity of many wetlands (Kentula *et al.* 2004). For example, some amphibian species such as mole salamanders (*Ambystoma* spp.) and wood frogs (*Rana sylvatica*) require a large core of upland forest associated with their wetland breeding habitats (Semlitsch and Bodie 2003, Colburn 2004) and urbanization negatively impacts these species (Knutson *et al.* 1999, Houlahan and Findlay 2003). Many amphibian species are maintained within metapopulations, requiring a heterogeneous forest-wetland landscape for population survival. Landscape influences other important characteristics of wetland ecosystems such as exotic plant species distribution and abundance (Ehrenfeld and Schneider 1991), bird community composition (Croonquist and Brooks 1993), and water quality (Houlahan and Findlay 2004). Examining the spatial distribution of wetlands within a watershed and the composition of the adjacent landscapes would allow

for a more comprehensive understanding of the changes resulting from mitigation practices.

CONCLUSION

Although the permits studied resulted in an overall net gain of wetlands, the CRW has experienced a net loss of wetland area. The majority of mitigation wetlands (and the functions they support) has been exported to other watersheds in the state, as a result of off-site mitigation, including the purchasing of wetland credits from mitigation banks. The net loss of wetland area from the watershed is also partly due to the inability of permit-holders to construct the required amount of mitigation wetland area. More rigorous follow-up and enforcement is necessary to ensure that wetland impacts and permit requirements are being adequately addressed. Permit-holders and regulatory agencies should also consider the locations of wetland impacts and mitigation instead of relying solely upon a site-by-site review. We strongly recommend that agencies consider changing policies to perform mitigation in the watershed from which the wetland was destroyed.

The CRW has experienced a shift in wetland structural characteristics as a result of wetland mitigation efforts. There are fewer, larger wetlands being constructed than are being lost. This shift could indicate an increase in the distance between wetlands and a loss of upland-wetland complexes. Many of the forested and scrub/shrub wetlands that are destroyed are being replaced with emergent vegetation and open-water wetlands. Although these structural characteristics are not measures of wetland function, they could be indicators that some functional changes are occurring both within wetlands and across the landscape. Incorporating landscape setting into the permitting process would allow for a more comprehensive understanding of any changes that are resulting from mitigation efforts. Additional research is necessary to understand how landscape structure affects the functioning of wetlands themselves and their ability to improve downstream water resources.

ACKNOWLEDGMENTS

This research was supported by the United States Environmental Protection Agency grant number CD97576201-0, the Ohio Environmental Protection Agency, and the School of Environment and Natural Resources at Ohio State University. We are grateful for useful comments provided by anonymous reviewers on an earlier version of this work.

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- Manuscript received 3 January 2007; accepted 5 September 2007.

EXHIBIT D

Why bartering biodiversity fails

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Keywords

Biodiversity offsets; environmental compensation; environmental mitigation; environmental trading markets, market-based instruments, no net loss; public choice theory.

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Received: 7 December 2008; accepted 4 May 2009.

doi: 10.1111/j.1755-263X.2009.00061.x

Abstract

Regulatory biodiversity trading (or biodiversity “offsets”) is increasingly promoted as a way to enable both conservation and development while achieving “no net loss” or even “net gain” in biodiversity, but to date has facilitated development while perpetuating biodiversity loss. Ecologists seeking improved biodiversity outcomes are developing better assessment tools and recommending more rigorous restrictions and enforcement. We explain why such recommendations overlook and cannot correct key causes of failure to protect biodiversity. Viable trading requires simple, measurable, and interchangeable commodities, but the currencies, restrictions, and oversight needed to protect complex, difficult-to-measure, and noninterchangeable resources like biodiversity are costly and intractable. These safeguards compromise trading viability and benefit neither traders nor regulatory officials. Political theory predicts that (1) biodiversity protection interests will fail to counter motivations for officials to resist and relax safeguards to facilitate exchanges and resource development at cost to biodiversity, and (2) trading is more vulnerable than pure administrative mechanisms to institutional dynamics that undermine environmental protection. Delivery of no net loss or net gain through biodiversity trading is thus administratively improbable and technically unrealistic. Their proliferation without credible solutions suggests biodiversity offset programs are successful “symbolic policies,” potentially obscuring biodiversity loss and dissipating impetus for action.

Introduction

Biodiversity trading programs (which include biodiversity compensation, offsets, banking, and biobanking) have proliferated internationally, and are promoted by policy makers and developers as facilitating both conservation and development. Like programs developed for simpler environmental commodities such as air pollutants (Pedersen 1994), most biodiversity trading has a regulatory or statutory basis that prohibits an activity (e.g., indigenous vegetation clearance, species habitat destruction, filling of wetlands) and later permits it conditionally (Salzman & Ruhl 2000).

As a regulatory incentive mechanism (Figure 1), environmental trading relies on developers’ self-interest and resources in addition to administrative enforcement

(Gustafsson 1998:268). Compared with pure administrative mechanisms (e.g., rules, standards), such market mechanisms are often purported to (1) allocate natural resources more efficiently, (2) satisfy developers better (increase access to resources, reduce compliance costs, and/or enhance green credentials; see Kate *et al.* 2004), and (3) provide improved environmental protection (see Gustafsson 1998; Kroeger & Casey 2007). In trading biodiversity, some programs aim to reduce rates of biodiversity loss (e.g., Lueck & Michael 2003; Chomitz 2004). Others, perhaps increasingly, propose to achieve no net loss or a net gain in biodiversity (e.g., WHOEP 1993; VDNRE 2002; WA EPA 2006).

So far, evaluations suggest that biodiversity trading has not produced its promised biodiversity outcomes. Typically, development proceeds while offsets fall short

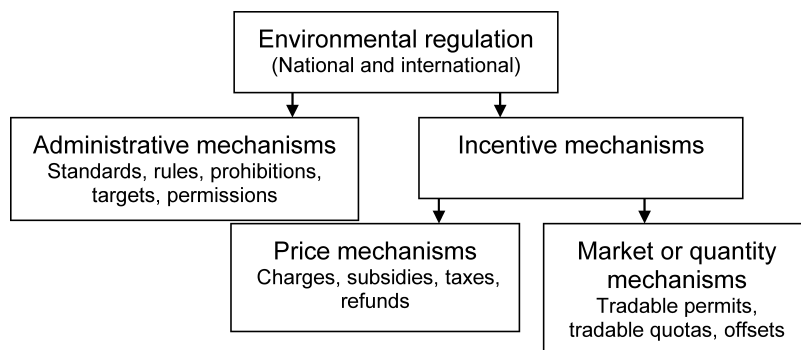


Figure 1 A taxonomy of environmental policy instruments (after Gustafsson 1998).

of goals or are never implemented (for some primary sources see Race 1985; Gardner 1996; Race & Fonseca 1996; NRC 2001; Brown & Veneman 2001; Quigley & Harper 2005a, b; Mack & Micacchion 2006; Gibbons & Lindenmayer 2007; Matthews & Endress 2008; Appendix S1). Such evaluations usually blame failure on inadequate assessment currencies, disregard for exchange restrictions, and poor enforcement. Their authors regularly recommend better currencies, more or different restrictions on exchanges, and better audit and compliance procedures.

We posit that weak technical design and lax enforcement are predictable features of regulatory biodiversity trading, and that sound and well-intentioned ecological advice is unlikely to correct this. We use three insights of Salzman & Ruhl (2000), who (1) provided a three-part analytical framework—currency, exchange restrictions, and review—to predict whether a trading program is likely to protect the environmental goods concerned; (2) recognized that simplicity, measurability, and interchangeability (also called *fungibility* or *substitutability*) determine whether environmental goods can be traded and protected simultaneously; and (3) predicted that in trading a complex, noninterchangeable and poorly measurable resource such as biodiversity, ecological realities, and political factors would combine to ensure inadequate currency, exchange restrictions, and review, to the detriment of that resource.

Our review examines ecological and political science theories that suggest protecting biodiversity in trading is neither technically realistic nor administratively probable. We first consider ecological aspects of recent biodiversity trading practice, using Salzman & Ruhl's framework. We assess the adequacy of currencies, exchange restrictions, and oversight to protect biodiversity, and identify issues ecologists have yet to consider. Next, we use public choice theory to extend Salzman & Ruhl's insights into problems of biodiversity trading administration. While biodiversity trading programs proliferate and advance optimistic promises to protect biodiversity,

core impediments to improved biodiversity outcomes remain largely unrecognized and unaddressed. We consider whether this trend is explained by the effectiveness of “symbolic policies,” (Edelman 1964), and suggest both ecological and political science are relevant for the assessment of biodiversity trading programs and potential alternative policy tools.

Inadequate biodiversity currencies

The test of a currency's adequacy is “... can [it] capture the significant values exchanged or do some important features remain external to the trades?” (Salzman & Ruhl 2000:614, Table 1). Simple environmental goods are easiest to commodify in currency: for example, a kilogram of sulfur dioxide provides a simple, relatively measurable, and adequate exchange currency for a unit of air pollution. But for biodiversity, there is no simple currency that adequately “... capture[s] what we care about” (Salzman & Ruhl 2000:623) (see also Robertson 2000). Biodiversity—the variety of living organisms—is hierarchical, with levels of organization from genes to ecosystems, an extraordinary number of elements at each level that vary in time and space, and diverse interactions within and between levels (e.g., Gaston 2000). Such complexity makes it exceptionally difficult to measure biodiversity, and to estimate an element's contribution to the whole.

Furthermore, if “what we care about” is persistence of the full variety of life, contributions of different biodiversity elements are noninterchangeable. This noninterchangeability can be conceived of in three different dimensions (Salzman & Ruhl 2000): *type* (e.g., endangered frog habitat is neither equivalent to nor exchangeable for endangered tree habitat; captive-bred subpopulations do not replicate a diverse population gene pool); *space* (e.g., isolated and contiguous habitat patches are not equivalent); and *time* (e.g., genetic bottlenecks alter population characteristics irreversibly; early and late seral stages of an ecosystem type support different species suites).

Table 1 Assessment framework adapted from Salzman & Ruhl (2000) for biodiversity trading, and examples of pertinent questions

Component 1. Currency adequacy		
<i>"Does the chosen metric fully capture the valued characteristics of the biodiversity exchanged, or do some important features remain external to the trades?" or, "Does the currency 'capture what we care about?'"</i>		
Component 2. Exchange adequacy		
<i>"Are market rules (exchange restrictions) adequate to ensure trades do not enable biodiversity loss?"</i>		
a. Type restrictions	b. Space restrictions	c. Time restrictions
<i>"Are like communities, species or processes replaced with like?" and if not</i>	<i>"Is the offset situated so ecological interactions and processes are maintained?"</i>	<i>"Will there be a temporal gap? And will it compromise biodiversity persistence?"</i>
<i>"Is this a trade-up (and what is a trade-up)?"</i>	<i>"Are existing biological communities and ecosystems displaced by the location of the offset?"</i>	<i>"What is the risk and cost of offset failure and permanent loss, and who bears that risk?"</i>
<i>"Are biodiversity platforms in place and is biodiversity information sufficient to inform exchange restrictions (and if not, who should pay for their development)?"</i>		
<i>"What is the logic behind offset ratios? Do ratios ensure replacement of like ecosystems with like, restoration of spatially dependent processes, and/or that risks and costs of biodiversity loss are fairly apportioned?"</i>		
<i>"What will be the cumulative effects on biodiversity of multiple exchanges and/or offset program(s)?"</i>		
Component 3. Review adequacy		
<i>"Do review provisions:</i>		
<i>a) Ensure robust valuation of the goods exchanged?</i>		
<i>b) Ensure fair apportioning of costs and risks (given who stands to gain from the exchange)?</i>		
<i>c) Effectively counteract agencies' and trading parties' incentives to transact trades that compromise biodiversity?"</i>		

Incomplete measurement, imprecise valuation, and noninterchangeability mean biodiversity exchange is strictly not commodity trading, but barter: "individuals haggling over goods and services with unique attributes" (Salzman & Ruhl 2000:614). But unlike barter in private goods, exchanges in environmental goods affect interests beyond direct participants; trading can erode the public's interest in public resources (Gustafsson 1998; Salzman & Ruhl 2000; Kroeger & Casey 2007). Unavoidably, simple biodiversity currencies are inadequate; they facilitate nominal biodiversity accounting, but omit, obscure, or conceal biodiversity features and noninterchangeabilities (Robertson 2000; Salzman & Ruhl 2000; e.g., see Stein *et al.* 2000; McCarthy *et al.* 2004; Fox & Nino-Murcia 2005). And in any exchange, a characteristic not counted is protected only by chance, which facilitates its loss. Simple currencies simultaneously enable poor accountability for biodiversity outcomes and provide opportunity for damage to biodiversity, bringing a need for restrictions on exchanges if public interests are to be protected (Salzman & Ruhl 2000).

Exchange restrictions to compensate for currency inadequacy

The literature describes many restrictions on biodiversity exchange intended to compensate for currency inadequacies in the three noninterchangeability dimensions.

In each case, a test of adequacy asks: "is this restriction adequate to ensure against biodiversity loss?" (Table 1).

(1) *Type*. Exchanges of dissimilar biodiversity risk loss of biodiversity components and functions (Salzman & Ruhl 2000; ten Kate *et al.* 2004). To counter this problem, some trading programs propose no-go areas to prohibit trading of critical assets (e.g., WA EPA 2006) but permit exchanges of noncritical biodiversity. Others limit exchanges to the same species, communities, or ecosystem type (e.g., VDNRE 2002; Brownlie *et al.* 2007), relying on simplified biodiversity classification tools. Some suggest out-of-kind exchanges ("like for like or better" or "trading up"; ten Kate *et al.* 2004:61; WA EPA 2006:10; Brownlie *et al.* 2007:6) might offer greater value if affected biodiversity is secure and more imperilled biodiversity is protected, although credible guidelines based on measures of complementarity (Justus & Sarkar 2002) have been slow to emerge.

(2) *Space*. The location of individuals, populations, and communities profoundly influences ecological interactions and biodiversity persistence (Hanski 1998); and ecosystems in different locations serve dissimilar functions (e.g., Mitsch 1998). To maintain biodiversity, exchanges must replace ecological interactions and functions lost in development, and restoration projects must not displace other natural ecosystems. Yet quantifying spatial dependency is data demanding, even for single species (e.g., Ovaskainen & Hanski 2004), and adverse effects of spatial displacement are poorly recognized and

rarely remedied in biodiversity trading. Some programs use a rule-of-thumb preference for nearby replacements over distant ones (ten Kate *et al.* 2004). Others restrict trades to within geographic zones (e.g., wetland service areas; Salzman & Ruhl 2000), or concentrate replacements in aggregated sites, intending to overcome fragmentation (e.g., Fox & Nino-Murcia 2005). Still others apparently ignore the problem (see Burgin 2008).

(3) *Time*. Development is usually permanent, life cycles of companies are finite, and ecosystem reconstruction seldom, if ever, succeeds in structure, composition, or function (e.g., Zedler & Callaway 1999; Hilderbrand *et al.* 2005; Quigley & Harper 2005a, b; Morris *et al.* 2006; Gibbons & Lindenmayer 2007; Matthews & Endress 2008). Even temporary losses may permanently damage populations and engender or aggravate cumulative effects. To provide certainty that development will not cause biodiversity loss, new, equivalent habitat must be created before existing habitat is destroyed or modified (Veltman 1995; Crooks & Ledoux 2002). This would restrict exchanges to a few, simple, predictable, quickly maturing ecosystem types (Morris *et al.* 2006). In biodiversity trading practice, time noninterchangeability is dealt with in three ways. First, *permanent drawdown* trading overlooks it, and exchanges destruction of existing ecosystems or species habitats for improved protection of other, existing ecosystems or habitats (as in USA's conservation banking) (Fox & Nino-Murcia 2005; Carroll *et al.* 2008) and Brazil's forest set-aside trading (Chomitz 2004)). Second, *interim drawdown* programs permit ecosystem or species habitat destruction before reconstruction (e.g., Australian states; VDNRE 2002; Gibbons & Lindenmayer 2007). Such programs generate immediate ecosystem or habitat loss, interrupt ecological processes (see Fig. 4 of Gibbons & Lindenmayer 2007:30), and risk permanent loss through restoration failure (Moilanen *et al.* 2008). Third, *true banking* programs nominally address time noninterchangeability by requiring biodiversity replacement before development occurs. This eliminates interim biodiversity loss and risk of restoration failure (though such requirements appear to be seldom enforced; see Salzman & Ruhl 2000; Mack & Micacchion 2006).

Further ecological problems

The above scan reveals persistent deficiencies in information and practice that facilitate net biodiversity loss through nonequivalent exchanges. Further problems span all three noninterchangeability dimensions. For example, the biodiversity data needed to inform exchange restrictions usually exceed those that governments, developers, or habitat bankers have been willing to fund.

Less comprehensive data bring greater uncertainty about biodiversity characteristics and hence increase potential for biodiversity loss. Also, researchers developing exchange restrictions at project scales often overlook cumulative (often nonlinear, synergistic, and indirect) negative effects of multiple nonequivalent exchanges in type, space, or time (Bedford & Preston 1988; Quigley & Harper 2005a; Mack & Micacchion 2006; but see Brownlie *et al.* 2007; Vesik *et al.* 2008). Another problem concerns ratios (or multipliers) applied to compensate for noninterchangeability in type, space, or time. Some have a statistical or ecological basis. For example, high offset ratios are needed to avoid risk of unfavorable biodiversity outcomes when restoration effectiveness is uncertain, failure is correlated among sites, or restoration is delayed (Moilanen *et al.* 2008). Brownlie *et al.* (2007) recommend multipliers to protect specified minimum areas, addressing the question "what ratio will achieve the biodiversity outcome sought?". Elsewhere, the basis for multipliers seems unsound: providing several times something different cannot replace a lost species or unique ecosystem; restoring something to higher abundance later may not compensate for consequences of a loss now. Similarly, financial insurance can neither restore the unrestorable nor remedy permanent loss.

Oversight of biodiversity barter

The currency and exchange inadequacies that beset biodiversity barter place a heavy burden on precautionary oversight (a review mechanism) to control exchanges sufficiently to protect biodiversity. Salzman & Ruhl (2000) suggest adequate oversight should ensure meaningful valuation of the public goods exchanged and fair apportioning of costs and risks, and counteract the agencies' and trading parties' incentives to transact bad deals (Table 1). Time and again, researchers report procedural and enforcement failures in biodiversity trading programs, and urge improvement, through more or better frameworks, resourcing, or insurance (e.g., Gibbons & Lindenmayer 2007; Matthews & Endress 2008; Norton 2008). But these suggestions do not address the political and administrative causes of inadequate review.

Administrative problems

Salzman & Ruhl (2000) observed an administrative playing field of biodiversity barter tilted toward development. We propose that classic theories of politics predict this tilt, and that biodiversity's poor measurability and noninterchangeability exacerbate it. Together, political, and

ecological factors create two fundamental problems for public administration of biodiversity barter:

(1) *Thin markets*. For a viable trading program to operate in practice, currencies must be simple, review cannot be onerous, and restrictions must be straightforward and few (Pedersen 1994; Salzman & Ruhl 2000). But to protect biodiversity, high-quality data must inform precautionary exchange restrictions. Such restrictions create transaction costs and allow few exchanges, constraining an otherwise well-supplied trading market (Salzman & Ruhl 2000; see e.g., Chomitz 2004).

(2) *Inequality, divergence, and coincidence of interests*. Precautionary exchange is also unlikely because of the unequal power and different goals of participants. This is foreseen by the public choice theory of politics, which predicts that rational actors act in their own self-interest, and that some actors are more powerful than others (e.g., see McCubbins *et al.* 1987; Eskridge 1988). Specifically, the motivated few will be more powerful than the disorganized many (Olson 1965); so public choice theory predicts private interests—such as developers—will often defeat public interests—such as biodiversity protection—and reap most policy benefits. As Eskridge (1988:294) observed, “[t]he legislative market is one that works badly. The public goods that government ought to be providing ... are seldom passed by the legislature, because demand for them is usually not strong and legislators gain too little from sponsoring them ... Conversely, rent-seeking statutes – primarily, concentrated benefit, distributed cost measures – seem inevitable.”

Three interests compete in biodiversity barter:

(a) *Traders* (developers and restoration/offset providers) have a financial, or vested, interest in obtaining permits to conduct business. Such traders in environmental goods need not be conscious of the quality of environmental outcomes if a permit is forthcoming (Gustafsson 1998; Floumoy 2000; Salzman & Ruhl 2000; Kroeger & Casey 2007). This encourages developers seeking permits to underestimate (perhaps unintentionally) environmental impacts, and restoration providers to exaggerate (maybe unwittingly) the value of biodiversity goods offered in exchange. Neither trader profits from investment in data to support independent assessment, robust exchange restrictions, and meaningful review. Instead, they benefit from simple currencies that are inexpensive to measure, plentiful trading options with few exchange restrictions, and limited review to minimize risk that a permit will be overturned.

(b) *Biodiversity protection interests* usually have no vested interest in biodiversity barter. They benefit from exchanges that are fully measured, exchange restrictions that are robust and upheld, and review mechanisms that are meaningful and effective in protecting biodiversity.

(c) *Regulatory officials* are those appointed to enforce trading conditions, and are both referee and representative of the public's interest in biodiversity. Because traders have little incentive to control quality, officials shoulder the full burden of enforcement. But officials are not disinterested “billiard balls,” faithfully implementing democratically determined rules (Wilson 1989:88). Without inferring corruption or malfeasance, public choice theory predicts that officials often have motivations that are different from their statutory mandates, and that, given freedom to choose, officials will often pursue their own self interest (e.g., Niskanen 1971; McCubbins *et al.* 1987; O'Toole 1988). In environmental regulation, incentives on officials often coincide more strongly with development than environmental interests: Winter (1985) even suggests that governments rarely fund full enforcement, and sometimes directly discourage officials from frustrating powerful vested interests. Therefore, officials can and sometimes do reduce their financial or political costs by offering development interests more palatable and less environmentally demanding options (Winter 1985; Salzman & Ruhl 2000:648–665; Brower 2008:20–22; 84–108). Simple inexpensive biodiversity currencies, weak or ambiguous exchange restrictions, and limited review benefit both officials and traders because they are cheap and offer flexibility, or utility (see Pedersen 1994; Parkes *et al.* 2004). Coincidentally, they also facilitate development at the expense of biodiversity.

The playing field on which these interests compete is far from level; the “default setting” (Brower 2008:14) predicted by Olson (1965) is that development will defeat biodiversity. To address biodiversity decline, policy instruments must level this playing field. But theory predicts biodiversity barter will reinforce, rather than correct, this default setting.

First, mandates to barter biodiversity weaken existing statutory constraints on biodiversity harm by allowing officials discretion to circumvent them; for example, the Habitat Conservation Plan provision of the USA's Endangered Species Act erodes its absolute prohibition on

species take (Ruhl 1999). Even in situations of routine noncompliance, legitimizing barter may produce worse environmental outcomes than policy regimes in which officials barter with developers “outside the shadow of the law” (Ellickson 1991:52), but the existence of a clear statute constrains their bartering leeway (see Winter 1985:240). More generally, in giving officials discretion to work toward unspecified outcomes, barter increases opportunity for officials already motivated to “skip rather lightly past avoidance and minimization and proceed instead directly to compensation” (Bean & Dwyer 2000:10537), while reducing public power to specify rules and goals through democratic processes (see Salzman & Ruhl 2000:683).

Second, the case-by-case decision making inherent in biodiversity barter reinforces dominance of vested development interests by constraining the effectiveness of biodiversity protection interests. Case-by-case decision making keeps biodiversity loss off the national radar and limits its importance, hence weakening the environmental voice (see Schattschneider 1960; Pralle 2006). It is more costly and less feasible for environmental interests to marshal the resources to challenge proposals case-by-case than through high-level orchestrated campaigns (Brower 2008:57).

Third, problematic measurement and case-by-case barter each render biodiversity trading especially vulnerable to *information asymmetry*—the situation in which insiders (traders and officials) know more than outsiders (biodiversity protection interests and the public), who are unable to measure the quality of biodiversity deals. Information asymmetry creates slack, or “a zone of freedom of action for regulators. . . in which they can operate with lessened fear of punishment by the polity for decisions that deviate from those the polity would adopt on its own” (Levine 1998:269). When officials’ and developers’ interests coincide in negotiating permits, a pattern of informal and less-than-transparent deals can result (Winter 1985; Freeman 2000; Brower 2008) with norms of behavior and standards of fairness that benefit insiders, but deviate from statutes and ideas of fairness held to protect outsiders—the public (Ellickson 1991). Thus, information asymmetry will systematically favor development over protection.

No net loss as symbolic policy

Absence of opportunity for public input in case-by-case decisions often renders ecological scientists the most vocal critics of biodiversity trading. But scientists appear reluctant to abandon hope that biodiversity offsets might yet deliver no net loss (see Gibbons & Lindenmayer 2007;

Burgin 2008; Norton 2008). We see compelling reasons for skepticism.

Some ecologists insist biodiversity barter could achieve no net loss—if only there were better currencies, informed exchange restrictions, and attention to review (e.g., ten Kate *et al.* 2004; Gibbons & Lindenmayer 2007). They assume that if improved information and measures were available, and rules were clear and transparently defensible on ecological grounds, officials would use and implement them. Empirical evidence shows that officials have repeatedly failed to do so (e.g., Salzman & Ruhl 2000; Fox & Nino-Murcia 2005; Burgin 2008); and public choice theory predicts this failure. Others might see opportunities to leverage funds for improved biodiversity data and measurement; developers, agencies, and governments are likely to resist this. Those recognizing the primacy of administrative problems posit carefully designed review might counter motivations of traders and officials (Salzman & Ruhl 2000:693). But this would constrain exchanges to the detriment of developers and officials, and no such review institution has emerged. In the absence of credible solutions to these problems, biodiversity trading is likely to continue to facilitate development at the expense of biodiversity.

In addition, biodiversity exchange has potential to postpone social and legislative changes needed to address the basic problem of biodiversity loss (see Pedersen 1994; Gustafsson 1998:271). We see two reasons. First, bartering focuses parties’ attention on immediate steps, rather than stimulating them to proceed “according to some larger progressive principle” (Winter 1985:246). This resembles displacement behavior in which “organizational means become transformed into ends-in-themselves and displace the principal goals of the organization” (Merton 1957). Conservation programs with a preference for near-term, achievable, procedural goals can deflect attention from long-term, more difficult goals for ecological outcomes (Brower *et al.* 2001).

Second, no net loss and net gain slogans themselves may be effective political diversions. We have argued that achieving no net biodiversity loss through barter is an illusion that crumbles under scrutiny from ecological and political science. But Edelman (1960, 1964) suggests that some policies are never intended by politicians to be more than hollow promises. Such symbolic policies promise much but guarantee little, and allow the motivated few to reap most of a policy’s benefits while leaving the disorganized many unaware, or lulled into “political quiescence” (Edelman 1964). No environmentalist will disagree with the goal of no net biodiversity loss. In attaching the slogan “no net loss” to biodiversity barter, politicians can appear to take action while continuing to serve development interests, and ignoring or perhaps

exacerbating biodiversity loss. In engaging ecologists' collaboration in a symbolic but illusory goal, biodiversity barter may succeed by "keeping friends close and enemies closer" (Brower 2008:58) thus defusing potential opposition (Robertson 2000). Developers, politicians, and officials embrace biodiversity barter under "no net loss" or "net gain" flags (Robertson 2000; Salzman & Ruhl 2000; Burgin 2008) because it benefits them to do so. Support from ecological scientists, whether tacit or active, sustains and authenticates the illusion.

Conclusions

Viable biodiversity barter and meaningful biodiversity protection seem mutually exclusive. We can achieve one or the other, but not both. Although compensation and no net loss are laudable ideals, ecological and political problems appear intractable, and mean that bartering is likely to accomplish more harm than good for biodiversity.

Ecological and political factors combine in bartering biodiversity to produce currencies, exchange restrictions, and oversight that are inadequate to protect biodiversity. Because biodiversity is complex and its elements noninterchangeable, there is no simple currency to measure fairness of exchange, and restrictive exchange rules and robust review institutions are needed to protect it. But a functioning exchange program requires simple currencies, few restrictions, and undemanding review. This gulf between market and ecological viability seems to render biodiversity trading doomed to fail—more specifically, to fail biodiversity. Indeed, the simplistic currencies, lax exchange restrictions and inadequate review that benefit both traders and officials are predicted by political theory and observed in practice. All come at a cost to biodiversity.

We further conclude that inequalities, divergence, and coincidence among interests in biodiversity barter mean that improved biodiversity measures and exchange restrictions recommended by ecologists will rarely be adopted. Few academics and practitioners have understood and tried to address these nonecological causes of failure (Salzman & Ruhl 2000:693).

The administrative playing field described in this article shapes the outcomes of not only biodiversity trading, but also all environmental policy. However, political theory predicts that biodiversity exchange policies—because of biodiversity's complexity, poor measurability, and noninterchangeability—will be more vulnerable to the institutional failings that undermine environmental protection than simple (albeit imperfectly enforced) prohibitions. Public choice theory suggests officials and

traders have more incentive to facilitate barter than to ensure biodiversity protection. Thus, given the option of saying to developers "yes, with conditions" rather than "no," officials will prefer "yes, with conditions"—particularly when compliance with conditions cannot be credibly measured and officials can avoid accountability for outcomes. Legitimized bartering can thus create a policy situation "obscure enough to please all parties ... and so ill-defined that failures ... will be difficult to detect and impossible to litigate" (Walker *et al.* 2008:226; see also Winter 1985).

Furthermore, recent proliferation of offset programs, with the promise of no net loss or net gain, is consistent with effective use of symbolic policy to "give the rhetoric to one side and the decision to the other" (Edelman 1960:703). Symbolic policy may cost conservation by obscuring biodiversity loss and dissipating impetus for social activism and forthright conservation planning.

In sum, while compensation and no net loss are worthy goals, and bartering biodiversity might appear more promising than simple and weakly enforced prohibitions, this article suggests policies that enable biodiversity trading may perversely yield worse biodiversity outcomes. All theoretical predictions point to further biodiversity loss paving the way for development in any biodiversity trading program, while a no net loss tag-line defuses potential opposition and impetus for change.

Acknowledgments

The authors acknowledge funding from New Zealand's Ministry of Research, Science and Technology, Lincoln University, and in-kind support from the Department of Conservation. We thank C. Bezar for technical editing and four anonymous reviewers for comments that improved the manuscript. We drew on the ideas of many colleagues, especially J. Overton (Landcare Research), B. Napp (Department of Conservation), and S. Bekessey, B. Langford, A. Moilanen, H. Possingham, and R. Pressey (the Applied Environmental Decision Analysis hub).

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1: Major regulatory biodiversity trading programs and references given in the manuscript.

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Editor: Dr. James Aronson

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EXHIBIT E



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Wetland Guidance for CAO Updates

Western Washington Version

June 2016

Publication No. 16-06-001

Publication and Contact Information

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Wetland Guidance for CAO Updates

Western Washington Version

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June 2016
Publication No. 16-06-001

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Summary

This publication replaces *Wetlands & CAO Updates: Guidance for Small Cities (Western Washington Version)*, Publication No. 10-06-002, January 2010. It also replaces the 1st revision dated July 2011 and the 2nd revision dated October 2012.

This new publication, for the most part, contains the same guidance as the “small cities guidance” referenced above. Over the last few years, it became obvious that the information in that document could apply to all cities and counties, not just small cities. However, the wetland buffer table may be too restrictive for county use because it assumes that adjacent land use intensity is high. Counties and larger cities generally have more staff and resources that allow more sophisticated approaches to assigning wetland buffers.

In addition, these jurisdictions may be able to provide additional protection for habitat function by requiring protected wildlife corridors between the wetland and other priority habitats in exchange for buffer reduction—something that is often impossible in small, urban jurisdictions.

Check with Ecology wetland staff for more information about using this guidance in your particular jurisdiction <http://www.ecy.wa.gov/programs/sea/wetlands/contacts.htm>.

Specific changes to this new publication include:

- Reference to the updated 2014 wetland rating system
- Updated definitions based on the updated 2014 wetland rating system
- Buffer tables that include habitat scores from the updated 2014 wetland rating system
- Addition of buffer table to be used if minimizing measures are not used
- Emphasis on the requirement to provide wildlife corridors where possible in exchange for buffer reduction
- Guidance on using wetlands for stormwater management facilities
- Revisions to exemptions for small wetlands
- Recommended language addressing agricultural activities in non-VSP jurisdictions
- Addition of recent mitigation documents and guidance
- Corrected links to resource documents and web pages

Introduction

This document is intended to provide guidance and tools useful in developing a wetland protection program for jurisdictions that are in the process of updating their critical areas ordinances (CAOs) to meet the Growth Management Act (GMA) requirements. Wetlands are one of the five types of critical areas identified in the GMA.

We recognize that many local governments lack the planning staff and resources necessary to develop and implement wetland standards that are both locally appropriate and based on best available science (BAS). Nonetheless, they must comply with the GMA requirement to designate and protect wetlands.

The first part of this document describes the important topics that should be addressed in the wetlands section of your CAO. It includes recommendations for wetland protection based on BAS. Appendix A is a sample CAO chapter for wetlands that incorporates these recommendations into a format similar to that found in many local CAOs. (Please note that the sample CAO will need to be tailored to your jurisdiction's naming and numbering system. There are several generic "XX" references throughout the text.) Appendix B contains definitions that are commonly used in wetlands regulations.

This document does not include the more general provisions typically found in regulations related to all critical areas. These can be found in Appendix A of the *Critical Areas Assistance Handbook* published by the Washington State Department of Commerce (formerly the Department of Community, Trade, and Economic Development) in November 2003 <http://www.commerce.wa.gov/Documents/GMS-Critical-Areas-Appendix-A-Sample-Code-Provisions.pdf>. This document revises the wetland-specific provisions in the *Critical Areas Assistance Handbook*.

The recommendations in this document and the sample ordinance may not be appropriate for use by rural **county** governments. Factors to consider are the county's rate of growth, the nature and intensity of land uses in the county, the wetland resources at risk, and the ability of the county to implement its CAO. We suggest that you contact us to determine whether this guidance is applicable to your county. Please use the following link to find Ecology's wetland specialist for your area:
<http://www.ecy.wa.gov/programs/sea/wetlands/contacts.htm>.

Guidance on the Science of Wetland Protection

Ecology has produced several different tools that can help local governments develop a comprehensive wetlands protection program for their jurisdictions. The Washington Departments of Ecology (Ecology) and Fish and Wildlife (WDFW) have published a two-volume guidance document to help local governments protect and manage wetlands:

- ***Wetlands in Washington State, Volume 1: A Synthesis of the Science*** (Washington State Department of Ecology Publication #05-06-006, Olympia, WA, March 2005). This volume is the result of an extensive search of over 17,000 scientific articles and synthesizes over 1,000 peer-reviewed works relevant to the management of Washington's wetlands.
- ***Wetlands in Washington State, Volume 2: Managing and Protecting Wetlands*** (Washington State Department of Ecology Publication #05-06-008, Olympia, WA, April 2005). This volume was developed with the assistance of local government planners and wetland consultants. It can be used to craft regulatory language that is based on BAS. We recommend that you review Chapter 8 and its appendices as you begin to work on updating your existing regulations. (Please note: Appendix 8-C was revised in October 2014.)

In October 2013, Ecology released an update of the science pertaining to wetland buffers. The new information on buffers provides a refinement of our knowledge and revisits the conclusions and key points in the 2005 synthesis.

- ***Update on Wetland Buffers: The State of the Science*** (Washington State Department of Ecology Publication #13-06-011, Olympia, WA, October 2013).

Ecology, in coordination with the U.S. Army Corps of Engineers (Corps) and the U.S. Environmental Protection Agency (EPA), has also developed a two-part guidance document aimed at improving the quality and effectiveness of compensatory mitigation in Washington State:

- ***Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance (Version 1)*** (Washington State Department of Ecology Publication #06-06-011a, Olympia, WA, March 2006). Part 1 provides a brief background on wetlands, an overview of the factors that go into the agencies' permitting decisions, and detailed guidance on the agencies' policies of wetland mitigation, particularly compensatory mitigation. It outlines the information the agencies use to determine whether specific mitigation plans are appropriate and adequate.
- ***Wetland Mitigation in Washington State–Part 2: Developing Mitigation Plans (Version 1)*** (Washington State Department of Ecology Publication #06-06-011b, Olympia, WA, March 2006). Part 2 provides technical information on preparing plans for compensatory mitigation.

Ecology has also developed a wetland ratings system for western Washington. The rating system is a useful tool for dividing wetlands into groups that have similar needs for protection.

- ***Washington State Wetland Rating System for Western Washington: 2014 Update*** (Washington State Department of Ecology Publication #14-06-29, Olympia, WA, October 2014).

Links to all of these documents can be found at:

<http://www.ecy.wa.gov/programs/sea/wetlands/gma/index.html>.

Relationship between the GMA and the SMA

You may be planning to adopt a Shoreline Master Program (SMP) that will rely on the CAO for protection of wetlands and other critical areas in shoreline jurisdiction. Ecology does not have an approval role in the CAO adoption process; our role is advisory. The SMP, however, is a joint document of Ecology and the local government requiring Ecology approval. Before the SMP can be approved by Ecology, the CAO must meet the “no net loss of ecological functions” requirement (WAC 173-26-186(8)(b)(i)).

You should be aware that the Shoreline Management Act (SMA) may preclude or alter the administration of your CAO. For example, certain activities exempted under the CAO will not qualify for exemption under the SMP. In addition, activities allowed without permits under the CAO may require permits under the SMP.

For assistance with CAO-SMP integration, please use the following link to find the shoreline planner for your area:

<http://www.ecy.wa.gov/programs/sea/sma/contacts/index.html>.

Policy Discussion for Your Wetlands Chapter

Your wetlands chapter will exist as one of several in your critical areas ordinance. Below we describe some of the important subsections in the wetlands chapter and include our recommendations for protecting wetlands based on the best available science.

Purpose

The chapter typically begins with a purpose statement, followed by designation criteria, which include a definition of wetlands and the methods by which they are identified and rated and other details listed below. The purpose statement may also state that this chapter is intended to be consistent with the requirements of 36.70A RCW and to implement the goals and policies of your Comprehensive Plan for protecting wetlands.

Definitions

Your wetlands chapter may include a separate list of definitions, or the definitions may be included in the general definitions section of the CAO. Appendix B is a list of

definitions relevant to your wetlands chapter. This list includes terms identified in state law and agency guidance documents. Clarity and consistency in the use of these terms will make ordinance implementation easier.

Identifying, Designating, and Rating Wetlands

The first steps in regulating wetlands are to define what is being regulated and specify how these areas will be identified. The GMA requires the use of the following definition of wetlands and specifies how to identify and delineate them.

In designating wetlands for regulatory purposes, **counties and cities are required to use the definition of wetlands in RCW 36.70A.030(21):**

“Wetland” or “wetlands” means areas that are inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from non-wetland areas created to mitigate conversion of wetlands.

Wetlands are subject to a local government’s regulatory authority if they meet the criteria in this definition. This includes Prior Converted Croplands (PCCs) and isolated wetlands. These wetlands can provide critical functions and habitat and should be regulated. **The GMA does not allow flexibility in adopting a modified definition of wetlands.**

Irrigation practices, such as the Irrigation District ditches in Sequim, can result in human-created wetlands. More frequently, however, irrigation practices may augment natural sources of water to a wetland. Wetlands that form along irrigation ditches that were intentionally created in uplands may be exempted from regulation. However, if a wetland is the unintentional by-product of irrigation activities, the wetland should be regulated. If a wetland disappears as the result of a change in irrigation practice, it will not be regulated in the future. However, most wetlands will not disappear completely as a result of local changes in irrigation practices because of natural sources of water or regional irrigation influences. Please see <http://www.ecy.wa.gov/programs/sea/wetlands/irrigation.html> for more information on how Ecology regulates irrigation-influenced wetlands.

Ecology is most concerned about those changes in land use that would eliminate wetlands as the result of fill or grading, such as a conversion to commercial or residential use. These activities should be regulated by the CAO, and appropriate protection standards

(such as buffers and mitigation) should be required in order to minimize the loss of wetland area and function.

Many jurisdictions use the National Wetland Inventory (NWI) to determine whether wetlands exist within their boundaries. Since the NWI is based on photographs that are over 30 years old and provides only a general approximation of wetland location, it cannot be used alone to designate wetlands. Wetlands are those areas that meet the above definition of “wetland.” Wetlands are also dynamic systems that change over time. It is important to adopt the GMA definition and to have regulations in place to protect wetland functions and values, should wetlands that do not currently appear on the NWI or other maps be identified in the future.

State laws require that wetlands protected under the GMA and the SMA be delineated using a manual that is developed by Ecology and adopted into rules ([RCW 36.70A.175](#); [RCW 90.58.380](#)). The Department of Ecology adopted a wetland delineation manual in 1997 ([WAC 173-22-080](#)) that was based on the original 1987 Corps of Engineers manual and subsequent Regulatory Guidance Letters.

During the last few years the Army Corps of Engineers has updated and expanded their delineation manual with regional supplements. To maintain consistency between the state and federal delineations of wetlands, Ecology has repealed [WAC 173-22-080](#) (the state delineation manual) and replaced it with a revision of [WAC 173-22-035](#) that states that delineations should be done according to the currently approved federal manual and regional supplements. **The changes became effective March 14, 2011.**

The GMA states that “wetlands regulated under development regulations adopted pursuant to this chapter shall be delineated in accordance with the manual adopted by the department pursuant to [RCW 90.58.380](#).” RCW 90.58.380 allows the Department of Ecology to adopt rules that incorporate changes to the manual. **Therefore, the currently approved federal manual and regional supplements should be used for delineating wetlands in GMA jurisdiction.** See: <http://www.ecy.wa.gov/programs/sea/wetlands/delineation.html>.

Local governments are not required to rate or classify wetlands when regulating them. However, methods that classify, categorize, or rate wetlands help target the appropriate level of protection to particular types of wetlands and avoid the “one-size-fits-all” approach. If a local government uses a wetland rating system, it must consider the criteria described in [WAC 365-190-090\(3\)](#).

The *Washington State Wetland Rating System for Western Washington: 2014 Update (Effective January 2015)*, (Ecology Publication #14-06-029, October 2014) is a useful tool for dividing wetlands into groups that have similar needs for protection. The revised rating system represents the best available science, as it is based on a better understanding of wetland functions, ways to evaluate them, and what is needed to protect them. It provides a quick “snapshot” characterization of a particular wetland. In many cases, it will provide enough information about existing wetland functions to allow

adequate plan review and land use decisions to be made without the additional expense of a separate wetland functional assessment.

While local governments are not required to use Ecology’s revised rating system, we strongly encourage you to adopt wetland regulations that require its use. Most qualified wetland specialists are using the revised rating system. In cases where state and federal permits are required, the use of this rating system would benefit applicants by eliminating the need to rate wetlands according to a different local standard. If you choose not to use the state’s wetland rating system, you must provide a rationale for this decision according to [WAC 365-190-090\(3\)](#).

We recommend that you include language that describes the four categories of wetlands. This text is different for eastern and western Washington jurisdictions. Please refer to Appendix A, Section XX.020.B.1-4 for the specific category descriptions.

Regulated Uses and Activities

Your wetland section should list those uses and activities that are regulated under the critical areas ordinance. Some of these items include: removal, excavation, grading, or dredging of material of any kind; draining, flooding, or disturbing of the wetland, water level, or water table; the construction, reconstruction, demolition, or expansion of any structure; etc. More extensive examples are provided in the sample ordinance.

Wetlands are often impacted by unauthorized **clearing and grading** that takes place before application for development permits. You should make sure your CAO adequately regulates clearing and grading. If it doesn’t, you should adopt a separate clearing and grading ordinance. The Department of Commerce (formerly Community, Trade and Economic Development) published technical guidance on developing a clearing and grading ordinance: <http://www.commerce.wa.gov/Documents/GMS-Clearing-and-Grading-Technical-Guidance-Final-2005.pdf>.

Most forest practices (as defined in [RCW 76.09](#)) are exempted from the provisions of a wetlands chapter in the CAO. However, those forest practices that are Class IV general should be regulated. These activities constitute a conversion from forestry to some other use. As such, buffers and wetland protections are appropriate.

Exemptions

Your wetlands section should identify those activities in or near wetlands that are regulated and those that are exempt from regulation. Exemptions include activities that will have little or no environmental effect or are an emergency that threatens public health or safety. In the case of emergency response activities that affect wetlands and buffers, the responsible party should be required to obtain after-the-fact permits and to rectify impacts. Some jurisdictions place the exemptions or exceptions in a general exemptions section near the front of the CAO. However, some exemptions or exceptions may apply only to wetlands, so it may be more practical to have these specific exemptions in the wetlands section.

Exempt activities should be limited to those that will not have a significant impact on a wetland's structure and function (including its water, soil, or vegetation) and those that are expected to be very short term. Local governments should, however, also consider the cumulative impacts from exempted activities. They can result in a loss of wetland acreage and function that are not replaced through compensatory mitigation.

The scope, coverage, and applicability of a critical areas ordinance should capture the full range of activities that are detrimental to wetland functions. Therefore, exemptions should be supported by the scientific literature and be carefully crafted to minimize the potential for adverse impacts. However, a local government should not assume that an exemption is appropriate in the absence of science to refute the exemption. The language should clearly state whether a given activity is exempt from applicable standards in the code or whether it is exempt from needing a permit but still must comply with the code. Exemptions should be limited and construed narrowly.

For more information on this topic, please refer to Chapter 8 of *Wetlands in Washington State, Volume 2: Managing and Protecting Wetlands* (Ecology Publication #05-06-008, Olympia, WA, April 2005:

<https://fortress.wa.gov/ecy/publications/summarypages/0506008.html>).

The GMA, in [RCW 36.70a.030\(21\)](#), requires local governments to regulate wetlands that meet the GMA-required definition of “wetland” (see the definition of “wetland” in the previous section). This includes **Prior Converted Croplands (PCCs)** and **hydrologically isolated wetlands**, two types of wetlands that have been exempt from federal regulation at times. PCCs are wetlands that have been ditched and drained for active agricultural use before December 23, 1985. Isolated wetlands are those wetlands that have no surface hydrologic connection to waters of the United States. These wetlands must be regulated by your CAO. Please see <http://www.ecy.wa.gov/programs/sea/wetlands/isolated.html> for more information on how the state of Washington currently regulates isolated wetlands.

The scientific literature does not support exempting wetlands that are below a certain size. While we recognize an administrative desire to place size thresholds on wetlands that are to be regulated, you need to be aware that it is not possible to conclude from size alone what functions a particular wetland may be providing. Ecology has developed a strategy for exempting small wetlands when additional criteria are considered. This language is present in the sample ordinance. **However, impacts to small wetlands are NOT exempt from the requirement to provide compensatory mitigation for those impacts.** If an in-lieu fee (ILF) program or a mitigation bank is available in your area (see page 15), these mitigation alternatives can help prevent a net loss of wetland function from impacts to small wetlands in your jurisdiction.

Exceptions are typically addressed in a CAO in the context of reasonable use of property. For more information about this regulatory tool, see Section VII of the *Critical Areas Assistance Handbook* published by the Washington State Department of Commerce: <http://www.commerce.wa.gov/Documents/GMS-Critical-Areas-Assist-Handbook.pdf> . You should keep in mind that the Shoreline Management Act does not allow reasonable

use exceptions, providing instead a variance pathway to afford regulatory relief. **If you decide to incorporate your CAO into your SMP when the latter document is updated, you will need to address this potential inconsistency.**

Forest Practices

Class I, II, and III forest practices should be exempted from the wetlands section of your CAO. These activities are regulated through RCW 76.09, the Forest Practices Act.

Agricultural Activities

In 2011 the Washington Legislature created the Voluntary Stewardship Program (VSP) as an alternative for meeting GMA requirements related to protecting critical areas and agricultural lands. In 2015 the state provided funding for participating counties to begin the VSP planning process. For more information on this program, see <http://www.scc.wa.gov/voluntary-stewardship/>.

For the GMA update cycle beginning 2015, some counties will begin addressing critical area issues related to agriculture through a VSP work plan.

If your jurisdiction is **not** in a participating county or not in a participating watershed, then you must review and revise your development regulations for protecting wetlands as they apply to agricultural activities (see [RCW 36.70A.710](#)).

If your jurisdiction is in a VSP watershed designated by a participating county, your GMA responsibilities to protect critical areas from agricultural activities in or near wetlands will be achieved through the VSP work plan.

However, it is important to keep in mind that federal and state regulations, such as the Clean Water Act and the State Water Pollution Control Act are still applicable in all jurisdictions regardless of participation or non-participation in the VSP. The VSP does not alter the responsibility of property owners to meet water quality standards, protect wetlands, and comply with state and federal environmental regulations.

Ecology recommends the following for non-VSP jurisdictions:

“Existing and ongoing agricultural activities” are often exempted from the provisions of a CAO. These activities should be clearly defined and should not include removing trees, diverting or impounding water, excavation, ditching, draining, culverting, filling, grading, or similar activities that introduce new adverse impacts to wetlands or other aquatic resources. Maintenance of agricultural ditches should be limited to removing sediment in existing ditches to a specified depth at date of last maintenance. Conversion of wetlands that are not currently in agricultural use to a new agricultural use should be subject to the same regulations that govern new development.

Ecology encourages the use of Best Management Practices (BMPs), farm conservation plans, and incentive-based programs to improve agricultural practices in and near wetlands. The goal of the BMPs should be to ensure that ongoing agricultural activities

minimize their effects on water quality, riparian ecology, salmonid populations, and wildlife habitat.

Strategies for Protecting Wetlands from Impacts

Wetlands Inventory

You may wish to pursue accurate identification and rating of all wetlands in your planning area based on the *Washington State Wetland Rating System for Western Washington: 2014 Update* (Washington State Department of Ecology Publication #14-06-29, Olympia, WA, October 2014) and the approved federal wetland delineation manual and applicable regional supplements. These documents can be downloaded at:

- <http://www.ecy.wa.gov/programs/sea/wetlands/ratingsystems/index.html> (rating systems)
- <http://www.ecy.wa.gov/programs/sea/wetlands/delineation.html> (delineation manual and supplements)

While this approach may initially be more labor intensive and expensive, such information will allow rapid review of development proposals and can help your jurisdiction prioritize areas for preservation or acquisition.

This approach is consistent with BAS. It can help with the development of a landscape-analysis approach to protecting wetlands in your jurisdiction. Landscape analysis for critical areas facilitates and informs long-range planning. The City of Aberdeen used this approach in their CAO update. (See Section XX.050.B in the sample ordinance.)

ABCs

The most basic approach to protecting wetland functions and values can be summarized as the **A-B-C Approach, or Avoid-Buffer-Compensate**. This means that a CAO should contain language to ensure that:

1. Wetlands impacts are **avoided** to the extent practicable.
2. Wetlands are **buffered** to protect them from adjacent land-use impacts.
3. Unavoidable impacts are **compensated**, or replaced.

Your CAO should provide requirements on how to reduce the severity of impacts to wetlands. When an alteration to a wetland is proposed, impacts should be avoided, minimized, or compensated for in the following sequential order of preference:

1. Avoiding the impact altogether by not taking a certain action or parts of an action;

2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;
3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;
5. Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or
6. Monitoring the impact and taking appropriate corrective measures.

Buffers

Establishing standards for wetland buffers is usually the most challenging part of developing a CAO. However, developing a predictable, reasonable approach for establishing buffers that includes the best available science is not as difficult as it may seem.

The scientific literature is unequivocal that **buffers are necessary to protect wetland functions** and values. The literature consistently reports that the primary factors to evaluate in determining appropriate buffer widths are:

1. The wetland type and functions needing protection (buffers filter sediment, nutrients, or toxics; screen noise and light; provide forage, nesting, or resting habitat for wetland-dependent species; etc.).
2. The types of adjacent land use and their expected impacts.
3. The characteristics of the buffer area (slope, soils, vegetation).

The widths of buffers needed vary widely, depending on these three factors. For example, providing filtration of coarse sediment from residential development next to a low-quality wetland would require only a relatively flat buffer of dense grasses or forest/shrub vegetation in the range of 20 to 30 feet. However, providing forage and nesting habitat for common wetland-dependent species such as waterfowl, herons, or amphibians in a high-quality wetland adjacent to residential development would require a buffer vegetated with trees and shrubs in the range of 200 to 300 feet. This illustrates the necessity of using an approach to buffers that incorporates wetland type and functions (based on an appropriate rating system), types of land use, and the environmental characteristics of the existing buffer.

Your CAO should require buffers for activities that will impact wetland functions. Ecology's complete buffer recommendations are presented in Appendix 8-C of *Wetlands*

in Washington State, Volume 2 (revised October 2014). We recommend using the tables shown in the sample ordinance.

Tables XX.1 and XX.3 are derived from the more-detailed tables in *Volume 2*. They are easy to use and are based on BAS. This approach provides the important balance of predictability and flexibility. Determination of buffer size is simply a matter of applying the results of the wetland rating system score to the buffer matrix, based on the wetland category and wildlife habitat score. It generally requires smaller buffers for those wetlands that do not have much wildlife use.

Table XX.1 requires the use of the minimizing measures in Table XX.2. These measures are intended to reduce the impacts of the adjacent land use on the wetland. If impacts are reduced, the size of the buffer required to protect the wetland's functions can be reduced. The buffer widths in Table XX.1 represent a 25% reduction in our recommended buffers in *Volume 2*.

Table XX.1 also requires the protection of a wildlife corridor between wetlands that score 5 or more habitat points and any other Priority Habitat. This requirement is particularly applicable in large or rural jurisdictions where species need to have access to other habitats to meet their life needs. A buffer is the usual means of providing this necessary habitat. However, if buffer reduction is allowed, we cannot ensure that these species will have adequate access to habitat without providing a connective corridor. In urban areas, the best solution is a landscape-based approach that takes into account actual species use and spatial arrangement and connectivity of habitats. Without such an approach, jurisdictions should use the guidance provided in the sample wetland chapter.

If your jurisdiction is small and urban, providing a wildlife corridor may not be an option. You should consult with Ecology wetland staff to determine whether using Tables XX.1 and XX.2 alone will provide adequate protection for your wetland functions.

Table XX.3 shows the buffer widths required if the minimizing measures in Table XX.2 are **not** implemented and if a wildlife corridor is **not** protected. These buffers are wider than those in Table XX.1, because the impacts to the wetland functions are potentially greater.

The buffer tables XX.1 and XX.3 do not consider land-use intensity in the buffer calculation, since it is presumed that most urban land uses will be high or moderate intensity. However, if your jurisdiction has an activity that can be considered low intensity, such as a passive recreation area or nature park with undeveloped trails, you may wish to prescribe a smaller buffer **for that area only**. The buffer for an area should be no less than 75% of the otherwise required buffer. Such a "low-intensity" buffer is not appropriate for residential, commercial, or industrial uses. Of course, if your jurisdiction includes rural land uses, you should consider using the buffer tables in Appendix 8-C of *Wetlands in Washington State, Volume 2* (revised October 2014).

Some wetland types listed in the buffer tables may not be present in your jurisdiction (e.g., coastal lagoons, bogs, interdunal wetlands, etc.). If you are certain that these wetlands do not occur within your jurisdiction and would not be introduced by future annexations, you may remove those wetland types from the buffer tables.

You may wish to adopt an even simpler approach to wetland buffers, one based only on wetland category. In this case, buffers must be large enough to protect the most-sensitive wetlands from the most-damaging land-use impacts. Please refer to Table 8C-1 of Appendix 8-C of *Wetlands in Washington State, Volume 2* (revised October 2014) for this example.

Ecology's buffer recommendations are based on a moderate-risk approach to protecting wetland functions. This means that there is a moderate risk that wetland functions will be impacted. Adopting smaller buffers represents a high-risk approach, and you need to be prepared to justify why such an approach is necessary and to offer alternative means of protecting wetland functions that help reduce the risk.

Ecology's buffer recommendations are also based on the assumption that the buffer is well vegetated with native species appropriate to the ecoregion. If the buffer does not consist of vegetation adequate to provide the necessary protection, then either the buffer area should be planted or the buffer width should be increased.

Buffer Averaging

Local governments often wish to allow buffer widths to be varied in certain circumstances. This may be reasonable if your standard buffers are adequate. The width of buffers may be averaged if this will improve the protection of wetland functions, or if it is the only way to allow for reasonable use of a parcel.

We recommend that a request for buffer averaging include a wetland report. The report should be prepared by a qualified professional describing the current functions of the wetland and its buffer and the measures that will be taken to ensure that there is no loss of wetland function due to the buffer averaging. The width of the buffer at any given point after averaging should be no smaller than 75% of the standard buffer.

If you choose to adopt narrower buffer widths than those supported by BAS, then further reductions to the buffer width should not be allowed under any circumstances.

Mitigation

Applicants are required by state and federal permitting agencies to show that they have followed mitigation sequencing and have first avoided and minimized impacts to wetlands wherever practicable. Your CAO should include the definition of mitigation sequencing and require applicants to demonstrate that they have applied avoidance and minimization. For more information and sample checklists, see <http://www.ecy.wa.gov/programs/sea/wetlands/avoidance.html>.

Unavoidable **impacts to wetlands should be offset by compensatory mitigation**. Your CAO should include standards for the type, location, amount, and timing of the mitigation. It should also include clear guidance on the design considerations and reporting requirements for mitigation plans.

Ecology's recommendations for the amount of mitigation (ratios) are based on wetland category, function, and special characteristics. Requiring a greater area for mitigation than the wetland area that will be impacted helps offset both the risk that compensatory mitigation will fail and the temporal loss of functions that may occur. We recommend using the ratio table shown in the sample ordinance. It is derived from the more-detailed tables in Part 1 of the joint agency guidance on mitigation: *Wetland Mitigation in Washington State, Parts 1 and 2* (Ecology Publications #06-06-011a & b, March 2006).

As an alternative to the mitigation ratios found in the joint guidance, Ecology has developed a credit-debit tool for calculating when a proposed wetland mitigation project adequately replaces the functions and values lost when wetlands are impacted. The tool is designed to provide guidance for both regulators and applicants during two stages of the mitigation process:

1. Estimating the functions and values lost when a wetland is altered (debits), and
2. Estimating the gain in functions and values that result from the mitigation (credits).

The Department of Ecology, however, does not require the use of this credit-debit method. It provides one method for determining the adequacy of compensatory wetland mitigation. It does not set any new regulatory requirements. The document and worksheets can be downloaded at:

<http://www.ecy.wa.gov/programs/sea/wetlands/mitigation/creditdebit/index.html>.

In 2008 the Corps and the EPA issued a rule governing compensatory mitigation. The rule establishes performance standards and criteria to improve the quality and success of compensatory mitigation, mitigation banks, and in-lieu fee programs. For more information on the federal rule, see:

http://water.epa.gov/lawsregs/guidance/wetlands/wetlandsmitigation_index.cfm.

By adopting mitigation standards based on the state and federal guidance and rules, you will be providing consistency for applicants who must also apply for state and federal permits.

Mitigation Alternatives

Various options are available for mitigation, in addition to the traditional on-site concurrent option. These options include placing the mitigation away from the project site (off-site mitigation), building mitigation in advance of project impacts, and using third-party mitigation providers such as wetland banks and in-lieu-fee programs. Deciding which option should be used depends on what works best for the applicant and

for the environment. Some of these options may not be available in your area at this time. However, we recommend that your CAO allow these options. They can be effective and valuable tools in preventing a net loss of wetland functions.

Some project applicants may propose mitigation that is consistent with sound ecological principles but is located outside of your jurisdiction. You may wish to include language in your CAO that enables your government to allow such out-of-jurisdiction mitigation opportunities.

In addition to the following options, you might want to consider allowing transfer of development rights (TDR) as a tool for protecting wetlands. The Department of Commerce is working with four Puget Sound counties in a pilot TDR program. For more information, contact the Commerce planner for your jurisdiction or see: [Commerce Regional Assistance Teams](#).

Mitigation Banking

A mitigation bank is a site where wetlands, streams, and/or other aquatic resource areas have been restored, established, enhanced, or (in certain circumstances) preserved for the purpose of providing compensation for unavoidable impacts to aquatic resources. A mitigation bank may be created by a government agency, corporation, nonprofit organization, or other entity. The bank sells its credits to permittees who are required to compensate for wetland impacts. Mitigation banks allow a permittee to simply write a check for their mitigation obligation. It is the bank owner who is responsible for the mitigation success. Mitigation banks require a formal agreement with the Corps, Ecology, and the local jurisdiction to be used for federal or state permits.

Ecology adopted the final Wetland Mitigation Banks Rule (WAC 173-700) in 2009. The purpose of the rule is to provide a framework for the certification, operation, and monitoring of wetland mitigation banks. To learn more about wetland banking and the rule, see Ecology's website at <http://www.ecy.wa.gov/programs/sea/wetlands/mitigation/banking/index.html>.

In-Lieu Fee (ILF)

In this approach to mitigation, a permittee pays a fee to a third party in lieu of conducting project-specific mitigation or buying credits from a mitigation bank. ILF mitigation is used mainly to compensate for impacts to wetlands when better approaches to compensation are not available or practicable, or when the use of an ILF is in the best interest of the environment.

An ILF represents the expected costs to a third party of replacing the wetland functions lost or degraded as a result of the permittee's project. Fees are typically held in trust until sufficient funds have been collected to finance a mitigation project. Only a nonprofit organization such as a local land trust, private conservation group, or government agency with demonstrated competence in natural resource management may operate an ILF program. All ILF programs must be approved by the Corps to be used for Section 404

permits. To learn more about ILF programs, see Ecology's website at <http://www.ecy.wa.gov/mitigation/ilf.html>.

Off-Site Mitigation

This refers to compensatory mitigation that is not located at or near the project that generates impacts to wetlands. Off-site mitigation is generally allowed when on-site mitigation is not practicable or environmentally preferable.

The 2008 federal rule on compensatory mitigation requires that some type of watershed approach be used in siting mitigation. Ecology, the Corps of Engineers, and EPA have developed guidance to help applicants select potential off-site mitigation sites. To download a copy of this guidance, *Selecting Wetland Mitigation Sites Using a Watershed Approach (Western Washington)* (Ecology Publication #09-06-032, December 2009), please see <https://fortress.wa.gov/ecy/publications/summarypages/0906032.html>.

Advance Mitigation

When compensatory mitigation is implemented before, and in anticipation of, future **known** impacts to wetlands, it is referred to as "advance mitigation." Advance mitigation has been used mostly for large mitigation projects that are constructed in distinct phases where the unavoidable impacts to wetlands are known. Advance mitigation lets an applicant provide all of the compensation needed for the entire project affecting wetlands at one time, which may result in more favorable mitigation ratios.

Although similar to mitigation banking, advance mitigation is different in several ways. Most importantly, advance mitigation is used only to compensate for the permittee's specific project (or projects) with pre-identified impacts to wetlands. Wetland banks provide mitigation for unknown future impacts within a specific "service" area. The advance mitigation can be used only by the permittee. Advance mitigation may not be sold unless it is changed to a wetland bank. Ecology, WDFW, and the Corps have developed guidance to help applicants develop advance mitigation proposals. To download a copy of this guidance, *Interagency Regulatory Guide: Advance Permittee-Responsible Mitigation* (Ecology Publication #12-06-015, December 2012), please see <https://fortress.wa.gov/ecy/publications/SummaryPages/1206015.html>

Conclusion

We hope you find this information helpful. If you have questions about this document or need additional assistance with the wetlands section of your critical areas ordinance update, please call Donna Bunten at (360) 407-7172 or donna.bunten@ecy.wa.gov.

You may also contact one of Ecology's regional wetland specialists. They are available to work with you during your update process. For example, they can offer presentations to elected officials and planning commissions. They can also provide technical assistance including help with wetland delineation, wetland rating, ordinary high water

mark determination, and project review. Please use the following link to find the wetland specialist for your area:

<http://www.ecy.wa.gov/programs/sea/wetlands/contacts.htm>.

For assistance with other aspects of your critical areas ordinance update, please contact the Department of Commerce at (360) 725-3000.

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Appendix A - Sample Wetlands Chapter

(Western Washington)

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Subchapter XX.XX Wetlands

Sections:

XX.010 Purpose
XX.020 Identification and Rating
XX.030 Regulated Activities
XX.040 Exemptions and Allowed Uses in Wetlands
XX.050 Wetland Buffers
XX.060 Critical Area Reports
XX.070 Compensatory Mitigation
XX.080 Unauthorized Alterations and Enforcement

XX.010 Purpose

The purposes of this Chapter are to:

- A. Recognize and protect the beneficial functions performed by many wetlands, which include, but are not limited to, providing food, breeding, nesting and/or rearing habitat for fish and wildlife; recharging and discharging ground water; contributing to stream flow during low flow periods; stabilizing stream banks and shorelines; storing storm and flood waters to reduce flooding and erosion; and improving water quality through biofiltration, adsorption, and retention and transformation of sediments, nutrients, and toxicants.
- B. Regulate land use to avoid adverse effects on wetlands and maintain the functions and values of wetlands throughout (name of jurisdiction).
- C. Establish review procedures for development proposals in and adjacent to wetlands.
 - 1. Compliance with the provisions of the Chapter does not constitute compliance with other federal, state, and local regulations and permit requirements that may be required (for example, Shoreline Substantial Development Permits, HPA permits, Army Corps of Engineers Section 404 permits, NPDES permits). The applicant is responsible for complying with these requirements, apart from the process established in this Chapter.

XX.020 Identification and Rating

A. Identification and Delineation. Identification of wetlands and delineation of their boundaries pursuant to this Chapter shall be done in accordance with the approved federal wetland delineation manual and applicable regional supplement. All areas within the City meeting the wetland designation criteria in that procedure are hereby designated critical areas and are subject to the provisions of this Chapter. Wetland delineations are

valid for five years; after such date the City shall determine whether a revision or additional assessment is necessary.

B. Rating. Wetlands shall be rated according to the Washington Department of Ecology wetland rating system, as set forth in the *Washington State Wetland Rating System for Western Washington: 2014 Update* (Ecology Publication #14-06-029, or as revised and approved by Ecology), which contains the definitions and methods for determining whether the criteria below are met.

1. Category I. Category I wetlands are: (1) relatively undisturbed estuarine wetlands larger than 1 acre; (2) wetlands of high conservation value that are identified by scientists of the Washington Natural Heritage Program/DNR; (3) bogs; (4) mature and old-growth forested wetlands larger than 1 acre; (5) wetlands in coastal lagoons; (6) interdunal wetlands that score 8 or 9 habitat points and are larger than 1 acre; and (7) wetlands that perform many functions well (scoring 23 points or more). These wetlands: (1) represent unique or rare wetland types; (2) are more sensitive to disturbance than most wetlands; (3) are relatively undisturbed and contain ecological attributes that are impossible to replace within a human lifetime; or (4) provide a high level of functions.
2. Category II. Category II wetlands are: (1) estuarine wetlands smaller than 1 acre, or disturbed estuarine wetlands larger than 1 acre; (2) interdunal wetlands larger than 1 acre or those found in a mosaic of wetlands; or (3) wetlands with a moderately high level of functions (scoring between 20 and 22 points).
3. Category III. Category III wetlands are: (1) wetlands with a moderate level of functions (scoring between 16 and 19 points); (2) can often be adequately replaced with a well-planned mitigation project; and (3) interdunal wetlands between 0.1 and 1 acre. Wetlands scoring between 16 and 19 points generally have been disturbed in some ways and are often less diverse or more isolated from other natural resources in the landscape than Category II wetlands.
4. Category IV. Category IV wetlands have the lowest levels of functions (scoring fewer than 16 points) and are often heavily disturbed. These are wetlands that we should be able to replace, or in some cases to improve. However, experience has shown that replacement cannot be guaranteed in any specific case. These wetlands may provide some important functions, and should be protected to some degree.

C. Illegal modifications. Wetland rating categories shall not change due to illegal modifications made by the applicant or with the applicant's knowledge.

XX.030 Regulated Activities

A. For any regulated activity, a critical areas report (see Chapter XX.060 of this Chapter) may be required to support the requested activity.

B. The following activities are regulated if they occur in a regulated wetland or its buffer:

1. The removal, excavation, grading, or dredging of soil, sand, gravel, minerals, organic matter, or material of any kind.
2. The dumping of, discharging of, or filling with any material.
3. The draining, flooding, or disturbing of the water level or water table.
4. Pile driving.
5. The placing of obstructions.
6. The construction, reconstruction, demolition, or expansion of any structure.
7. The destruction or alteration of wetland vegetation through clearing, harvesting, shading, intentional burning, or planting of vegetation that would alter the character of a regulated wetland.
8. "Class IV - General Forest Practices" under the authority of the "1992 Washington State Forest Practices Act Rules and Regulations," WAC 222-12-030, or as thereafter amended.
9. Activities that result in:
 - a. A significant change of water temperature.
 - b. A significant change of physical or chemical characteristics of the sources of water to the wetland.
 - c. A significant change in the quantity, timing, or duration of the water entering the wetland.
 - d. The introduction of pollutants.

C. Subdivisions. The subdivision and/or short subdivision of land in wetlands and associated buffers are subject to the following:

1. Land that is located wholly within a wetland or its buffer may not be subdivided.

2. Land that is located partially within a wetland or its buffer may be subdivided provided that an accessible and contiguous portion of each new lot is:
 - a. Located outside of the wetland and its buffer; and
 - b. Meets the minimum lot size requirements of Chapter XX.XX.

XX.040 Exemptions and Allowed Uses in Wetlands

A. The following wetlands may be exempt from the requirement to avoid impacts (Chapter XX.070.A.1), and they may be filled if the impacts are fully mitigated based on the remaining actions in Chapter XX.070.A.2 through 6. If available, impacts should be mitigated through the purchase of credits from an in-lieu fee program or mitigation bank, consistent with the terms and conditions of the program or bank. In order to verify the following conditions, a critical area report for wetlands meeting the requirements in Chapter XX.060 must be submitted.

1. All isolated Category IV wetlands less than 4,000 square feet that:
 - a. Are not associated with riparian areas or their buffers
 - b. Are not associated with shorelines of the state or their associated buffers
 - c. Are not part of a wetland mosaic
 - d. Do not score 5 or more points for habitat function based on the 2014 update to the *Washington State Wetland Rating System for Western Washington: 2014 Update* (Ecology Publication #14-06-029, or as revised and approved by Ecology)
 - e. Do not contain a Priority Habitat or a Priority Area¹ for a Priority Species identified by the Washington Department of Fish and Wildlife, do not contain federally listed species or their critical habitat, or species of local importance identified in Chapter XX.XX.
2. Wetlands less than 1,000 square feet that meet the above criteria and do not contain federally listed species or their critical habitat are exempt from the buffer provisions contained in this Chapter.

¹See page 6 of “Priority Habitat and Species List,” Washington Department of Fish and Wildlife, 2008, Olympia, Washington. 177 pp.

B. Activities Allowed in Wetlands. The activities listed below are allowed in wetlands. These activities do not require submission of a critical area report, except where such activities result in a loss of the functions and values of a wetland or wetland buffer. These activities include:

1. Existing and ongoing agricultural activities, provided that they implement applicable Best Management Practices (BMPs) contained in the latest editions of the USDA Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG); or develop a farm conservation plan in coordination with the local conservation district. BMPs and/or farm plans should address potential impacts to wetlands from livestock, nutrient and farm chemicals, soil erosion and sediment control and agricultural drainage infrastructure. BMPs and/or farm plans should ensure that ongoing agricultural activities minimize their effects on water quality, riparian ecology, salmonid populations, and wildlife habitat.
2. Those activities and uses conducted pursuant to the Washington State Forest Practices Act and its rules and regulations, WAC 222-12-030, where state law specifically exempts local authority, except those developments requiring local approval for Class 4 – General Forest Practice Permits (conversions) as defined in RCW 76.09 and WAC 222-12.
3. Conservation or preservation of soil, water, vegetation, fish, shellfish, and/or other wildlife that does not entail changing the structure or functions of the existing wetland.
4. The harvesting of wild crops in a manner that is not injurious to natural reproduction of such crops and provided the harvesting does not require tilling of soil, planting of crops, chemical applications, or alteration of the wetland by changing existing topography, water conditions, or water sources.
5. Drilling for utilities/utility corridors under a wetland, with entrance/exit portals located completely outside of the wetland buffer, provided that the drilling does not interrupt the ground water connection to the wetland or percolation of surface water down through the soil column. Specific studies by a hydrologist are necessary to determine whether the ground water connection to the wetland or percolation of surface water down through the soil column will be disturbed.
6. Enhancement of a wetland through the removal of non-native invasive plant species. Removal of invasive plant species shall be restricted to hand removal unless permits from the appropriate regulatory agencies have been obtained for approved biological or chemical treatments. All removed plant material shall be taken away from the site and appropriately

disposed of. Plants that appear on the Washington State Noxious Weed Control Board list of noxious weeds must be handled and disposed of according to a noxious weed control plan appropriate to that species. Re-vegetation with appropriate native species at natural densities is allowed in conjunction with removal of invasive plant species.

7. Educational and scientific research activities.
8. Normal and routine maintenance and repair of any existing public or private facilities within an existing right-of-way, provided that the maintenance or repair does not expand the footprint of the facility or right-of-way.
9. Stormwater management facilities. A wetland or its buffer can be physically or hydrologically altered to meet the requirements of an LID, Runoff Treatment or Flow Control BMP if ALL of the following criteria are met:
 - a. The wetland is classified as a Category IV or a Category III wetland with a habitat score of 3-4 points, and
 - b. There will be “no net loss” of functions and values of the wetland, and
 - c. The wetland does not contain a breeding population of any native amphibian species, and
 - d. The hydrologic functions of the wetland can be improved as outlined in questions 3, 4, 5 of Chart 4 and questions 2, 3, 4 of Chart 5 in the “Guide for Selecting Mitigation Sites Using a Watershed Approach,” (available here: <http://www.ecy.wa.gov/biblio/0906032.html>); or the wetland is part of a priority restoration plan that achieves restoration goals identified in a Shoreline Master Program or other local or regional watershed plan, and
 - e. The wetland lies in the natural routing of the runoff, and the discharge follows the natural routing, and
 - f. All regulations regarding stormwater and wetland management are followed, including but not limited to local and state wetland and stormwater codes, manuals, and permits, and
 - g. **Modifications that alter the structure of a wetland or its soils will require permits. Existing functions and values that are lost would have to be compensated/replaced.**

Stormwater LID BMPs required as part of New and Redevelopment projects can be considered within wetlands and their buffers. However, these areas may contain features that render LID BMPs infeasible. A site-specific characterization is required to determine if an LID BMP is feasible at the project site.

XX.050 Wetland Buffers

A. Buffer Requirements. The following buffer widths have been established in accordance with the best available science. They are based on the category of wetland and the habitat score as determined by a qualified wetland professional using the *Washington State Wetland Rating System for Western Washington: 2014 Update* (Ecology Publication #14-06-029, or as revised and approved by Ecology). The adjacent land use intensity is assumed to be high.

1. For wetlands that score 5 points or more for habitat function, the buffers in Table XX.1 can be used if both of the following criteria are met:

- A relatively undisturbed, vegetated corridor at least 100 feet wide is protected between the wetland and any other Priority Habitats as defined by the Washington State Department of Fish and Wildlife. The latest definitions of priority habitats and their locations are available on the WDFW web site at: <http://wdfw.wa.gov/hab/phshabs.htm>)

The corridor must be protected for the entire distance between the wetland and the Priority Habitat by some type of legal protection such as a conservation easement.

Presence or absence of a nearby habitat must be confirmed by a qualified biologist. If no option for providing a corridor is available, Table XX.1 may be used with the required measures in Table XX.2 alone.²

- The measures in Table XX.2 are implemented, where applicable, to minimize the impacts of the adjacent land uses.
2. For wetlands that score 3-4 habitat points, only the measures in Table XX.2 are required for the use of Table XX.1
 3. If an applicant chooses **not** to apply the mitigation measures in Table XX.2, or is unable to provide a protected corridor where available, then Table XX.3 **must** be used.

² See discussion in the Introduction, page 12 as to whether this applies in small urban jurisdictions.

4. The buffer widths in Table XX.1 and XX.3 assume that the buffer is vegetated with a native plant community appropriate for the ecoregion. If the existing buffer is unvegetated, sparsely vegetated, or vegetated with invasive species that do not perform needed functions, the buffer should either be planted to create the appropriate plant community or the buffer should be widened to ensure that adequate functions of the buffer are provided.

**Table XX.1 Wetland Buffer Requirements for Western Washington
if Table XX.2 is Implemented and Corridor Provided**

	Buffer width (in feet) based on habitat score			
Wetland Category	3-4	5	6-7	8-9
Category I: Based on total score	75	105	165	225
Category I: Bogs and Wetlands of High Conservation Value	190			225
Category I: Coastal Lagoons	150		165	225
Category I: Interdunal				225
Category I: Forested	75	105	165	225
Category I: Estuarine	150 (buffer width not based on habitat scores)			
Category II: Based on score	75	105	165	225
Category II: Interdunal Wetlands	110		165	225
Category II: Estuarine	110 (buffer width not based on habitat scores)			
Category III (all)	60	105	165	225
Category IV (all)	40			

Table XX.2 Required measures to minimize impacts to wetlands
(Measures are required if applicable to a specific proposal)

Disturbance	Required Measures to Minimize Impacts
Lights	• Direct lights away from wetland
Noise	• Locate activity that generates noise away from wetland • If warranted, enhance existing buffer with native vegetation plantings adjacent to noise source • For activities that generate relatively continuous, potentially disruptive noise, such as certain heavy industry or mining, establish an additional 10' heavily vegetated buffer strip immediately adjacent to the outer wetland buffer
Toxic runoff	• Route all new, untreated runoff away from wetland while ensuring wetland is not dewatered • Establish covenants limiting use of pesticides within 150 ft of wetland • Apply integrated pest management
Stormwater runoff	• Retrofit stormwater detention and treatment for roads and existing adjacent development • Prevent channelized flow from lawns that directly enters the buffer • Use Low Intensity Development techniques (for more information refer to the drainage ordinance and manual)
Change in water regime	• Infiltrate or treat, detain, and disperse into buffer new runoff from impervious surfaces and new lawns
Pets and human disturbance	• Use privacy fencing OR plant dense vegetation to delineate buffer edge and to discourage disturbance using vegetation appropriate for the ecoregion • Place wetland and its buffer in a separate tract or protect with a conservation easement
Dust	• Use best management practices to control dust

**Table XX.3 Wetland Buffer Requirements for Western Washington
if Table XX.2 is NOT Implemented or Corridor NOT provided**

	Buffer width (in feet) based on habitat score			
Wetland Category	3-4	5	6-7	8-9
Category I: Based on total score	100	140	220	300
Category I: Bogs and Wetlands of High Conservation Value	250			300
Category I: Coastal Lagoons	200		220	300
Category I: Interdunal				300
Category I: Forested	100	140	220	300
Category I: Estuarine	200 (buffer width not based on habitat scores)			
Category II: Based on score	100	140	220	300
Category II: Interdunal Wetlands	150		220	300
Category II: Estuarine	150 (buffer width not based on habitat scores)			
Category III (all)	80	140	220	300
Category IV (all)	50			

5. Increased Wetland Buffer Area Width. Buffer widths shall be increased on a case-by-case basis as determined by the Administrator when a larger buffer is necessary to protect wetland functions and values. This determination shall be supported by appropriate documentation showing that it is reasonably related to protection of the functions and values of the wetland. The documentation must include but not be limited to the following criteria:
 - a. The wetland is used by a state or federally listed plant or animal species or has essential or outstanding habitat for those species, or has unusual nesting or resting sites such as heron rookeries or raptor nesting trees; or
 - b. The adjacent land is susceptible to severe erosion, and erosion-control measures will not effectively prevent adverse wetland impacts; or
 - c. The adjacent land has minimal vegetative cover or slopes greater than 30 percent.
6. Buffer averaging to *improve wetland protection* may be permitted when **all** of the following conditions are met:
 - a. The wetland has significant differences in characteristics that affect its habitat functions, such as a wetland with a forested component adjacent to a degraded emergent component or a “dual-rated” wetland with a Category I area adjacent to a lower-rated area.
 - b. The buffer is increased adjacent to the higher-functioning area of habitat or more-sensitive portion of the wetland and decreased adjacent to the lower-functioning or less-sensitive portion as demonstrated by a critical areas report from a qualified wetland professional.
 - c. The total area of the buffer after averaging is equal to the area required without averaging.
 - d. The buffer at its narrowest point is never less than either $\frac{3}{4}$ of the required width or 75 feet for Category I and II, 50 feet for Category III, and 25 feet for Category IV, whichever is greater.
7. Averaging to *allow reasonable use* of a parcel may be permitted when **all** of the following are met:
 - a. There are no feasible alternatives to the site design that could be accomplished without buffer averaging.

- b. The averaged buffer will not result in degradation of the wetland's functions and values as demonstrated by a critical areas report from a qualified wetland professional.
- c. The total buffer area after averaging is equal to the area required without averaging.
- d. The buffer at its narrowest point is never less than either $\frac{3}{4}$ of the required width or 75 feet for Category I and II, 50 feet for Category III and 25 feet for Category IV, whichever is greater.

B. To facilitate long-range planning using a landscape approach, the Administrator may identify and pre-assess wetlands using the rating system and establish appropriate wetland buffer widths for such wetlands. The Administrator will prepare maps of wetlands that have been pre-assessed in this manner.

C. Measurement of Wetland Buffers. All buffers shall be measured perpendicular from the wetland boundary as surveyed in the field. The buffer for a wetland created, restored, or enhanced as compensation for approved wetland alterations shall be the same as the buffer required for the category of the created, restored, or enhanced wetland. Buffers must be fully vegetated in order to be included in buffer area calculations. Lawns, walkways, driveways, and other mowed or paved areas will not be considered buffers or included in buffer area calculations.

D. Buffers on Wetland Mitigation Sites. All wetland mitigation sites shall have buffers consistent with the buffer requirements of this Chapter. Buffers shall be based on the expected or target category of the proposed wetland mitigation site.

E. Buffer Maintenance. Except as otherwise specified or allowed in accordance with this Chapter, wetland buffers shall be retained in an undisturbed or enhanced condition. In the case of compensatory mitigation sites, removal of invasive non-native weeds is required for the duration of the mitigation bond (Section XX.070.J.2.a.x).

F. Impacts to Buffers. Requirements for the compensation for impacts to buffers are outlined in Section XX.070 of this Chapter.

G. Overlapping Critical Area Buffers. If buffers for two contiguous critical areas overlap (such as buffers for a stream and a wetland), the wider buffer applies.

H. Allowed Buffer Uses. The following uses may be allowed within a wetland buffer in accordance with the review procedures of this Chapter, provided they are not prohibited by any other applicable law and they are conducted in a manner so as to minimize impacts to the buffer and adjacent wetland:

- 1. Conservation or restoration activities aimed at protecting the soil, water, vegetation, or wildlife.

2. Passive recreation facilities designed and in accordance with an approved critical area report, including:
 - a. Walkways and trails, provided that those pathways are limited to minor crossings having no adverse impact on water quality. They should be generally parallel to the perimeter of the wetland, located only in the outer twenty-five percent (25%) of the wetland buffer area, and located to avoid removal of significant trees. They should be limited to pervious surfaces no more than five (5) feet in width for pedestrian use only. Raised boardwalks utilizing non-treated pilings may be acceptable.
 - b. Wildlife-viewing structures.
3. Educational and scientific research activities.
4. Normal and routine maintenance and repair of any existing public or private facilities within an existing right-of-way, provided that the maintenance or repair does not increase the footprint or use of the facility or right-of-way.
5. The harvesting of wild crops in a manner that is not injurious to natural reproduction of such crops and provided the harvesting does not require tilling of soil, planting of crops, chemical applications, or alteration of the wetland by changing existing topography, water conditions, or water sources.
6. Drilling for utilities/utility corridors under a buffer, with entrance/exit portals located completely outside of the wetland buffer boundary, provided that the drilling does not interrupt the ground water connection to the wetland or percolation of surface water down through the soil column. Specific studies by a hydrologist are necessary to determine whether the ground water connection to the wetland or percolation of surface water down through the soil column would be disturbed.
7. Enhancement of a wetland buffer through the removal of non-native invasive plant species. Removal of invasive plant species shall be restricted to hand removal. All removed plant material shall be taken away from the site and appropriately disposed of. Plants that appear on the Washington State Noxious Weed Control Board list of noxious weeds must be handled and disposed of according to a noxious weed control plan appropriate to that species. Revegetation with appropriate native species at natural densities is allowed in conjunction with removal of invasive plant species.

8. Repair and maintenance of non-conforming uses or structures, where legally established within the buffer, provided they do not increase the degree of nonconformity.

I. Signs and Fencing of Wetlands and Buffers:

1. Temporary markers. The outer perimeter of the wetland buffer and the clearing limits identified by an approved permit or authorization shall be marked in the field with temporary “clearing limits” fencing in such a way as to ensure that no unauthorized intrusion will occur. The marking is subject to inspection by the Administrator prior to the commencement of permitted activities. This temporary marking shall be maintained throughout construction and shall not be removed until permanent signs, if required, are in place.
2. Permanent signs. As a condition of any permit or authorization issued pursuant to this Chapter, the Administrator may require the applicant to install permanent signs along the boundary of a wetland or buffer.
 - a. Permanent signs shall be made of an enamel-coated metal face and attached to a metal post or another non-treated material of equal durability. Signs must be posted at an interval of one (1) every fifty (50) feet, or one (1) per lot if the lot is less than fifty (50) feet wide, and must be maintained by the property owner in perpetuity. The signs shall be worded as follows or with alternative language approved by the Administrator:

**Protected Wetland Area
Do Not Disturb
Contact [Local Jurisdiction]
Regarding Uses, Restrictions, and Opportunities for Stewardship**

- b. The provisions of Subsection (a) may be modified as necessary to assure protection of sensitive features or wildlife.
3. Fencing
 - a. The applicant shall be required to install a permanent fence around the wetland or buffer when domestic grazing animals are present or may be introduced on site.
 - b. Fencing installed as part of a proposed activity or as required in this Subsection shall be designed so as to not interfere with species migration, including fish runs, and shall be constructed in a manner that minimizes impacts to the wetland and associated habitat.

XX.060 Critical Area Report for Wetlands

A. If the Administrator determines that the site of a proposed development includes, is likely to include, or is adjacent to a wetland, a wetland report, prepared by a qualified professional, shall be required. The expense of preparing the wetland report shall be borne by the applicant.

B. Minimum Standards for Wetland Reports. The written report and the accompanying plan sheets shall contain the following information, at a minimum:

1. The written report shall include at a minimum:
 - a. The name and contact information of the applicant; the name, qualifications, and contact information for the primary author(s) of the wetland critical area report; a description of the proposal; identification of all the local, state, and/or federal wetland-related permit(s) required for the project; and a vicinity map for the project.
 - b. A statement specifying the accuracy of the report and all assumptions made and relied upon.
 - c. Documentation of any fieldwork performed on the site, including field data sheets for delineations, rating system forms, baseline hydrologic data, etc.
 - d. A description of the methodologies used to conduct the wetland delineations, wetland ratings, or impact analyses, including references.
 - e. Identification and characterization of all critical areas, wetlands, water bodies, shorelines, floodplains, and buffers on or adjacent to the proposed project area. For areas off site of the project site, estimate conditions within 300 feet of the project boundaries using the best available information.
 - f. For each wetland identified on site and within 300 feet of the project boundary, provide: the wetland rating, including a description of and score for each function, per *Wetland Ratings* (Section XX.020.B) of this Chapter; required buffers; hydrogeomorphic classification; wetland acreage based on a professional survey from the field delineation (acreages for on-site portion or estimate entire wetland area including off-site portions); Cowardin classification of vegetation communities; habitat elements; soil conditions based on site assessment and/or soil survey information; and to the extent possible, hydrologic information such as location and condition of inlets/outlets (if they can be legally accessed), estimated water depths within the wetland, and estimated hydroperiod patterns based on visual cues (e.g.,

algal mats, drift lines, flood debris, etc.). Provide acreage estimates, classifications, and ratings based on entire wetland complexes, not only the portion present on the proposed project site.

- g. A description of the proposed actions, including an estimation of acreages of impacts to wetlands and buffers based on the field delineation and survey and an analysis of site development alternatives, including a no-development alternative.
 - h. An assessment of the probable cumulative impacts to the wetlands and buffers resulting from the proposed development.
 - i. A description of reasonable efforts made to apply mitigation sequencing pursuant to *Mitigation Sequencing* (Chapter XX.070.A) to avoid, minimize, and mitigate impacts to critical areas.
 - j. A discussion of measures, including avoidance, minimization, and compensation, proposed to preserve existing wetlands and restore any wetlands that were degraded prior to the current proposed land-use activity.
 - k. A conservation strategy for habitat and native vegetation that addresses methods to protect and enhance on-site habitat and wetland functions.
 - l. An evaluation of the functions of the wetland and its buffer. Include references for the method used and data sheets.
2. A copy of the site plan sheet(s) for the project must be included with the written report and must include, at a minimum:
- a. Maps (to scale) depicting delineated and surveyed wetland and required buffers on site, including buffers for off-site critical areas that extend onto the project site; the development proposal; other critical areas; grading and clearing limits; and areas of proposed impacts to wetlands and/or buffers (include square footage estimates).
 - b. A depiction of the proposed stormwater management facilities and outlets (to scale) for the development, including estimated areas of intrusion into the buffers of any critical areas. The written report shall contain a discussion of the potential impacts to the wetland(s) associated with anticipated hydroperiod alterations from the project.

XX.070 Compensatory Mitigation.

A. Mitigation Sequencing. Before impacting any wetland or its buffer, an applicant shall demonstrate that the following actions have been taken. Actions are listed in the order of preference:

1. Avoid the impact altogether by not taking a certain action or parts of an action.
2. Minimize impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts.
3. Rectify the impact by repairing, rehabilitating, or restoring the affected environment.
4. Reduce or eliminate the impact over time by preservation and maintenance operations.
5. Compensate for the impact by replacing, enhancing, or providing substitute resources or environments.
6. Monitor the required compensation and take remedial or corrective measures when necessary.

B. Requirements for Compensatory Mitigation:

1. Compensatory mitigation for alterations to wetlands shall be used only for impacts that cannot be avoided or minimized and shall achieve equivalent or greater biologic functions. Compensatory mitigation plans shall be consistent with *Wetland Mitigation in Washington State—Part 2: Developing Mitigation Plans—Version 1*, (Ecology Publication #06-06-011b, Olympia, WA, March 2006, or as revised), and *Selecting Wetland Mitigation Sites Using a Watershed Approach (Western Washington)* (Publication #09-06-32, Olympia, WA, December 2009).
2. Mitigation ratios shall be consistent with Subsection H of this Chapter.
3. Mitigation requirements may also be determined using the credit/debit tool described in *Calculating Credits and Debits for Compensatory Mitigation in Wetlands of Western Washington: Final Report* (Ecology Publication #10-06-011, Olympia, WA, March 2012, or as revised) consistent with subsection H of this Chapter.

C. Compensating for Lost or Affected Functions. Compensatory mitigation shall address the functions affected by the proposed project, with an intention to achieve functional equivalency or improvement of functions. The goal shall be for the

compensatory mitigation to provide similar wetland functions as those lost, except when either:

1. The lost wetland provides minimal functions, and the proposed compensatory mitigation action(s) will provide equal or greater functions or will provide functions shown to be limiting within a watershed through a formal Washington state watershed assessment plan or protocol; or
2. Out-of-kind replacement of wetland type or functions will best meet watershed goals formally identified by the City, such as replacement of historically diminished wetland types.

D. Approaches to Compensatory Mitigation. Mitigation for lost or diminished wetland and buffer functions shall rely on the approaches listed below.

1. Wetland mitigation banks. Credits from a certified wetland mitigation bank may be used to compensate for impacts located within the service area specified in the mitigation bank instrument. Use of credits from a wetland mitigation bank certified under Chapter 173-700 WAC is allowed if:
 - a. The approval authority determines that it would provide appropriate compensation for the proposed impacts; and
 - b. The impact site is located in the service area of the bank.
 - c. The proposed use of credits is consistent with the terms and conditions of the certified mitigation bank instrument.
 - d. Replacement ratios for projects using bank credits is consistent with replacement ratios specified in the certified mitigation bank instrument.
2. In-Lieu Fee Mitigation: Credits from an approved in-lieu-fee program may be used when all of the following apply:
 - a. The approval authority determines that it would provide environmentally appropriate compensation for the proposed impacts.
 - b. The proposed use of credits is consistent with the terms and conditions of the approved in-lieu-fee program instrument.
 - c. Projects using in-lieu-fee credits shall have debits associated with the proposed impacts calculated by the applicant's qualified wetland professional using the credit assessment method specified in the approved instrument for the in-lieu-fee program.

- d. The impacts are located within the service area specified in the approved in-lieu-fee instrument.
3. Permittee-responsible mitigation. In this situation, the permittee performs the mitigation after the permit is issued and is ultimately responsible for implementation and success of the mitigation. Permittee-responsible mitigation may occur at the site of the permitted impacts or at an off-site location within the same watershed. Permittee-responsible mitigation shall be used only if the applicant's qualified wetland professional demonstrates to the approval authority's satisfaction that the proposed approach is ecologically preferable to use of a bank or ILF program, consistent with the criteria in this section.

E. Types of Compensatory Mitigation. Mitigation for lost or diminished wetland and buffer functions shall rely on a type listed below in order of preference. A lower-preference form of mitigation shall be used only if the applicant's qualified wetland professional demonstrates to the approval authority's satisfaction that all higher-ranked types of mitigation are not viable, consistent with the criteria in this section.

1. Restoration: The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural or historic functions to a former or degraded wetland. For the purpose of tracking net gains in wetland acres, restoration is divided into:
 - a. Re-establishment: The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural or historic functions to a former wetland. Re-establishment results in a gain in wetland acres (and functions). Activities could include removing fill material, plugging ditches, or breaking drain tiles.
 - b. Rehabilitation: The manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural or historic functions of a degraded wetland. Rehabilitation results in a gain in wetland function but does not result in a gain in wetland acres. Activities could involve breaching a dike to reconnect wetlands to a floodplain or return tidal influence to a wetland.
2. Establishment (Creation): The manipulation of the physical, chemical, or biological characteristics of a site to develop a wetland on an upland or deepwater site where a wetland did not previously exist. Establishment results in a gain in wetland acres. Activities typically involve excavation of upland soils to elevations that will produce a wetland hydroperiod, create hydric soils, and support the growth of hydrophytic plant species.
 - a. If a site is not available for wetland restoration to compensate for expected wetland and/or buffer impacts, the approval authority may

authorize creation of a wetland and buffer upon demonstration by the applicant's qualified wetland professional that:

- i. The hydrology and soil conditions at the proposed mitigation site are conducive for sustaining the proposed wetland and that creation of a wetland at the site will not likely cause hydrologic problems elsewhere;
 - ii. Adjacent land uses and site conditions do not jeopardize the viability of the proposed wetland and buffer (e.g., due to the presence of invasive plants or noxious weeds, stormwater runoff, noise, light, or other impacts); and
 - iii. The proposed wetland and buffer will eventually be self-sustaining with little or no long-term maintenance.
3. **Enhancement.** The manipulation of the physical, chemical, or biological characteristics of a wetland site to heighten, intensify, or improve specific function(s) or to change the growth stage or composition of the vegetation present. Enhancement is undertaken for specified purposes such as water quality improvement, flood water retention, or wildlife habitat. Enhancement results in a change in some wetland functions and can lead to a decline in other wetland functions, but does not result in a gain in wetland acres. Activities typically consist of planting vegetation, controlling non-native or invasive species, modifying site elevations or the proportion of open water to influence hydroperiods, or some combination of these activities. Applicants proposing to enhance wetlands or associated buffers shall demonstrate how the proposed enhancement will increase the wetland's/buffer's functions, how this increase in function will adequately compensate for the impacts, and how existing wetland functions at the mitigation site will be protected.
4. **Protection/Maintenance (Preservation).** Removing a threat to, or preventing the decline of, wetland conditions by an action in or near a wetland. This includes the purchase of land or easements, or repairing water control structures or fences. This term also includes activities commonly associated with the term *preservation*. Preservation does not result in a gain of wetland acres. Permanent protection of a Category I or II wetland and associated buffer at risk of degradation can be used only if:
 - a. The approval authority determines that the proposed preservation is the best mitigation option;
 - b. The proposed preservation site is under threat of undesirable ecological change due to permitted, planned, or likely actions that will not be adequately mitigated under existing regulations;

- c. The area proposed for preservation is of high quality or critical for the health of the watershed or basin due to its location. Some of the following features may be indicative of high-quality sites:
 - i. Category I or II wetland rating (using the wetland rating system for western Washington)
 - ii. Rare or irreplaceable wetland type (for example, bogs, mature forested wetlands, estuarine wetlands) or aquatic habitat that is rare or a limited resource in the area;
 - iii. The presence of habitat for priority or locally important wildlife species; or also list has provides biological and/or hydrological connectivity;
 - iv. Provides biological and/or hydrological connectivity;
 - v. Priority sites in an adopted watershed plan.
- d. Permanent preservation of the wetland and buffer will be provided through a conservation easement or tract held by an appropriate natural land resource manager, such as a land trust.
- e. The approval authority may approve other legal and administrative mechanisms in lieu of a conservation easement if it determines they are adequate to protect the site.
- f. Ratios for preservation in combination with other forms of mitigation generally range from 10:1 to 20:1, as determined on a case-by-case basis, depending on the quality of the wetlands being impacted and the quality of the wetlands being preserved. Ratios for preservation as the sole means of mitigation generally start at 20:1.

F. Location of Compensatory Mitigation. Compensatory mitigation actions shall generally be conducted within the same sub-drainage basin and on the site of the alteration except when the applicant can demonstrate that off-site mitigation is ecologically preferable. The following criteria will be evaluated when determining whether the proposal is ecologically preferable. When considering off-site mitigation, preference should be given to using alternative mitigation, such as a mitigation bank, an in-lieu-fee program, or advance mitigation.

- 1. There are no reasonable opportunities on site or within the sub-drainage basin (e.g., on-site options would require elimination of high-functioning upland habitat), or opportunities on site or within the sub-drainage basin do not have a high likelihood of success based on a determination of the capacity of the site to compensate for the impacts. Considerations should

include: anticipated replacement ratios for wetland mitigation, buffer conditions and required widths, available water to maintain anticipated hydrogeomorphic classes of wetlands when restored, proposed flood storage capacity, and potential to mitigate riparian fish and wildlife impacts (such as connectivity);

2. On-site mitigation would require elimination of high-quality upland habitat.
3. Off-site mitigation has a greater likelihood of providing equal or improved wetland functions than the altered wetland.
4. Off-site locations shall be in the same sub-drainage basin unless:
 - a. Established watershed goals for water quality, flood storage or conveyance, habitat, or other wetland functions have been established by the City and strongly justify location of mitigation at another site; or
 - b. Credits from a state-certified wetland mitigation bank are used as compensation, and the use of credits is consistent with the terms of the certified bank instrument;
 - c. Fees are paid to an approved in-lieu-fee program to compensate for the impacts.
5. The design for the compensatory mitigation project needs to be appropriate for its location (i.e., position in the landscape). Therefore, compensatory mitigation should not result in the creation, restoration, or enhancement of an atypical wetland.

G. Timing of Compensatory Mitigation. It is preferred that compensatory mitigation projects be completed prior to activities that will impact wetlands. At the least, compensatory mitigation shall be completed immediately following disturbance and prior to use or occupancy of the action or development. Construction of mitigation projects shall be timed to reduce impacts to existing fisheries, wildlife, and flora.

1. The Administrator may authorize a one-time temporary delay in completing construction or installation of the compensatory mitigation when the applicant provides a written explanation from a qualified wetland professional as to the rationale for the delay. An appropriate rationale would include identification of the environmental conditions that could produce a high probability of failure or significant construction difficulties (e.g., project delay lapses past a fisheries window, or installing plants should be delayed until the dormant season to ensure greater survival of installed materials). The delay shall not create or perpetuate hazardous conditions or environmental damage or degradation, and the

delay shall not be injurious to the health, safety, or general welfare of the public. The request for the temporary delay must include a written justification that documents the environmental constraints that preclude implementation of the compensatory mitigation plan. The justification must be verified and approved by the City.

H. Wetland Mitigation Ratios³:

Category and Type of Wetland	Creation or Re-establishment	Rehabilitation	Enhancement
Category I: Bog, Natural Heritage site	Not considered possible	Case by case	Case by case
Category I: Mature Forested	6:1	12:1	24:1
Category I: Based on functions	4:1	8:1	16:1
Category II	3:1	6:1	12:1
Category III	2:1	4:1	8:1
Category IV	1.5:1	3:1	6:1

I. Credit/Debit Method. To more fully protect functions and values, and as an alternative to the mitigation ratios found in the joint guidance *Wetland Mitigation in Washington State Parts I and II* (Ecology Publication #06-06-011a-b, Olympia, WA, March 2006), the administrator may allow mitigation based on the “credit/debit” method developed by the Department of Ecology in *Calculating Credits and Debits for Compensatory Mitigation in Wetlands of Western Washington: Final Report*, (Ecology Publication #10-06-011, Olympia, WA, March 2012, or as revised).

³ Ratios for rehabilitation and enhancement may be reduced when combined with 1:1 replacement through creation or re-establishment. See Table 1a, *Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance –Version 1*, (Ecology Publication #06-06-011a, Olympia, WA, March 2006 or as revised). See also Paragraph D.4 for more information on using preservation as compensation.

J. Compensatory Mitigation Plan. When a project involves wetland and/or buffer impacts, a compensatory mitigation plan prepared by a qualified professional shall be required, meeting the following minimum standards:

1. Wetland Critical Area Report. A critical area report for wetlands must accompany or be included in the compensatory mitigation plan and include the minimum parameters described in *Minimum Standards for Wetland Reports* (Section XX.060.B) of this Chapter.
2. Compensatory Mitigation Report. The report must include a written report and plan sheets that contain, at a minimum, the following elements. Full guidance can be found in *Wetland Mitigation in Washington State– Part 2: Developing Mitigation Plans (Version 1)* (Ecology Publication #06-06-011b, Olympia, WA, March 2006 or as revised).
 - a. The written report must contain, at a minimum:
 - i. The name and contact information of the applicant; the name, qualifications, and contact information for the primary author(s) of the compensatory mitigation report; a description of the proposal; a summary of the impacts and proposed compensation concept; identification of all the local, state, and/or federal wetland-related permit(s) required for the project; and a vicinity map for the project.
 - ii. Description of how the project design has been modified to avoid, minimize, or reduce adverse impacts to wetlands.
 - iii. Description of the existing wetland and buffer areas proposed to be altered. Include acreage (or square footage), water regime, vegetation, soils, landscape position, surrounding land uses, and functions. Also describe impacts in terms of acreage by Cowardin classification, hydrogeomorphic classification, and wetland rating, based on *Wetland Ratings* (Section XX.XX) of this Chapter.
 - iv. Description of the compensatory mitigation site, including location and rationale for selection. Include an assessment of existing conditions: acreage (or square footage) of wetlands and uplands, water regime, sources of water, vegetation, soils, landscape position, surrounding land uses, and functions. Estimate future conditions in this location if the compensation actions are NOT undertaken (i.e., how would this site progress through natural succession?).
 - v. Surface and subsurface hydrologic conditions, including an analysis of existing and proposed hydrologic regimes for enhanced, created, or restored compensatory mitigation areas.

Include illustrations of how data for existing hydrologic conditions were used to determine the estimates of future hydrologic conditions

- vi. A description of the proposed actions for compensation of wetland and upland areas affected by the project. Include overall goals of the proposed mitigation, including a description of the targeted functions, hydrogeomorphic classification, and categories of wetlands.
 - vii. A description of the proposed mitigation construction activities and timing of activities.
 - viii. Performance standards (measurable standards for years post-installation) for upland and wetland communities, a monitoring schedule, and a maintenance schedule and actions proposed by year.
 - ix. A discussion of ongoing management practices that will protect wetlands after the development project has been implemented, including proposed monitoring and maintenance programs (for remaining wetlands and compensatory mitigation wetlands).
 - x. A bond estimate for the entire compensatory mitigation project, including the following elements: site preparation, plant materials, construction materials, installation oversight, maintenance twice per year for up to five (5) years, annual monitoring field work and reporting, and contingency actions for a maximum of the total required number of years for monitoring.
 - xi. Proof of establishment of Notice on Title for the wetlands and buffers on the project site, including the compensatory mitigation areas.
- b. The scaled plan sheets for the compensatory mitigation must contain, at a minimum:
- i. Surveyed edges of the existing wetland and buffers, proposed areas of wetland and/or buffer impacts, location of proposed wetland and/or buffer compensation actions.
 - ii. Existing topography, ground-proofed, at two-foot contour intervals in the zone of the proposed compensation actions if any grading activity is proposed in the compensation area(s). Also include existing cross-sections (estimated one-foot intervals) of wetland areas on the development site that are proposed to be altered and for the proposed areas of wetland or buffer compensation.

- iii. Conditions expected from the proposed actions on site, including future hydrogeomorphic types, vegetation community types by dominant species (wetland and upland), and future water regimes.
- iv. Required wetland buffers for existing wetlands and proposed compensation areas. Also identify any zones where buffers are proposed to be reduced or enlarged outside of the standards identified in this Chapter.
- v. A planting plan for the compensation area, including all species by proposed community type and water regime, size and type of plant material to be installed, spacing of plants, typical clustering patterns, total number of each species by community type, and timing of installation.

K. Buffer Mitigation Ratios. Impacts to buffers shall be mitigated at a minimum 1:1 ratio. Compensatory buffer mitigation shall replace those buffer functions lost from development.

L. Protection of the Mitigation Site. The mitigation area and any associated buffer shall be located in a critical area tract or a conservation easement consistent with Chapter XX.XX.

M. Monitoring. Mitigation monitoring shall be required for a period necessary to establish that performance standards have been met, but not for a period less than five years. If a scrub-shrub or forested vegetation community is proposed, monitoring may be required for ten years or more. The project mitigation plan shall include monitoring elements that ensure certainty of success for the project's natural resource values and functions. If the mitigation goals are not obtained within the initial five-year period, the applicant remains responsible for restoration of the natural resource values and functions until the mitigation goals agreed to in the mitigation plan are achieved.

N. Advance Mitigation. Mitigation for projects with pre-identified impacts to wetlands may be constructed in advance of the impacts if the mitigation is implemented according to federal rules, state policy on advance mitigation, and state water quality regulations consistent with *Interagency Regulatory Guide: Advance Permittee-Responsible Mitigation* (Ecology Publication #12-06-015, Olympia, WA, December 2012).

O. Alternative Mitigation Plans. The Administrator may approve alternative wetland mitigation plans that are based on best available science, such as priority restoration plans that achieve restoration goals identified in the SMP. Alternative mitigation proposals must provide an equivalent or better level of protection of wetland functions and values than would be provided by the strict application of this chapter.

The Administrator shall consider the following for approval of an alternative mitigation proposal:

1. The proposal uses a watershed approach consistent with *Selecting Wetland Mitigation Sites Using a Watershed Approach (Western Washington)* (Ecology Publication #09-06-32, Olympia, WA, December 2009).
2. Creation or enhancement of a larger system of natural areas and open space is preferable to the preservation of many individual habitat areas.
3. Mitigation according to Section E is not feasible due to site constraints such as parcel size, stream type, wetland category, or geologic hazards.
4. There is clear potential for success of the proposed mitigation at the proposed mitigation site.
5. The plan shall contain clear and measurable standards for achieving compliance with the specific provisions of the plan. A monitoring plan shall, at a minimum, meet the provisions in Section J.
6. The plan shall be reviewed and approved as part of overall approval of the proposed use.
7. A wetland of a different type may be justified based on regional needs or functions and values; the replacement ratios may not be reduced or eliminated unless the reduction results in a preferred environmental alternative.
8. Mitigation guarantees shall meet the minimum requirements as outlined in Section J.2.a.viii.
9. Qualified professionals in each of the critical areas addressed shall prepare the plan.
10. The City may consult with agencies with expertise and jurisdiction over the critical areas during the review to assist with analysis and identification of appropriate performance measures that adequately safeguard critical areas.

XX.080 Unauthorized Alterations and Enforcement

A. When a wetland or its buffer has been altered in violation of this Chapter, all ongoing development work shall stop, and the critical area shall be restored. The City shall have the authority to issue a “stop-work” order to cease all ongoing development work and order restoration, rehabilitation, or replacement measures at the owner’s or other responsible party’s expense to compensate for violation of provisions of this Chapter.

B. Requirement for Restoration Plan. All development work shall remain stopped until a restoration plan is prepared and approved by the City. Such a plan shall be prepared by a qualified professional using the currently accepted scientific principles and shall describe how the actions proposed meet the minimum requirements described in Subsection C below. The Administrator shall, at the applicant or other responsible party's expense, seek expert advice in determining the adequacy of the plan. Inadequate plans shall be returned to the applicant or other responsible party for revision and re-submittal.

C. Minimum Performance Standards for Restoration. The following minimum performance standards shall be met for the restoration of a wetland, provided that if the applicant or other responsible party can demonstrate that greater functions and habitat values can be obtained, these standards may be modified:

1. The historic structure, functions, and values of the affected wetland shall be restored, including water quality and habitat functions.
2. The historic soil types and configuration shall be restored to the extent practicable.
3. The wetland and buffers shall be replanted with native vegetation that replicates the vegetation historically found on the site in species types, sizes, and densities. The historic functions and values should be replicated at the location of the alteration.
4. Information demonstrating compliance with other applicable provisions of this Chapter shall be submitted to the Administrator.

D. Site Investigations. The Administrator is authorized to make site inspections and take such actions as are necessary to enforce this Chapter. The Administrator shall present proper credentials and make a reasonable effort to contact any property owner before entering onto private property.

E. Penalties. Any person, party, firm, corporation, or other legal entity convicted of violating any of the provisions of this Chapter shall be guilty of a misdemeanor.

1. Each day or portion of a day during which a violation of this Chapter is committed or continued shall constitute a separate offense. Any development carried out contrary to the provisions of this Chapter shall constitute a public nuisance and may be enjoined as provided by the statutes of the state of Washington. The City may levy civil penalties against any person, party, firm, corporation, or other legal entity for violation of any of the provisions of this Chapter. The civil penalty shall be assessed at a maximum rate of \$XX dollars per day per violation.
2. If the wetland affected cannot be restored, monies collected as penalties shall be deposited in a dedicated account for the preservation or

restoration of landscape processes and functions in the watershed in which the affected wetland is located. The City may coordinate its preservation or restoration activities with other cities in the watershed to optimize the effectiveness of the restoration action.

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Appendix B - Wetland Definitions

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Appendix B – Wetland Definitions

Agricultural Activities, Existing and Ongoing – Those activities conducted on lands defined in RCW 84.34.020(2), and those activities involved in the production of crops and livestock, including but not limited to operation, maintenance and conservation measures of farm and stock ponds or drainage ditches, irrigation systems, changes between agricultural activities, and normal operation, maintenance or repair of existing serviceable structures, facilities or improved areas. Activities which bring an area into agricultural use are not part of an ongoing activity. An operation ceases to be ongoing when the area in which it was conducted is proposed for conversion to a nonagricultural use or has lain idle for a period of longer than five years, unless the idle land is registered in a federal or state soils conversation program.

Alteration – Any human-induced change in an existing condition of a critical area or its buffer. Alterations include, but are not limited to, grading, filling, channelizing, dredging, clearing of vegetation, construction, compaction, excavation, or any other activity that changes the character of the critical area.

Best Available Science – Current scientific information used in the process to designate, protect, or restore critical areas; that is, derived from a valid scientific process as defined by WAC 365-195-900 through 925.

Best Management Practices (BMPs) – Conservation practices or systems of practices and management measures that:

- (a) Control soil loss and reduce water quality degradation caused by high concentrations of nutrients, animal waste, toxics, or sediment;
- (b) Minimize adverse impacts to surface water and ground water flow and circulation patterns and to the chemical, physical, and biological characteristics of wetlands;
- (c) Protect trees, vegetation, and soils designated to be retained during and following site construction and use native plant species appropriate to the site for re-vegetation of disturbed areas; and
- (d) Provide standards for proper use of chemical herbicides within critical areas.

Bog – A low-nutrient, acidic wetland with organic soils and characteristic bog plants, as described in *Washington State Wetland Rating System for Western Washington: 2014 Update* (Washington State Department of Ecology Publication #14-06-29, Olympia, WA, October 2014).

Buffer or Buffer Zone – The area contiguous with a critical area that maintains the functions and/or structural stability of the critical area.

Coastal Lagoon – A shallow body of water partly or completely separated from the sea by a barrier beach that receives periodic influxes of salt water, as described in *Washington State Wetland Rating System for Western Washington: 2014 Update* (Washington State Department of Ecology Publication #14-06-29, Olympia, WA, October 2014).

Critical Areas – Critical areas include any of the following areas or ecosystems: critical aquifer recharge areas, fish and wildlife habitat conservation areas, geologically hazardous areas, frequently flooded areas, and wetlands, as defined in RCW 36.70A and this Chapter.

Creation – The manipulation of the physical, chemical, or biological characteristics to develop a wetland on an upland or deepwater site where a wetland did not previously exist. Creation results in a gain in wetland acreage and function. A typical action is the excavation of upland soils to elevations that will produce a wetland *hydroperiod* and hydric soils, and support the growth of hydrophytic plant species.

Cumulative Impacts or Effects – The combined, incremental effects of human activity on ecological or critical area functions and values. Cumulative impacts result when the effects of an action are added to or interact with the effects of other actions in a particular place and within a particular time. It is the combination of these effects, and any resulting environmental degradation, that should be the focus of cumulative impact analysis and changes to policies and permitting decisions.

Development – A land use consisting of the construction or exterior alteration of structures; grading, dredging, drilling, or dumping; filling; removal of sand, gravel, or minerals; bulk heading; driving of pilings; or any project of a temporary or permanent nature which modifies structures, land, wetlands, or shorelines and which does not fall within the allowable exemptions contained in the City Code.

Enhancement – The manipulation of the physical, chemical, or biological characteristics of a wetland to heighten, intensify, or improve specific function(s) or to change the growth stage or composition of the vegetation present. Enhancement is undertaken for specified purposes such as water quality improvement, flood water retention, or wildlife habitat. Enhancement results in a change in wetland function(s) and can lead to a decline in other wetland functions, but does not result in a gain in wetland acres. Examples are planting vegetation, controlling non-native or invasive species, and modifying site elevations to alter hydroperiods.

Estuarine Wetland – A vegetated wetland with a water regime that is predominately tidal, as described in *Washington State Wetland Rating System for Western Washington: 2014 Update* (Washington State Department of Ecology Publication #14-06-29, Olympia, WA, October 2014).

Functions and Values – The services provided by critical areas to society, including, but not limited to, improving and maintaining water quality, providing fish and wildlife habitat, supporting terrestrial and aquatic food chains, reducing flooding and erosive

flows, wave attenuation, historical or archaeological importance, educational opportunities, and recreation.

Growth Management Act – RCW 36.70A and 36.70B, as amended.

Hazardous Substances – Any liquid, solid, gas, or sludge, including any material, substance, product, commodity, or waste, regardless of quantity, that exhibits any of the physical, chemical, or biological properties described in WAC 173-303-090 or 173-303-100.

Impervious Surface – A surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development. A non-vegetated surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under pre-development or pre-developed conditions. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater.

In-Kind Compensation – To replace critical areas with substitute areas whose characteristics and functions closely approximate those destroyed or degraded by a regulated activity.

In-Lieu-Fee Program – An agreement between a regulatory agency (state, federal, or local) and a single sponsor, generally a public natural resource agency or non-profit organization. Under an in-lieu-fee agreement, the mitigation sponsor collects funds from an individual or a number of individuals who are required to conduct compensatory mitigation required under a wetland regulatory program. The sponsor may use the funds pooled from multiple permittees to create one or a number of sites under the authority of the agreement to satisfy the permittees' required mitigation.

Infiltration – The downward entry of water into the immediate surface of soil.

Interdunal Wetland – A wetland that forms in the deflation plains and swales that are geomorphic features in areas of coastal dunes, as described in *Washington State Wetland Rating System for Western Washington: 2014 Update* (Washington State Department of Ecology).

Isolated Wetland – A wetland that is hydrologically isolated from other aquatic resources, as determined by the United States Army Corps of Engineers (USACE). Isolated wetlands may perform important functions and are protected by state law (RCW 90.48) whether or not they are protected by federal law.

Mature and Old-Growth Forested Wetland – A wetland having at least 1 contiguous acre of either old-growth forest or mature forest, as described in *Washington State Wetland Rating System for Western Washington: 2014 Update* (Washington State Department of Ecology Publication #14-06-29, Olympia, WA, October 2014).

Mitigation – Avoiding, minimizing, or compensating for adverse critical areas impacts. Mitigation, in the following sequential order of preference, is:

- (a) Avoiding the impact altogether by not taking a certain action or parts of an action;
- (b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation by using appropriate technology or by taking affirmative steps to avoid or reduce impacts;
- (c) Rectifying the impact to wetlands, critical aquifer recharge areas, and habitat conservation areas by repairing, rehabilitating, or restoring the affected environment to the conditions existing at the time of the initiation of the project;
- (d) Reducing or eliminating the impact or hazard over time by preservation and maintenance operations during the life of the action;
- (e) Compensating for the impact to wetlands, critical aquifer recharge areas, and habitat conservation areas by replacing, enhancing, or providing substitute resources or environments; and
- (f) Monitoring the hazard or other required mitigation and taking remedial action when necessary.

Mitigation for individual actions may include a combination of the above measures.

Monitoring – Evaluating the impacts of development proposals on the biological, hydrological, and geological elements of such systems, and assessing the performance of required mitigation measures through the collection and analysis of data by various methods for the purpose of understanding and documenting changes in natural ecosystems and features. Monitoring includes gathering baseline data.

Native Vegetation – Plant species that occur naturally in a particular region or environment and were present before European colonization.

Off-Site Compensation – To replace critical areas away from the site on which a critical area has been impacted.

On-Site Compensation – To replace critical areas at or adjacent to the site on which a critical areas has been impacted.

Ordinary High Water Mark – That mark which is found by examining the bed and banks of water bodies and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, that the soil has a character distinct from that of the abutting upland in respect to vegetation.

Preservation – The removal of a threat to, or preventing the decline of, wetland conditions by an action in or near a wetland. This term includes the purchase of land or conservation easements, repairing water control structures or fences, or structural protection. Preservation does not result in a gain of wetland acres but may result in a gain in functions over the long term.

Project Area – All areas, including those within fifty (50) feet of the area, proposed to be disturbed, altered, or used by the proposed activity or the construction of any proposed structures. When the action binds the land, such as a subdivision, short subdivision, binding site plan, planned unit development, or rezone, the project area shall include the entire parcel, at a minimum.

Prior Converted Croplands – Prior converted croplands (PCCs) are defined in federal law as wetlands that were drained, dredged, filled, leveled, or otherwise manipulated, including the removal of woody vegetation, before December 23, 1985, to enable production of an agricultural commodity, and that: 1) have had an agricultural commodity planted or produced at least once prior to December 23, 1985; 2) do not have standing water for more than 14 consecutive days during the growing season, and 3) have not since been abandoned.

Qualified Professional – A qualified professional for wetlands must be a professional wetland scientist with at least two years of full-time work experience as a wetlands professional, including delineating wetlands using the federal manual and supplements, preparing wetlands reports, conducting function assessments, and developing and implementing mitigation plans.

Re-establishment – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural or historic functions to a former wetland. Re-establishment results in rebuilding a former wetland and results in a gain in wetland acres and functions. Activities could include removing fill, plugging ditches, or breaking drain tiles.

Rehabilitation – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural or historic functions and processes of a degraded wetland. Rehabilitation results in a gain in wetland function but does not result in a gain in wetland acres. Activities could involve breaching a dike to reconnect wetlands to a floodplain or returning tidal influence to a wetland.

Repair or Maintenance – An activity that restores the character, scope, size, and design of a serviceable area, structure, or land use to its previously authorized and undamaged condition. Activities that change the character, size, or scope of a project beyond the original design and drain, dredge, fill, flood, or otherwise alter critical areas are not included in this definition.

Restoration – Measures taken to restore an altered or damaged natural feature, including:

- (a) Active steps taken to restore damaged wetlands, streams, protected habitat, or their buffers to the functioning condition that existed prior to an unauthorized alteration; and
- (b) Actions performed to re-establish structural and functional characteristics of a critical area that have been lost by alteration, past management activities, or catastrophic events.

SEPA – Washington State Environmental Policy Act, 43.21C RCW.

Service Area – The geographic area within which impacts can be mitigated at a specific mitigation bank or an in-lieu-fee program, as designated in its instrument.

Soil Survey – The most recent soil survey for the local area or county by the National Resources Conservation Service, U.S. Department of Agriculture.

Species – Any group of animals or plants classified as a species or subspecies as commonly accepted by the scientific community.

Species of Local Importance – Those species of local concern designated by the City in Chapter XX.XX due to their population status or their sensitivity to habitat manipulation.

Species, Listed -- Any species listed under the federal Endangered Species Act or state endangered, threatened, and sensitive, or priority lists (see WAC 232-12-297 or page 6 of “Priority Habitat and Species List,” Washington Department of Fish and Wildlife, 2008, Olympia, Washington. 177 pp.)

Stream – An area where open surface water produces a defined channel or bed, not including irrigation ditches, canals, storm or surface water runoff devices, or other entirely artificial watercourses, unless they are used by salmonids or are used to convey a watercourse naturally occurring prior to construction. A channel or bed need not contain water year-round, provided there is evidence of at least intermittent flow during years of normal rainfall.

Unavoidable Impacts – Adverse impacts that remain after all appropriate and practicable avoidance and minimization has been achieved.

Washington Administration Code (WAC) – Administrative rules implementing state laws.

Wetlands – Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction

of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from non-wetland areas to mitigate the conversion of wetlands.

Wetland of High Conservation Value – A wetland that has been identified by scientists from the Washington Natural Heritage Program (WHNHP) as an important ecosystem for maintaining plant diversity in Washington State. See <http://www.dnr.wa.gov/data-information-natural-heritage-features> .

Wetland Mitigation Bank – A site where wetlands are restored, created, enhanced, or in exceptional circumstances, preserved, expressly for the purpose of providing compensatory mitigation in advance of unavoidable impacts to wetlands or other aquatic resources that typically are unknown at the time of certification to compensate for future, permitted impacts to similar resources.

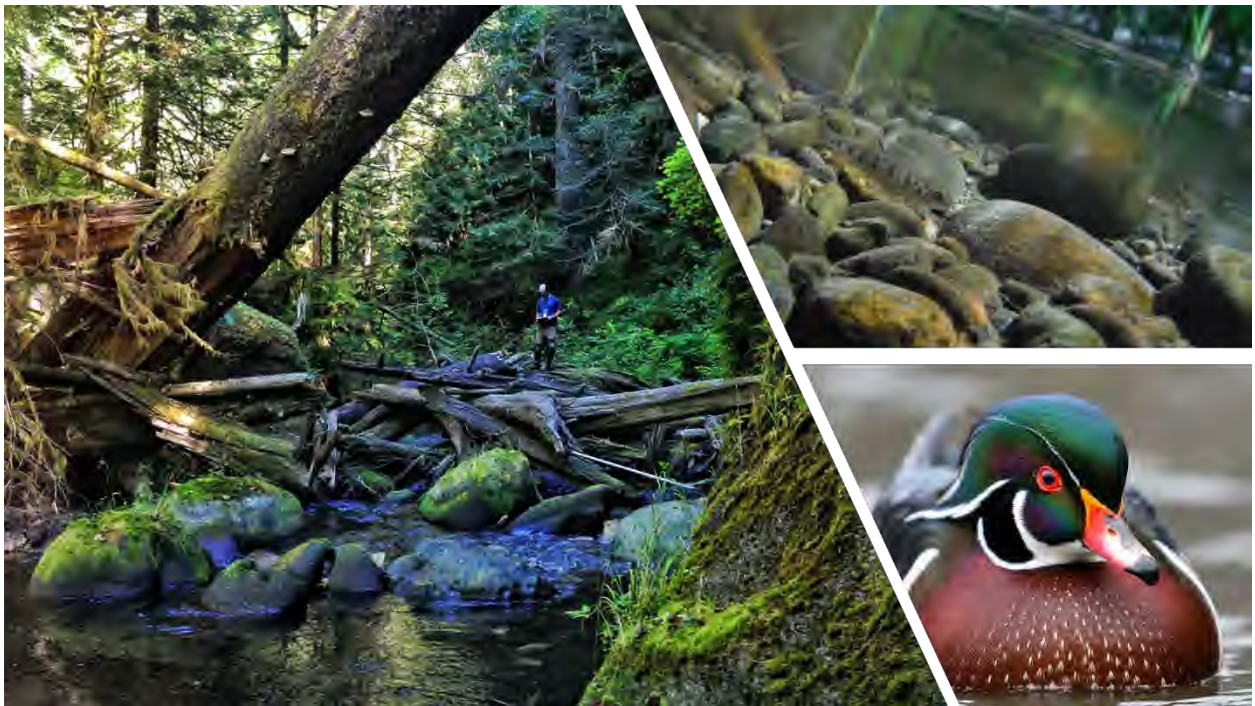
Wetland Mosaic – An area with a concentration of multiple small wetlands, in which each patch of wetland is less than one acre; on average, patches are less than 100 feet from each other; and areas delineated as vegetated wetland are more than 50% of the total area of the entire mosaic, including uplands and open water.

EXHIBIT F

RIPARIAN ECOSYSTEMS, VOLUME 2: MANAGEMENT RECOMMENDATIONS

*A PRIORITY HABITATS AND SPECIES DOCUMENT OF THE
WASHINGTON DEPARTMENT OF FISH AND WILDLIFE*

December 2020



This document should be cited as follows:

Riparian Ecosystems, Volume 2: Management Recommendations. 2020. Amy Windrope, Terra Rentz, Keith Folkerts, and Jeff Azerrad. A Priority Habitats and Species Document of the Washington Department of Fish and Wildlife, Olympia, Washington.

ACKNOWLEDGMENTS

Land Acknowledgement: We acknowledge the traditional, ancestral, territory of Washington state on which we are learning, working, and organizing today. We recognize the longstanding history that has brought us to reside on this land and seek to understand those who first lived here.

Many people were involved with creation of both Volumes 1 and 2 for Priority Habitats and Species (PHS) Riparian Ecosystems. WDFW extends our sincere appreciation to the following individuals and organizations that played important roles during development and/or review of both volumes.

The Washington Department of Ecology (Ecology) and U.S. Environmental Protection Agency (EPA) provided funds that made this document possible (Contract C1300107).

The Washington State Academy of Sciences, with coordination by Dr. Robert Bates, provided an independent peer review that improved the scientific rigor of Volume 1.

Federal (EPA and NOAA Fisheries) and tribal entities (individual tribes, the Northwest Indian Fisheries Commission, Columbia River Inter-Tribal Fish Commission, and Upper Columbia United Tribes) as well as numerous state agencies (Washington State departments of Ecology, Natural Resources, and Commerce; Recreation and Conservation Office; Washington State Conservation Commission; and Puget Sound Partnership) reviewed draft versions of this document. During the summer 2018 public comment period, local governments and members of the public provided valuable feedback that led to a more concise and user-friendly final version of Volume 2.

Within WDFW, Keith Folkerts led coordination, contract planning and budgeting for this work. Tim Quinn and George Wilhere were integral in ensuring a strong relationship with information in Volume 1 and provided additional valuable feedback on multiple drafts. Terry Johnson developed the Site-Potential Tree Height mapping tool and wrote the associated user guide information in the Appendix to this Volume 2. Alison Hart produced final graphics and ensured consistent formatting and stylistic usage throughout. Mary Huff provided editorial support, improved the document's organization, and (in late 2020) took it across the finish line.

WDFW recognizes and appreciates the significant role that tribes, local governments, conservation organizations, and others play in accomplishing our agency's mission. Indeed, we are certain that without these concerted efforts to designate and protect the riparian ecosystems that are essential for most of the state's fish and wildlife species, WDFW would be unable to fulfill its mandate on behalf of all of Washington's residents.

While we acknowledge and have deep appreciation for all the review and comments provided, WDFW bears sole responsibility for this document and any errors contained herein.

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ACRONYMS FOR VOLUME 2

CAO	Critical Areas Ordinance
CMZ	Channel Migration Zone
CREP	Conservation Reserve Enhancement Program
DFC	Desired Future Condition
DNR	Department of Natural Resources (Washington State)
EBM	Ecosystem Based Management
EPA	Environmental Protection Agency (U.S.)
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FEMAT	Forest Ecosystem Management Assessment Team
FPA	Forest Practices Act
FWHCA	Fish and Wildlife Habitat Conservation Area
GIS	Geographic Information System
GMA	Growth Management Act
HMP	Habitat Management Plan
HRCD	High Resolution Change Detection
LID	Low Impact Development
NHD	National Hydrography Dataset
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OHWM	Ordinary High-Water Mark
OSS	On-site Sewage Systems
PHS	Priority Habitats and Species
RCO	Recreation and Conservation Office (Washington State)
RCW	Revised Code of Washington
RMZ	Riparian Management Zone
RZ	Riparian Zone
SMA	Shoreline Management Act
SMP	Shoreline Master Program
SPTH	Site-Potential Tree Height
SPTH ₂₀₀	Site-Potential Tree Height (at age 200 years)
USFS	United States Forest Service

USFWS	United States Fish and Wildlife Service
UWCIG	University of Washington Climate Impacts Group
VSP	Voluntary Stewardship Program
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WFPB	Washington Forest Practices Board
WRIA	Water Resource Inventory Area
WSCC	Washington State Conservation Commission
WWRP	Washington Wildlife and Recreation Program

CHAPTER 1. OVERVIEW

1.1 OUR ROLE AS WASHINGTON’S CONSERVATION AGENCY

The mission of the Washington Department of Fish and Wildlife (WDFW) is to preserve, protect, and perpetuate the state’s fish, wildlife, and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities.

We offer the following science-based guidance to further that mission through the preservation, protection, and—where possible—restoration of healthy, intact, and fully functioning riparian ecosystems statewide. As described throughout this volume, we believe that protection *and* restoration¹ of Washington’s riparian ecosystems is a foundational conservation action; considering a growing population and changing climate, it is also an urgent one.

Within the State of Washington’s land use decision-making framework, WDFW’s role is that of advisor. We provide information relative to our mission about the habitat needs of fish and wildlife, and the likely implications of various land use decisions on those resources over time. Through the Priority Habitats and Species (PHS) Program, we work cooperatively with land use decision makers and landowners to facilitate solutions that accommodate their needs *and* the needs of fish and wildlife. We provide this PHS document, *Riparian Ecosystems Volume 2: Management Recommendations* in support of that effort.

Priority Habitats are places that warrant special consideration for protection when land use decisions are made and should also be prioritized for restoration or enhancement wherever possible. To qualify as a “Priority Habitat” in WDFW’s PHS program, an ecosystem or habitat component must provide unique or significant value to many species. Specifically, it must have one or more of the following attributes (WDFW 2008):

- Comparatively high fish and wildlife density
- Comparatively high fish and wildlife species diversity
- Important fish or wildlife breeding habitat

WDFW’S MISSION

To preserve, protect, and perpetuate Washington’s fish, wildlife, and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities.

WDFW’S RIPARIAN VALUES

We value the protection and restoration of healthy, intact, and fully functioning riparian ecosystems statewide.

WDFW’S RECOMMENDATION

Within the context of wise watershed management, preserve, protect, and—where possible—restore the full extent of riparian ecosystems.

¹ Restoration of riparian ecosystems is critically important because legacy of environmental impacts resulting from the ways land use has affected riparian areas over the past 200 years. In other words, what remains available for protection is not enough to provide the full functions and values Washington’s fish and wildlife need.

- Important fish or wildlife seasonal ranges
- Important fish or wildlife movement corridors
- Limited availability
- High vulnerability to habitat alteration
- Unique or dependent species

Riparian areas (comprised of riparian ecosystems, active floodplains, and riverine wetlands) meet all these criteria, and were among the first Priority Habitats described by WDFW. Riparian areas provide important ecological functions that help create and maintain aquatic habitats in addition to supporting terrestrial wildlife. Riparian areas alongside rivers and streams are the focus of this document, however much of the science reviewed in Volume 1 and the recommendations in this Volume 2 are relevant for lakes, ponds, and marine shorelines as well.

As previously mentioned, one role of WDFW in land use decision making is that of advisor. In that role, recommendations like those contained in this document and in complementary PHS documents (available at <https://wdfw.wa.gov/species-habitats/at-risk/phs/recommendations>) provide critical information for the protection (and where necessary, recovery) of Washington's fish and wildlife. We recognize landowners and land managers most often face situations where various human needs must also be met; and thus, considerations other than fish and wildlife will be incorporated into land use decision making.

The information presented in this management recommendation document is not, in and of itself, science. Rather, it consists of policy recommendations which are informed by the best available science summarized in Volume 1² and which reflect WDFW's mission and legislative mandate. To that end, these recommendations represent WDFW's guidance for the protection and restoration of healthy, intact, and fully functioning riparian ecosystems and

Ecosystem Based Management & WDFW's Conservation Principles

In 2013, WDFW adopted ecosystem-based management principles into policy (WDFW Policy 5004). Ecosystem-based management is an integrated, science-based approach to natural resource management that aims to sustain the ability of ecosystems to provide goods and services upon which humans and other species depend. Importantly, ecosystem-based management recognizes the magnitude of humans as change agents in the ecosystem, and the role of social, economic, and ecological factors in managing complex and dynamic systems.

We believe that conservation is best achieved through employing the following ecosystem-based management principles:

1. We practice conservation by managing, protecting, and restoring ecosystems for the long-term benefit of people, and for fish wildlife and their habitats.
 2. We work across disciplines to solve problems because of their connections among organisms, species and habitats.
 3. We integrate ecological, social, economic, and institutional perspectives into our decision-making.
 4. We embrace new knowledge and apply best science to address changing conditions through adaptive management.
 5. We collaborate with our co-managers and conservation and community partners to help us achieve our shared goals.
-

² The original manuscript of *Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications* was publicly released in May 2018. In 2020, the format of the document was professionally designed, which included making limited updates to content focused on copyediting and improving usability. In accordance with standard citation practice, Volume 1 is now cited as having a 2020 publication date, but substantively, the current document is equivalent to the original 2018 version.

for how land managers and land use regulators can utilize best available science to protect these ecosystems within the scope of their authority and/or ability.

For example, local governments are encouraged to use information provided through PHS to guide critical area ordinance (CAO) updates and other land use policies, plans, or regulations. More specifically, WDFW advises using the information in this PHS Riparian Volume 2 for designating riparian areas as Fish and Wildlife Habitat Conservation Areas (FWHCAs) and protecting them for their inherent value, rather than just as buffers for rivers and streams. This is because riparian areas are so important for helping sustain endangered, threatened, and sensitive species; providing habitat connectivity for both aquatic and terrestrial wildlife; and for their critical role in protecting salmonid habitat (WAC 365-190-130).

In short, Volumes 1 and 2 focus on the science and management, respectively, of riparian ecosystems to support fish and aquatic wildlife species. Volume 1 characterizes riparian ecosystem functions and essential processes, while Volume 2 provides management guidance for riparian ecosystems in the context of watershed processes. To be clear, these two volumes do *not* provide a summary of science or recommendations regarding the contribution of riparian ecosystems for the protection of terrestrial wildlife species. However, our first generation PHS Riparian-specific document, *Management Recommendations for Washington's Priority Habitats: Riparian* (Knutson and Naef 1997) does provide terrestrial species information related to riparian areas. Further, PHS has separate, species-specific management recommendations that address the needs of many terrestrial Priority Species.

This document provides recommendations applicable across the State of Washington but does not address unusual, site-scale environmental conditions or issues specific to particular ecological communities. We strongly encourage addressing such matters at a local level with the assistance of WDFW regional habitat biologists, and other technical experts and stakeholders such as tribal biologists and conservation organizations.

1.2 PURPOSE AND APPLICABILITY OF VOLUME 2

The purpose of this document is to provide guidance to protect and—where possible—restore healthy, intact, and fully functioning riparian ecosystems, which are fundamental for clean water, healthy salmon populations, and climate resilient watersheds.

Volume 2 provides information to:

- Protect existing and restore degraded riparian ecosystem functions in support of aquatic and terrestrial species recovery;
- Assist local governments with their responsibilities to protect priority fish and wildlife and their habitats;
- Assist landowners and local groups in implementing voluntary restoration actions on and off working lands; and
- Incorporate monitoring and adaptive management to understand how well regulatory and non-regulatory efforts are protecting riparian functions and values.

This guidance is applicable to riparian ecosystems statewide. We offer a specific focus on lands within the purview of the Growth Management Act (GMA) and Shoreline Management Act (SMA), although a broader application by local governments and other users is also appropriate.

While many other federal, state, and tribal government programs and policies pertain to riparian ecosystems, they are not specifically addressed in this document. For instance, we do not discuss holistic protection of floodplains, nor do we discuss specific Endangered Species Act (ESA) requirements relative to listed salmonids and other species. Also, we do not address commercial forestlands that fall under the jurisdiction of the Forest Practices Act (FPA), or the Department of Ecology's clean water regulations. These other programs and policies were developed with specific goals and objectives that may be different from the goals of this document, and as such may differ with guidance provided herein.

1.3 SCIENCE SYNTHESIS AND MANAGEMENT IMPLICATIONS (VOLUME 1) SUMMARY

As stated above, Volume 1 (Quinn et al. 2020; see footnote 2) provides important information integral to the development of these management recommendations. It includes both overarching as well as specific considerations important to all efforts, large and small, to protect rivers and streams for the benefit of the aquatic species associated with them. Volume 1 focuses on the science of riparian ecosystems—specifically, how riparian areas interact with large-scale drivers (e.g., topography, geology, climate, and land use) and watershed processes to create and maintain riparian and aquatic habitat in support of fish and wildlife. Thus, we provide here an explicit definition of riparian ecosystems from Volume 1 that combines a variety of conceptual riparian descriptions from the scientific literature:

Riparian ecosystems are transitional between terrestrial and aquatic ecosystems, distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with adjacent uplands. They include those portions of terrestrial ecosystems (i.e., *a zone of influence*) that significantly influence exchanges of energy and matter with aquatic ecosystems and the portion of the ecosystem characterized by moist soils and plants adapted to periodically saturated soils – the *riparian zone* (RZ). The width of the riparian ecosystem is typically defined by the outer edge of the zone of influence, which, in forested regions, is based on site-potential tree height (SPTH) measured from the edge of the active channel. While our definition of riparian ecosystem does not include the water in river or streams, it does include riverine wetlands and recognizes the riparian zone as a distinctive area within riparian ecosystems.

To assist managers in understanding important implications of the science synthesized in Volume 1, we reiterate the ten overarching findings of that document below. These findings are also discussed in more detail in later chapters.

1. Protection and restoration of riparian ecosystems continues to be critically important because: (a) they are disproportionately important, relative to area, for aquatic species (e.g., salmon) and terrestrial wildlife; (b) they provide ecosystem services such as water purification and fisheries (Naiman and Bilby 2001, NRC 2002, Richardson et al. 2005); and (c) by interacting with watershed-scale processes, they contribute to the creation and maintenance of aquatic habitats.
2. Stream riparian ecosystems encompass the riparian zone; the active floodplain, including riverine wetlands and the terraces; and adjacent uplands that contribute matter and energy

to the active channel or active floodplain (Gregory et al. 1991, Naiman and Bilby 1998). Such terraces and adjacent uplands are called the zone of influence.

3. The width of the riparian ecosystem is estimated by one 200-year SPTH measured from the edge of the active channel or active floodplain. Protecting functions within at least one 200-year SPTH is a scientifically supported approach if the goal is to protect and maintain full function of the riparian ecosystem.
4. Where the riparian zone is narrow (<100 ft [30 m]) and the zone of influence lacks tall trees (<100 ft), (e.g., in parts of the Columbia Plateau Ecoregion), the pollution removal function may determine the width of the zone of influence.
5. The riparian ecosystem begins at the edge of the active channel or active floodplain, whichever is wider. As the active channel moves back and forth across the channel migration zone (CMZ), the riparian ecosystem moves with it. Consequently, there are times when the riparian ecosystem lies adjacent to or overlaps the CMZ (see Figure 2.3). Hence, to maintain riparian ecosystem functions, management must anticipate and protect future locations of the riparian ecosystem.
6. A near consensus of scientific opinion holds that the most effective and reliable means of maintaining viable self-sustaining fish, especially salmon, and wildlife populations is to maintain/restore ecosystems to conditions that resemble or emulate their historical range of natural variability (Swanson et al. 1994, Reeves et al. 1995, Bisson et al. 2009). This opinion is based in part on the complexity of processes that affect the expression of habitats over time and space.
7. The protection and restoration of watershed-scale processes, especially related to hydrology, water quality, connectivity, and inputs of wood, shade, and sediment are important for aquatic system function, and help maximize the ecological benefits of riparian ecosystem protections.
8. Riparian areas and surrounding watersheds are complex and dynamic systems comprised of many interacting components. Natural disturbances (flood, fire, and landslides) across the watershed and through time create the mosaic of conditions necessary for self-sustaining populations of fish, especially salmon, and other aquatic organisms.
9. Impending changes to aquatic systems as a result of climate change increase risk to species already threatened by human activities. The effects of climate change on rivers and streams threaten to reduce fish distribution and viability throughout the Pacific Northwest (Beechie et al. 2013).
10. The use of the precautionary principle and adaptive management are particularly appropriate when dealing with complex and dynamic systems, and when we have uncertainty related to exactly how management activities affect functioning of watersheds and riparian ecosystems.

1.4 KEY FINDINGS AND RECOMMENDATIONS

WDFW recognizes that there is a significant amount of work currently being done throughout the state to protect and restore riparian areas. This focus is longstanding and has ranged from regulatory protections that guide Washington's growing population to voluntary conservation on our working lands. Below, we highlight what we believe—based on best available science and our agency's mission—are the most important recommendations to ensure healthy, intact, and fully functioning riparian ecosystems that provide for the preservation, protection and perpetuation of Washington's fish and wildlife:

1. **Designate riparian ecosystems as critical areas:** WDFW recognizes riparian ecosystems as a Priority Habitat for fish and wildlife and recommends that local jurisdictions designate those ecosystems as Fish and Wildlife Habitat Conservation Areas (FWHCAs), a type of critical area. We define the bounds of the riparian ecosystem as the riparian management zone (RMZ), and this RMZ should be designated as the location where protection and restoration of riparian ecosystem functions and values are addressed. RMZs provide a framework for delineating, evaluating, planning, and managing functions and values. In this volume, we provide a process for RMZ delineation (Chapter 2).
2. **Include watershed-scale management considerations:** Watershed-scale management is critical to realizing the full benefits of riparian ecosystem protection and restoration. Certain types of anthropogenic changes at the watershed scale can dramatically reduce the effectiveness of riparian ecosystems to protect aquatic habitat. For example, unmitigated delivery of stormwater from impervious surfaces like roads, parking lots, and rooftops to streams, for example, dramatically increases peak stream flows, alters channel form, and short-circuits the capacity of riparian areas to remove pollutants from runoff. Similarly, road-crossing culverts that are impassible to fish can reduce stream-network connectivity and dramatically reduce amounts of otherwise suitable habitat.
3. **Use reference points to locate the inner edge of the RMZ:**
 - For streams without Channel Migration Zones (CMZs), the inner edge of the RMZ should be delineated starting at the outer edge of active floodplain, if this has or can be determined; otherwise, from the active channel, as delineated by the Ordinary High-Water Mark (OHWM)³.
 - For streams with CMZs, the unpredictable nature of channel migration should be accommodated through delineation of an RMZ that encompasses both the entire CMZ and future locations of the riparian ecosystem. In these instances, the inner edge of the RMZ should be located at the outer edge of the CMZ.

Whether or not a stream has a CMZ, the distance from the inner edge of the RMZ to the outer edge of the RMZ should be one SPTH₂₀₀.

³ Active floodplain delineations are rarely available, and we currently lack a repeatable, well-vetted, and widely accepted method for the delineation of active floodplains. Therefore, until such a process is developed, we recommend delineating the RMZ's inner edge using the OHWM for streams without CMZs.

4. **Include CMZs in delineation of the RMZ:** CMZs are important to protect for maintaining riparian functions and values, and so are included in the delineation of RMZs. Over time, a riparian ecosystem will occupy different parts of the CMZ and uplands outside the CMZ. Lateral channel migration and related streambank erosion processes can pose risks to homes and communities located near rivers; however, when channels are constrained from moving, aquatic and riparian ecosystems may degrade over time. To maintain riparian ecosystem functions, land managers must anticipate and protect future locations of the riparian ecosystem and thus delineate the RMZ accordingly.
5. **Establish RMZ widths based on site-specific conditions:** From the perspective of those riparian ecosystem functions affecting aquatic systems, the width of the riparian ecosystem varies with ecological conditions. The most efficient way to protect riparian functions is to adopt protections that recognize these differences, rather than uniform-width (i.e., one-size-fits-all) RMZs, as these may result in over-protection in some places and under-protection in others.
 - a. **In forested ecoregions, start with SPTH₂₀₀:** At most riparian areas in forested ecoregions, SPTH₂₀₀ is 100 feet or greater, and so the RMZ is delineated using one SPTH₂₀₀. If SPTH₂₀₀ is less than 100 feet, the RMZ is delineated by the pollution removal function (see below). In highly altered areas where soil data are not available, it may be necessary to estimate SPTH₂₀₀ values based on nearby soils.
 - b. **In dryland ecoregions, start with SPTH₂₀₀ (if available), or the width of the riparian vegetation community:** If site conditions do not support tree species or SPTH₂₀₀ is less than 100 feet, then RMZ width is determined by the full extent of all riparian vegetation (the riparian zone) or by the pollution removal function—see below.
 - c. **For both forested and dryland ecoregions, use the pollution removal function when appropriate:** Where the SPTH₂₀₀ and/or the width of the riparian vegetative community is less than 100 feet, we recommend that RMZ width be delineated at a minimum of 100 feet, as this provides the width necessary for 95% pollution removal target for most pollutants (approximately 85% for surface nitrogen.)⁴

To aid with site-specific RMZ delineation, WDFW created an internet-based mapping tool that reports recommended widths for RMZs (Appendix 1) statewide based on SPTH₂₀₀. The tool also notes instances where a 100-foot RMZ should be applied to support the pollution removal function.

6. **Apply the recommended RMZ delineation steps to all streams, whether or not they are fish-bearing:** In 1997, WDFW recommended a lower level of protection for non-fish bearing streams than fish-bearing streams. In reviewing the current science literature for Volume 1, we found no evidence that full riparian ecosystem functions along non-fish-bearing streams are less important to aquatic ecosystems than full riparian ecosystem

⁴ See Chapter 2, Section 2.3.5 for more information about surface nitrogen removal and other site-specific characteristics that may require RMZ distances greater than 100 feet in order to ensure an adequate pollution removal function.

functions along fish-bearing streams. This recommendation is based on four additional considerations. Non-fish-bearing streams:

- Support a unique community of aquatic and riparian-obligate wildlife;
- Provide movement corridors for wildlife, particularly in the face of changing climate conditions;
- Provision fish-bearing streams with matter and energy; and
- Provide cool water to downstream reaches. Washington State has already experienced increased stream temperatures due to climate change and expect further increases, which have direct implications for the persistence of fish.

7. **Establish monitoring and adaptive management frameworks:** We believe it is critical to understand if riparian ecosystems protections are working as intended, and if not, to adjust them accordingly. We recommend the establishment of monitoring and adaptive management designed to improve (where necessary) local permit implementation and compliance, and to increase effectiveness of actions intended to protect aquatic species.

8. **Consider needs of relevant terrestrial species:** As stated earlier, a review of new literature related to the needs of terrestrial Priority Species was not a focus of Volume 1.

Nonetheless, riparian areas provide important functions for threatened, endangered, and sensitive terrestrial wildlife that require consideration by landowners and land managers. WDFW regional habitat biologists, tribal biologists and/or other local habitat experts can assist in identification of site-specific terrestrial species needs. Because riparian protections

WAC 365-190-130

FISH AND WILDLIFE HABITAT CONSERVATION AREAS

(1) "Fish and wildlife habitat conservation" means land managed for maintaining populations of species in suitable habitats within their natural geographic distribution, so that the habitat is sufficient to support viable populations over the long term and isolated subpopulations are not created. This does not mean maintaining all individuals of all species at all times, but it does mean not degrading or reducing populations or habitats so that they are no longer viable over the long term. Counties and cities should engage in cooperative planning and coordination to help assure population viability.

Fish and wildlife habitat conservation areas contribute to the state's biodiversity and occur on both publicly- and privately-owned lands. Designating these areas is an important part of land use planning for appropriate development densities, urban growth area boundaries, open space corridors, and incentive-based land conservation and stewardship programs."



WAC 173-26-186

GOVERNING PRINCIPLES OF THE [SMP] GUIDELINES

(8) "Through numerous references to and emphasis on the maintenance, protection, restoration, and preservation of "fragile" shoreline "natural resources," "public health," "the land and its vegetation and wildlife," "the waters and their aquatic life," "ecology," and "environment," the act makes protection of the shoreline environment an essential statewide policy goal consistent with other policy goals of the act. It is recognized that shoreline ecological functions may be imparted not only by shoreline development subject to the substantial development permit requirements of the act but also by past actions, unregulated activities, and development that is exempt from the act's permit requirements. The principle regarding protecting shoreline ecological systems is accomplished by these guidelines in several ways, and in the context of related principles."

benefit both aquatic and many terrestrial wildlife species, concentrating protections around riparian areas may also be an efficient use of resources.

1.5 RELATIONSHIP WITH WASHINGTON'S DEVELOPMENT LAWS AND REGULATIONS

1.5.1 *Relationship with the Growth Management Act (GMA)*

The GMA requires local jurisdictions to designate and protect critical areas, and in so doing, use best available science and give special consideration to anadromous species⁵. The GMA also encourages state agencies to provide technical assistance to counties and cities in the review of their critical areas ordinances (CAOs), comprehensive plans, and development regulations [RCW [36.70A.130\(6\)\(g\)](#)]. While the Washington State Department of Commerce (Commerce) administers the GMA, WDFW is the lead state agency for advising local governments on matters related to one type of critical area: Fish and Wildlife Habitat Conservation Areas (FWHCAs), and we produce PHS Management Recommendations like this Volume 2 in support of that role.

This document provides guidance that is consistent with the GMA, under which local governments exercise their land use responsibilities: specifically, protection of the functions and values of critical areas. It also reflects the legal and policy framework within which WDFW and the PHS program operate, which includes among other things providing a source of best available science necessary to support local governments in distinguishing and delineating those critical areas (e.g., FWHCAs).

WDFW understands that local jurisdictions have existing critical area regulations that have been approved by elected officials and in many cases have been found to be compliant with GMA through the Growth Management Hearings Board and courts. We acknowledge that revising a critical area regulation can be a lengthy, expensive, and contentious process, and so jurisdictions frequently do not make updates to their CAOs more frequently than required by law or rule. In this volume, we aim to be more precise about where recent science has improved our certainty around the need for riparian protections, as well as for specific practices; and how to incorporate best available science and WDFW's management recommendations.

WDFW also recommends local jurisdictions continue considering PHS best available science (e.g., Volume 1; PHS maps), incorporating PHS Management Recommendations, and seeking technical assistance from WDFW's regional habitat biologists not just when updating and implementing critical area policies and regulations, but in all land use planning efforts.

1.5.2 *Relationship with the Shoreline Management Act (SMA)*

As with GMA, WDFW plays a role of technical advisor under SMA, working directly through locally led development processes, with the goal of addressing needs for fish and wildlife. Under SMA, the Department of Ecology (Ecology) has a role approving Shoreline Master Program (SMP) updates when they are deemed consistent with all statutory and regulatory requirements. Ecology also has

⁵ RCW 36.70A.172(1): "In designating and protecting critical areas under this chapter, counties and cities shall include the best available science in developing policies and development regulations to protect the functions and values of critical areas. In addition, counties and cities shall give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries."

a direct role in implementation of SMPs, including issuing the final decision to approve, deny, or put conditions on locally issued conditional use permits and variances. [Under GMA, Commerce does not approve comprehensive plan updates or CAOs.]

The goal of SMA is “to prevent the inherent harm in an uncoordinated and piecemeal development of the state’s shorelines” (RCW [90.58.020](#)). To achieve that end, WDFW recommends local jurisdictions designate riparian areas and provide the same levels of protection for them within the SMA jurisdiction areas as they do under GMA. While the SMA does not apply to streams with 20 cubic feet per second (cfs) or less mean annual flow, we recommend the application of the guidelines in this Volume 2 to all rivers and streams, regardless of size.

1.6 ORGANIZATION OF VOLUME 2

Chapter 1 aims to establish Volume 2’s purpose and intent; articulate WDFW’s values; and provide policy context regarding protection and designation of riparian ecosystems.

In Chapter 2, we define the RMZ based on SPTH₂₀₀ with special considerations for urban and dryland landscapes; and provide a stepwise process for identifying and delineating the RMZ both for requiring riparian protections and for classifying RMZs as a FWHCA under GMA.

Chapter 3 articulates policies, plans, and practices that protect riparian ecosystems. WDFW recognizes that counties and cities have a long history of providing such protections, and the responsibility to include best available science when updating CAOs. The protection recommendations described in this chapter are intended to help counties and cities moving forward with reviewing and updating their CAOs and other relevant policies and plans.

Chapter 4 explains the importance of restoration in riparian management, which is necessary for recovery of the degraded riparian functions present in many locations and is critical to recover salmon stocks and preserve Washington’s riparian-dependent Priority Species. To that end, we outline voluntary approaches to improve riparian functions. Although Volume 2 is not a restoration guide, it is applicable to restoration practitioners in that it describes management actions that enhance riparian functions and values. We do not address restoration project design or standards but provide links within this chapter to resources that do.

Chapter 5 will assist with developing monitoring programs in support of adaptive management, designed to ensure transparent programs that consistently deliver sufficient protection of riparian functions. Careful monitoring and adaptive management are particularly important when a land use may harm a critical area and scientific information about the likely severity of harm is lacking. Although specific to local governments, this chapter provides valuable resources for any land manager interested in engaging in adaptive management.

Finally, this volume includes an appendix that contains a “how-to” process for utilizing WDFW’s SPTH mapping tool to help determine recommended minimum RMZ widths around the state. The tool itself is available at wdfw.maps.arcgis.com/apps/MapSeries/index.html?appid=919ea98204eb4f5fa70eca99cd5b0de1.

CHAPTER 2. RIPARIAN MANAGEMENT ZONE DELINEATION

2.1 INTRODUCTION

We define the extent of the riparian ecosystem as the area that provides full ecological function for bank stability, shade, pollution removal, contributions of detrital nutrients, and recruitment of large woody debris. For the purposes of management or regulatory protection, the riparian management zone (RMZ) encompasses the riparian ecosystem, and—when present—the channel migration zone (CMZ) to account for lateral movement of the riparian ecosystem over time. RMZs can also provide habitat for many terrestrial wildlife species including movement corridors. WDFW categorizes the riparian ecosystem as a Priority Habitat, and thus recommends local jurisdictions designate all riparian areas as critical areas: specifically, Fish and Wildlife Habitat Conservation Areas (FWHCAs), as mentioned in Chapter 1.

The RMZ provide an initial framework for delineating, assessing, planning, and managing riparian ecosystems. The RMZ as defined here is not necessarily the same as setbacks or buffers. Setbacks are areas meant to protect an important feature (e.g., a stream or wetland) from certain types of adjacent activities, e.g., the area separating a building from the bank of a river. Setbacks are not typically designed to provide ecological function. On the other hand, buffers, which also protect important features, are commonly undeveloped, naturally vegetated areas that can contribute habitat and in the case of a stream, to riparian functions. In this document, we reserve the use of the term RMZ to mean the area capable of providing full function and managed to that end.

2.2 FOUNDATIONAL CONCEPTS IN RMZ DETERMINATIONS

2.2.1 *Desired Future Condition*

A major goal in fulfilling WDFW's mission to preserve, protect, and perpetuate Washington's fish, wildlife, and ecosystems is the protection and restoration of healthy, intact, and fully functioning riparian areas. More specifically, the goal will be achieved through management strategies that result in ecosystem composition and structure that provides the five key ecological functions associated with riparian ecosystems. A useful benchmark for this goal is desired future condition (DFC) for riparian areas. DFC describes what land managers are attempting to achieve, often in terms of composition and structure (e.g., vegetation or land-use), over a period of time in a given geographic area. The DFC we recommend results in fully functioning riparian ecosystems as measured by the five key ecological functions (bank stability, shade, pollution removal, contributions of detrital nutrients, and recruitment of large woody debris) in western Washington. The DFC for composition and structure is old, structurally complex conifer-dominant forest. Such forests exhibit large diameter trees, contain numerous large snags and logs, and have multi-layered canopies and canopy gaps, which promote understory plant diversity.

Throughout the Columbia Plateau, differences in hydrology and geomorphology manifest substantial site-level differences in composition and structure of riparian vegetation, and hence, the DFC for composition and structure is more site-dependent in the Columbia Plateau than in western Washington. Nonetheless, the DFC in the Columbia Plateau is based on the same concepts of ecosystem composition and structure that support the same five key ecological functions in forested regions; specifically, biologically diverse vegetation communities consisting of native trees,

shrubs, grasses and forbs. In addition, the DFC for the upland portion of the riparian ecosystem which serves as the zone of influence and contributes to the pollution removal function in the Columbia Plateau is often intact native shrub-steppe or prairie vegetation.

2.2.2 Site-Potential Tree Height (SPTH) Background

A fundamental component of our recommendation is the use of site-potential tree height (SPTH). In this section, we provide background information on its origin, applicability, and usefulness (see also Volume 1, Chapter 9).

In 1993, a group of experts (Forest Ecosystem Management Assessment Team [FEMAT]) was convened to develop a conceptual model to determine how to protect riparian areas in forested landscapes. This model has come to be known as the FEMAT curves (FEMAT 1993). Though this model is over 25 years old, it continues to be one of the most useful conceptual models informing riparian management.

The FEMAT curves provide a conceptual model of important riparian functions and how those functions change with increased distance from the stream channel (Figure 2.1). The model conveys two important points: (1) four of the five riparian ecosystem functions or processes occur within one 200-year SPTH; and (2) the marginal return for each function or process decreases as distance from the stream channel increases. Thus, designating a riparian area based on at least one SPTH₂₀₀ is a scientifically supported approach if the goal is to protect and maintain full function of the riparian ecosystem for aquatic habitat and species, including salmon.

The FEMAT curves and SPTH have been used to describe the lateral extent of riparian ecosystems, and accordingly, the width of the RMZ needed to provide full riparian ecosystem function.

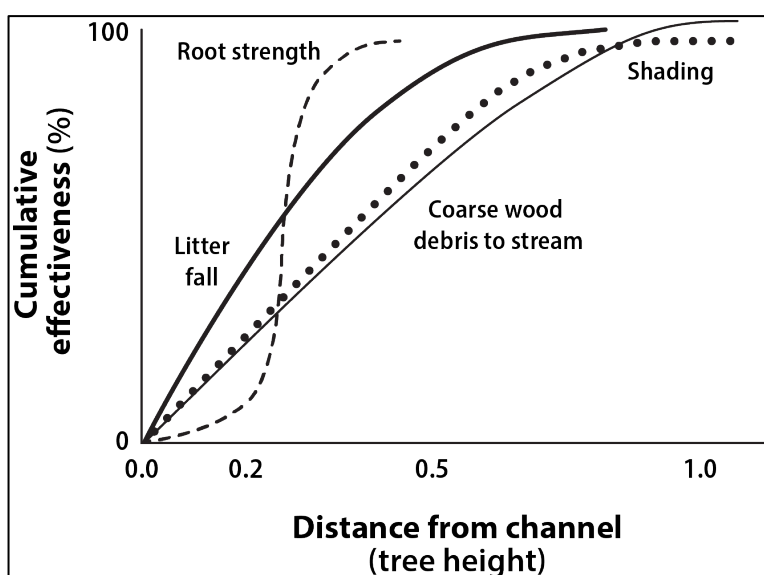


Figure 2.1. The “FEMAT Curves” (FEMAT 1993): a generalized conceptual model describing contributions of key riparian ecosystem functions to aquatic ecosystems as the distance from a stream channel increases. “Tree height” refers to average height of the tallest dominant tree (200 years old or greater); referred to as site-potential tree height (SPTH).

FEMAT (1993, p. V-34) defined SPTH as “the average maximum height of the tallest dominant trees (200 years or more) for a given site class.” The key phrase in this definition is “200 years or more” which refers to the approximate minimum age of old-growth forests. This reflects FEMAT’s underlying assumption that old-growth forest conditions are needed for full riparian ecosystem functions. WDFW uses SPTH at 200 years (abbreviated SPTH₂₀₀) in our recommendations in this Volume 2.

Given its utility, the height of site-potential trees has been described for a variety of tree species and can be readily found in silvicultural literature. Mean heights of dominant trees in riparian old-growth forest of Washington range from 100 to 240 feet (Fox 2003). The wide range of heights reflects differences in site productivity, i.e., local differences in soil nutrients and moisture, light and temperature regimes, and topography. Site productivity is described quantitatively through a site index, which is the average height that dominant trees of a species are expected to obtain at a specified tree age at a given location.

FEMAT defined Site potential tree height (SPTH) as “the average maximum height of the tallest dominant trees (200 years or more) for a given site class.”

“200 years or more” is the approximate minimum age of old-growth forests which are thought to be necessary for full riparian ecosystem functions.

2.2.3 *The Importance of Channel Migration Zones (CMZs)*

Not all streams have CMZs, but where CMZs are present, it is necessary to map the CMZ in order to establish an RMZ. The Washington Forest Practices Board Manual (DNR 2004) provides a useful definition of the CMZ as “the area where the active channel of a stream is prone to move and this results in a potential near-term loss of riparian function and associated habitat adjacent to the stream, except as modified by a permanent levee or dike” (DNR 2004, Section M2).

Protecting the CMZ from incompatible land uses (e.g., development) is important for providing riparian ecosystem functions. Human alterations to river channels that limit channel migration and bank erosion can degrade aquatic and riparian habitats. For these reasons, geomorphologists have developed protocols for delineating CMZs. Further, RMZ delineation along streams with CMZs ensures that riparian functions do not degrade as a channel moves. Proper delineation also helps landowners avoid siting homes and infrastructure in CMZs that coincide with geologically hazardous critical areas and floodplains ([WAC 365-190-120\[6f\]](#)).

2.2.4 *Relationship of CMZs and Floodplains*

This document does not include guidance on the integration of floodplains into RMZ delineation (see footnote 4 for a brief explanation about the active floodplain). However, a general understanding of floodplains and their relationship to CMZs is valuable, as the two often overlap.

Both federal and state regulations establish floodplain protections. Floodplain data and [maps](#) (typically 100-year floodplains) are readily available through the Federal Emergency Management Agency’s National Flood Insurance Management Program. Ecology is the state’s authority as lead on floodplain management and we support their recommendations for management of [Frequently Flooded Areas](#) (another type of critical area specified in GMA) and the use of the [Floodplains by Design](#) grant program to reduce hazards and restore natural functions. Proper floodplain delineation and protection helps landowners and land managers avoid placing homes and infrastructure in areas at high-risk of flooding.

The Bureau of Land Management provides common clues to help determine the presence of an active floodplain (BLM 2015) such as visual evidence of frequent inundation, which may include but is not limited to:

- Fresh deposits of fine sediment;
- Floodplain vegetation matted down or lying flat on floodplain from overbank flow or by deposition or overbank sediment;
- Debris piled on the upstream side of tree trunks; or
- High water marks seen on rocks, trees, or other stationary objects; and ice-rafted deposits on the floodplain.

However, BLM advises caution when relying on these visual clues. Furthermore, looking for signs that an active floodplain is present is only the first step toward delineating the outer edge of an active floodplain. We recommend reviewing BLM's technical reference titled *Proper Functioning Condition Assessment for Lotic Areas* (BLM 2015) and to consult Ecology for assistance regarding floodplain delineation and protections.

Good floodplain management is not only beneficial for human communities, it is also good for fish and wildlife. Although we do not describe use of the 100-year floodplain to measure the RMZ in Volume 2, we recommend that landowners and land use decision makers treat floodplains similarly to RMZs due to their importance to instream health, as habitat, and for their ecological services.

2.3 PROCEDURES FOR RMZ DELINEATION

To conserve riparian habitat, one must first establish the lateral extent (i.e., width) of the RMZ. In Chapter 1, we noted that an RMZ encompasses the riparian zone and zone of influence (Figure 2.2, page 16), and, where present, considers the CMZ (Figure 2.3, page 18). In this section, we outline general steps for collecting site-specific information essential to map an RMZ. These steps will help you identify a site's proximity to streams as well as essential site characteristics. With this information, we then explain how to delineate an RMZ.

In the rest of this section, we explain how to:

- Identify the ecoregion in which the riparian ecosystem is located (e.g., forested or dryland);
- Verify the presence of a stream;
- Identify the inner edge of the RMZ; and finally
- Determine the RMZ width.

2.3.1 *Determining Ecosystem Location*

We have identified two distinct types of ecoregions statewide, each with a slightly different RMZ delineation procedure: (1) Forested, and (2) Dryland. In general, forested ecoregions dominate western Washington, northeastern Washington, and portions of southeast, north central, and eastern Cascades. Dryland ecosystems are more readily contained in the Columbia Plateau Ecoregion east of the Cascade Range.

Landowners and land use planners should utilize the SPTH mapping tool, described in Appendix 1, to determine the ecoregion where the river or stream lies. Appendix 1 also provides instructions for using this tool to determine the 200-year site-potential tree height (SPTH₂₀₀) at a given location.

2.3.2 *Verifying the Presence of a Stream*

Once you have identified which ecoregion you are in (e.g., Columbia Plateau), a qualified professional⁶ should visit the site to verify the stream's location on or near the project area. It is very important not to rely solely on "stream maps" (e.g., DNR stream layer, National Hydrography Dataset) in place of a site visit (which is also important for mapping RMZs) because existing mapped stream layers often have errors, including streams whose locations are mapped inaccurately on the landscape, and streams actually present on the landscape that are missing from maps. Instead, use the site visit to validate existing stream maps.

2.3.3 *Identifying the Inner Edge of the RMZ*

Once you have verified a stream's location, proceed to locate the inner edge of the RMZ. Accurate RMZ delineation is dependent on using the correct starting point. In this section, we describe how to determine the location of the RMZ's inner edge using either the Channel Migration Zone (CMZ), if one is present; or the Ordinary High-Water Mark (OHWM). Ecology, as the state's water quality lead, provides extensive guidance and resources associated with OHWM or CMZ, and those resources are referenced here forward.

2.3.3 (A) Identifying Ordinary High-Water Mark (OHWM)

Delineate the RMZ's inner edge by identifying the OHWM along both sides of the stream following the procedure in Chapter 3 of Ecology's [OHWM delineation manual](#) (Anderson et al. 2016).

⁶ Qualified professionals can be entities and individuals identified by the jurisdiction, WDFW regional habitat biologists, tribal biologists, Ecology staff, and/or other individuals familiar with stream verification and who have local expertise (e.g., Conservation District staff, Stream Teams, etc.).

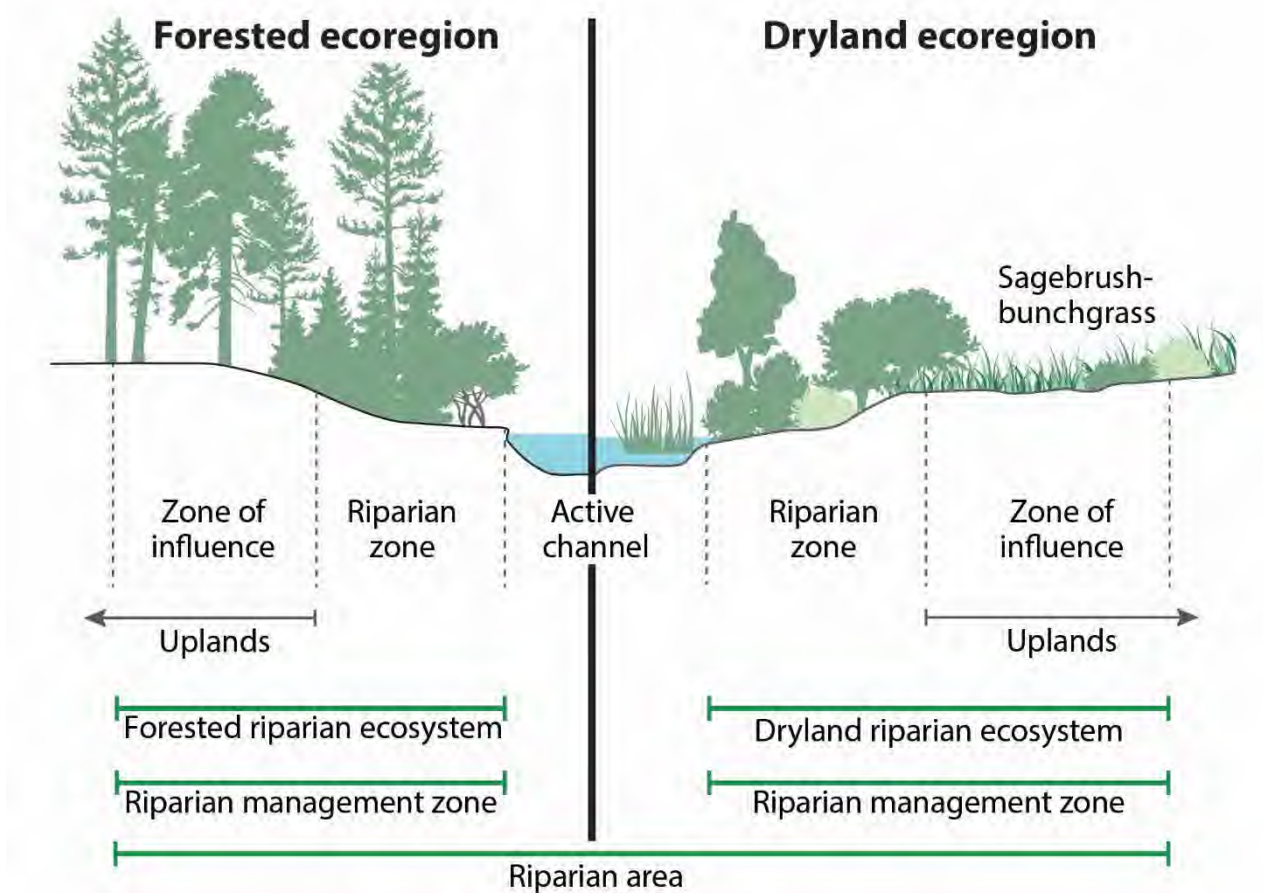


Figure 2.2. The diagram depicts the *riparian management zone* (RMZ) for both forested (left) and dryland (right) ecoregions. The RMZ is coincident with the *riparian ecosystem*, which consists of the *riparian zone* (riparian vegetative community) and the *zone of influence*. The *riparian zone* extends from the edge of the active channel towards the uplands and it includes areas where vegetation is influenced at least periodically by flowing waters. The *zone of influence* includes areas where ecological processes significantly influence the stream, at least periodically.

2.3.3 (B) Identifying the Channel Migration Zone

Delineate the RMZ's inner edge by identifying the edge of the CMZ. Information about CMZs is available for certain streams in the state. For example:

- **SMA-Covered Shorelines** – During Shoreline Master Program comprehensive updates, many jurisdictions map the general location of CMZs associated with shorelines that fall under the jurisdiction of SMA (RCW [36.70A.480](#)). Note that even smaller streams not subject to SMA jurisdiction can have CMZs. In these cases, we recommend jurisdictions still identify and analyze CMZs to protect riparian ecosystems and public health and safety.
- **Puget Sound Streams** – The federal Endangered Species Act may require CMZ delineation in Puget Sound basin streams under the FEMA National Flood Insurance Program Biological Opinion for Puget Sound.

- **Other Local Examples** – Check with your jurisdiction to see if they have more detailed CMZ maps.

Ecology provides the following resources which can help landowners and land managers assess the presence and extent of CMZs where maps and data on CMZs do not currently exist:

- [CMZ Home Page](#) provides a high-level look at CMZ identification, and references useful documents;
- [Channel Migration Processes and Patterns in Western Washington](#) (Legg and Olson 2014) describes the general channel migration processes that occur in western Washington;
- [A Methodology for Delineating Planning-Level Channel Migration Zones](#) (Olson et al. 2014) provides a process for delineating “planning-level” CMZs and gives a few good examples in the appendices;
- [A Framework for Delineating Channel Migration Zones](#) (Rapp and Abbe 2003) is a more in-depth guide on how to develop “detailed” CMZs; and
- [Screening Tools for Identifying Migrating Stream Channels in Western Washington](#) (Legg and Olson 2015) outlines the “CHAMP” (channel migration potential) GIS layer with guidance on using it to identify high-risk CMZs.

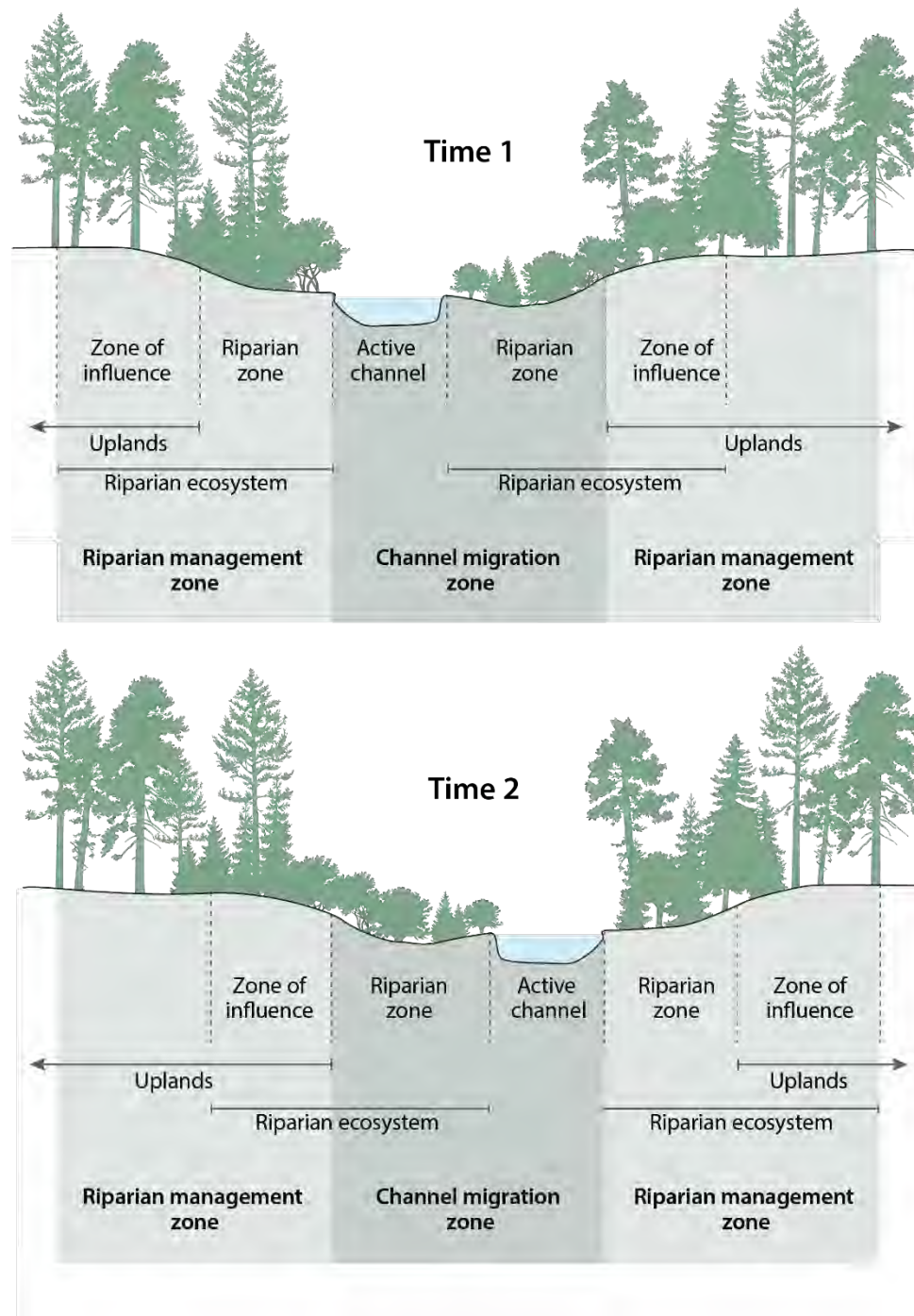


Figure 2.3. This diagram depicts the spatial relationship between the riparian management zone (RMZ) and channel migration zone (CMZ) over time. As the active channel moves laterally within the CMZ, the riparian ecosystem moves with it. As a result, when considering the establishment of an RMZ, delineation should occur at the edge of the CMZ to account for the full extent of both the present day and future riparian ecosystems. Time 1 and Time 2 could be separated by days or centuries. This depiction of a forested system is one representation of a CMZ, which are also present in dryland systems: both should be managed for accordingly.

2.3.4 Determining RMZ Width

Once you have determined the location of the RMZ's inner edge, you then establish the width of the RMZ. The following stepwise process aims to establish recommended minimum delineation distances based on $SPTH_{200}$, vegetation composition, and pollution removal function (Figure 2.4). We say “recommended minimum” because upland adjacent land uses may require further adjustment of the RMZ to provide adequate pollution removal functions. Landowners and land use regulators should also consider additional actions to support wildlife connectivity and/or to protect riparian adjacent Priority Habitats.

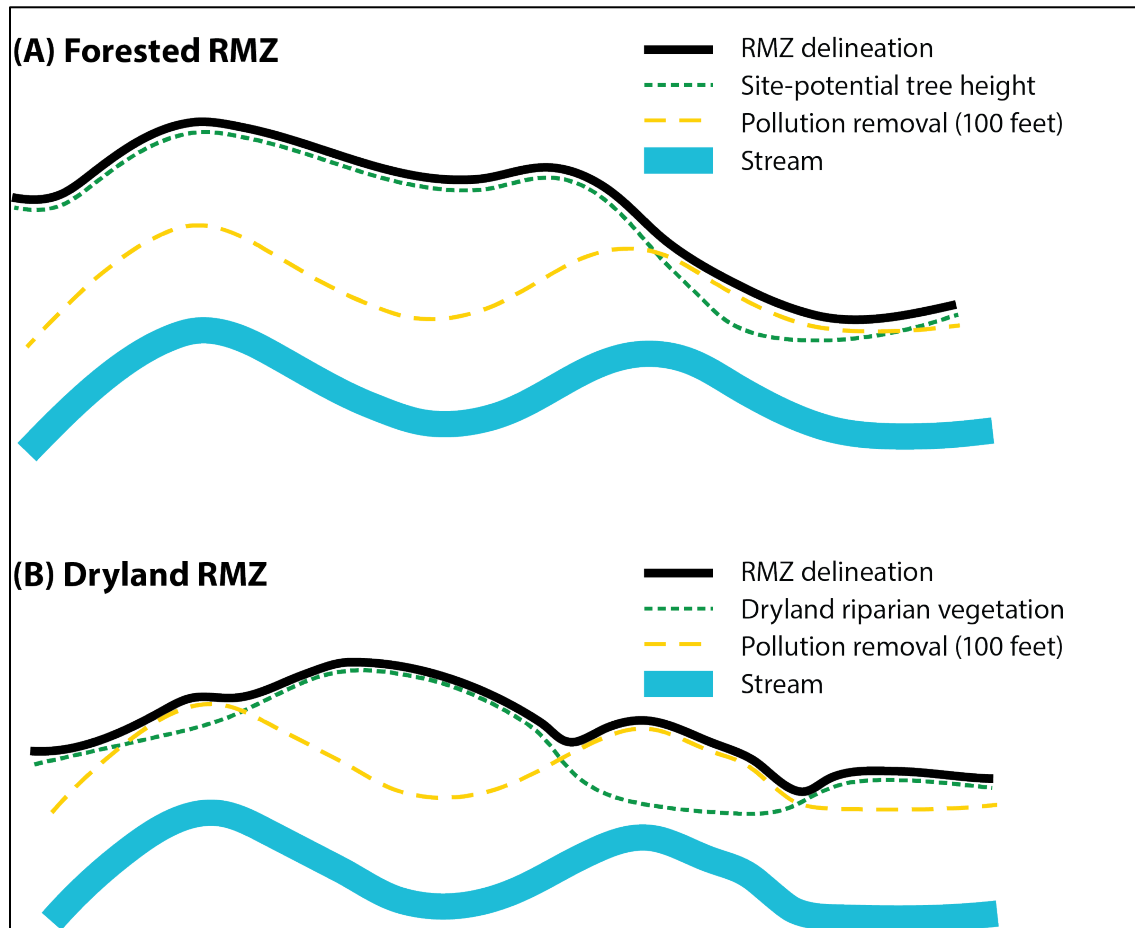


Figure 2.4. Aerial view of variable width RMZ delineation process for forested (A) and dryland (B) systems.

- Step 1: Identify the SPTH or full extent of the riparian vegetative community (green);
- Step 2: Overlay a 100-foot pollution removal distance (yellow);
- Step 3: Delineate the RMZ (black) as the greater of the two distances.

We tailor the following guidance based on two types of ecoregion: (1) Forested and (2) Dryland.

2.3.4 (A) Forested Ecoregions

Forested ecoregions are well-suited for using $SPTH_{200}$ consistently to establish RMZ widths, and so for these areas, landowners and land managers can rely on the $SPTH_{200}$ information provided in the SPTH mapping tool (see Appendix 1). The tool provides the derived average height attained by the dominant tree species at age 200 years ($SPTH_{200}$) using the U.S. Natural Resource Conservation

Service (NRCS) forest productivity site index values, which we recommend for delineation of RMZs (see Sec 9.3 in [Volume 1](#) for background on the origin and use of SPTH₂₀₀). In forested ecoregions, contributions of large wood as a riparian ecosystem function often define the farthest lateral extent of the RMZ.

Occasionally, the SPTH₂₀₀ may be less than 100 feet, in which case the pollution removal function (described in more detail in Section 2.3.5 below) defines the lateral extent of the RMZ.

In Washington, SPTH₂₀₀ can be as large as 260 feet: therefore, be sure to evaluate each soil polygon within 260 feet of the stream channel to ensure that RMZ delineation is in fact being driven by the largest dominant tree species.

2.3.4 (B) Dryland Ecoregion

Riparian ecosystems in arid and semi-arid regions of North America (also referred to as the dryland ecoregion) make up less than 1 to 3 percent of the landscape (Patten 1998). Dryland riparian ecosystems are hydrologically linked to and influenced by adjacent surface waters; as a result, surface waters sustain riparian vegetation that is clearly distinct from upland vegetation.

Riparian ecosystems in dryland environments are highly variable due to various site-level conditions. While these ecosystems may support large trees in low gradient floodplains, tree presence in riparian ecosystems throughout the dryland ecoregion is much more varied than in forested ecoregions, and so in many cases, the contribution of large wood no longer serves as the outermost ecological function for RMZ delineation. Further, riparian vegetation may be minimal or even non-existent, particularly along degraded, incised streams. In dryland ecoregions, the outermost of three factors drives delineation of the RMZ: (1) SPTH₂₀₀ (if trees are present); (2) riparian vegetative community; or (3) pollution removal function.

2.3.4 (C) Considerations in Highly Modified and Urban Systems

In some locations, riparian systems have been substantially modified, and current site-specific conditions may not provide adequate indication of where riparian vegetation would naturally occur. On the whole, this is particularly true of riparian systems in dryland ecoregions. In these instances, we recommend considering nearby sites with unaltered vegetation or selecting a representative site with similar bank height and gradient conditions to identify adequate riparian vegetation delineation for both protection and restoration.

Protecting Columbia Plateau's Priority Habitats Supports Riparian Health

Native shrub-steppe vegetation and other drought-tolerant plant communities dominate Washington's dryland environments. Approximately 450 plant community associations occur in this region, with over 20% of these associations considered vulnerable (WDFW 2005, p. 523). Among the most imperiled ecosystems in North America, historical shrub-steppe has been greatly reduced due to conversion to other land uses (Vander Haegen 2007).

Riparian areas are critical to most animal species using shrub-steppe. Biodiversity in these vegetative communities increases dramatically where surface water occurs, and riparian areas directly support numerous species found only in or near water (Rogers et al. 1988, Johnson and O'Neil 2001). Linking and protecting upland adjacent Priority Habitat(s) not only aims to support Washington's wildlife and their associated habitat conservation goals, but also works to protect and maintain riparian ecosystem integrity.

Similarly, four major urban areas (Seattle, Spokane, Tacoma, and Bellingham) in forested ecoregions lack NRCS soils data. For these areas, WDFW identified nearby NRCS soils polygons and calculated weighted averages as estimates reflective of the surrounding environment (“imputed SPTH₂₀₀”). Much like in forested areas where SPTH₂₀₀ data are available, we recommend using the imputed SPTH₂₀₀ values specified for each of these urban areas to delineate RMZs within them.

2.3.5 Width delineation steps

Step 1: Use SPTH₂₀₀ if it is at least 100 feet.

In **forested ecoregions**, WDFW recommends full protection within one SPTH₂₀₀, identified with the use of our SPTH mapping tool (<https://arccg.is/1ueq0a>). The mean SPTH₂₀₀ in western Washington ranges from 100 to 240 feet (Fox 2003). Some soil polygons have SPTH₂₀₀ information for multiple tree species; therefore, each soil polygon within one SPTH₂₀₀ should be evaluated to ensure RMZ delineation is driven by the largest dominant tree species. Occasionally the SPTH₂₀₀ in forested ecoregions is less than 100 feet; for example, red alder is a fairly common riparian tree species, yet the SPTH₂₀₀ for this species does not always exceed 100 feet. If red alder is the only species for which SPTH₂₀₀ information is available for a certain location, and it is less than 100 feet, then skip to Step 3.

In **dryland ecoregions**, it is less common, but still possible to find riparian vegetation which includes—and may even be dominated by—large trees. Examples of large tree species in these areas are black cottonwood (*Populus trichocarpa*) and ponderosa pine (*Pinus ponderosa*). If SPTH₂₀₀ in dryland ecoregions exceeds 100 feet, then it should be used for the RMZ width.

Step 2: In dryland ecoregions, if SPTH₂₀₀ is less than 100 feet or if no large trees are present, identify the extent of the riparian vegetative community.

In **dryland ecoregions**, the riparian vegetative community is often comprised of shrubs, sedges, grasses, and forbs that are distinct from upland communities. For example, in the Columbia Plateau, vegetation within riparian ecosystems often exhibits an abrupt demarcation between the riparian zone and zone of influence. Phreatophytic⁷ trees and shrubs and hydrophytic⁸ herbaceous plants are confined to moist streamside areas, but the upland zone of influence may consist of sagebrush or bunchgrass communities [for more information, see Volume 1, Chapter 7 (Section 7.1.1)]. Where trees are not present or consist only of small species (less than 100 feet tall), WDFW recommends full protection of the entire riparian vegetative community. In some places the community may only be a few feet wide but in others it may extend up to several hundred feet, particularly when associated with a wetland or floodplain (Bermingham et al. 2013). Where the riparian vegetative community is less than 100 feet wide, go to step 3.

⁷ A phreatophytic plant is a species that obtains water from the subsurface zone of saturation either directly or through the capillary fringe (Thomas 2014).

⁸ Hydrophytic plants are those that are adapted to growing conditions associated with periodically saturated soils. They include obligate wetland plants that almost always occur in wetlands under natural conditions, facultative wetland plants that usually occur in wetlands but are occasionally found in non-wetlands, and facultative plants that equally likely to occur in wetlands or non-wetlands (Lichvar et al. 2012).

Step 3: Overlay 100-foot pollution removal delineation

The following applies to both **forested and dryland ecoregions**.

Our recommendation to protect full riparian function recognizes the importance of the pollution removal function of riparian ecosystems. Because pollution removal depends on multiple factors, including slope, soils, plant community composition, and upland uses, establishing a standard RMZ width for 100% pollution removal even at the site scale was impractical.

Where neither SPTH₂₀₀ nor the extent of the riparian vegetative community is at least 100 feet, we recommend RMZ delineation of a *minimum* distance of 100 feet, because this distance will achieve 95% or more removal efficacy of phosphorous, sediment, and most pesticides. To be clear, we value a similar removal efficacy for nitrogen, and at a 100-foot width, an RMZ would achieve only 80% removal efficacy for surface runoff containing excess nitrogen. However, the literature reflects that both the actual risk posed by excess nitrogen, as well as the efficacy of its removal, are very site-specific. In recognition of this, we strongly recommend that, where upland uses contribute nitrogen, the 100-foot minimum pollution removal distance be extended accordingly when determining the appropriate RMZ width.

Further, if RMZ widths are being based on a minimum pollution removal function at locations with steep slopes or poorly drained soils, distances greater than 100 feet should also be considered: this applies for all pollutants. Additionally, WDFW recommends cities and counties identify high intensity land uses that may be located adjacent to riparian areas within their jurisdiction and establish wider RMZs to enhance the pollution removal function in these locations as well, following guidance from Ecology.

When dealing with variables such as those outlined above, it may be necessary to seek expert assistance in determining the appropriate adjustments to RMZ widths based on the pollution removal function.

CHAPTER 3. RIPARIAN REGULATORY PROTECTIONS

3.1 INTRODUCTION

This chapter gives guidance to help local governments review, develop, and implement regulatory tools to protect riparian ecosystems as critical areas, i.e., Fish and Wildlife Habitat Conservation Areas (FWHCAs). We describe key steps toward creating effective programs to protect riparian ecosystems consistent with the goals of the Growth Management Act (GMA), Shoreline Management Act (SMA), and Voluntary Stewardship Program (VSP). More specifically, this chapter describes recommendations for carrying out common land use activities and provides steps for developing Habitat Management Plans (HMPs). The riparian management zone (RMZ) should serve as the focal area to apply our recommendations.

Parcel-scale regulations are foundational to Washington's traditional land use regulatory approaches for protecting rivers and streams and their adjacent riparian ecosystem. However, sole reliance upon a regulatory approach at this site scale may result in loss of aquatic system function over the long term (see Volume 1). Thus, we believe that site-scale regulations must work in coordination with watershed-scale planning (Chapter 4) and that both should be monitored and adaptively managed (Chapter 5). In this chapter, we present considerations and recommendations for managing and protecting riparian ecosystems at both site- and watershed-scales.

3.2 RECOMMENDATIONS TO LOCAL JURISDICTIONS

Protection of watersheds commonly falls under the purview of agencies other than WDFW. Nonetheless, we encourage local jurisdictions (and their long-range planners in particular) to consider how land use patterns at all scales collectively affect fish and wildlife and other important ecosystem services.

The scientific literature review (see [Volume 1](#)) informs WDFW's position that protecting the area within one SPTH₂₀₀ from the edge of a stream channel maintains full riparian ecosystem functions for all aquatic species, including salmon, and promotes healthy, intact riparian ecosystems. This recommendation provides the greatest level of certainty that land use activities do not impair functions and values of riparian ecosystems. We recommend the use of monitoring and adaptive management (see Chapter 5) to inform regulations and evaluate the complement of both regulatory and voluntary conservation measures in achieving outcomes.

Land use decision makers should ensure all programs that can affect riparian habitat (e.g., CAOs; SMPs; and ordinances for clearing and grading, fire hazard reduction, and tree protection) are coordinated to optimize the ability of local policies, rules, and management activities to protect those habitats. Further, jurisdictions should look for gaps such as inconsistencies, exemptions and loopholes, or inefficient practices (e.g., inspection and monitoring protocols) that could impede protection of or cause harm to riparian ecosystems.

To that end, we provide important questions to consider when reviewing CAOs, Comprehensive Plans, or other plans that can affect riparian ecosystems:

1. Conservation Strategies:

- What external strategies exist (salmon recovery plans, reach-scale assessments, and incentive-based plans) to maintain, protect and restore riparian areas?
- Which of these strategies (if any) currently inform your regulatory, planning, and/or voluntary processes or programs?
- If these strategies are not in your current programs, could they be incorporated to provide additional benefits to riparian ecosystems? Are there other strategies that could also (or instead) benefit riparian ecosystems?
- Which of these strategies may help your jurisdiction satisfy mitigation obligations?
- How are riparian restoration and/or enhancement programs informed by these strategies?

2. Regulatory Buffers:

- Does your jurisdiction rely on $SPTH_{200}$ for delineating regulatory riparian buffers?
- If your jurisdiction does not rely on $SPTH_{200}$ for delineating those buffers, does your jurisdiction currently have regulatory buffers for riparian areas that are equal to or greater than the distance equal to $SPTH_{200}$?
- Are there buffer exemptions? If so, how do those affect riparian function across your jurisdiction?
- Do your buffers consider the CMZ?
- Do your buffers consider adjacent wetlands and appropriate wetland delineation methodology as prescribed by Ecology?
- If your jurisdiction's CAO or SMP buffers are less than $SPTH_{200}$, can you use the RMZ to identify areas to do mitigation or areas impacted that will require mitigation?

3. Restoration and Adaptive Management (see also Chapter 5):

- Can your jurisdiction use the RMZ to identify areas for incentive-based restoration?
- Do you have a monitoring and adaptive management program for improving permit implementation?
- Is your jurisdiction collecting information on effectiveness of protecting riparian areas?
- If you collect effectiveness information, what programs (e.g., incentives, regulations) could you improve to increase riparian conservation?

4. Other Programs and Regulations

- What other regulations separate from CAOs, may inadvertently affect riparian areas? (e.g., clearing and grading ordinance that lack safeguards for riparian protection.)
- Are there opportunities to connect riparian areas with other protected areas (e.g., frequently flooded areas, geologically hazardous areas, green belts, parks, wetlands, and aquifer recharge areas)?

3.2.1 Recommendations for Common Activities in the RMZ

Local governments should regulate all land use activities that are likely to impact functions of a riparian ecosystem found within the RMZ to ensure, at a minimum, that the existing functions and values are protected from development actions. For the purposes of meeting requirements under GMA, SMA, and VSP, we describe the RMZ as the area in which functions and values are contributed

to the riparian ecosystem: providing a delineated space not just for protection, but also for mitigation and management. We also recommend prioritizing the RMZ as the space for restoration⁹. We provide specific information and recommendations for the following ten common activities: (Note that neither the list of activities nor the recommendations themselves are exhaustive; for more information, contact your WDFW regional habitat biologist.)

1. On-site Sewage Systems (OSS)
 2. Bank hardening
 3. Clearing, grading, and placement of fill
 4. Removal of noxious weeds
 5. Forest practices and conversions
 6. Firewise and wildfire hazard reduction
 7. Removal of hazard trees
 8. Non-compensatory restoration and enhancement
 9. Emergency activities
 10. Educational or Recreational Areas
1. *On-site Sewage Systems (OSS)* – Historically, developers sited OSS at lower elevations bordering streams, lakes and wetlands in order to use passive gravity flow. The disadvantage of these systems is that when drain fields are located near water features, they can more easily contaminate water with high loads of nutrients and toxic pollutants, causing significant impacts to flora, fauna and water quality. The State Department of Health adopted rules establishing public health standards for location, design, installation, operation, maintenance, and monitoring of OSS, including requiring setbacks from waterbodies ([WAC 246-272A](#)) which modern OSS systems, using pump systems, can support. Some OSS may meet public health standards even if located within RMZs; nevertheless, jurisdictions should exercise authority to require HMPs to ensure project proponents protect habitat functions of riparian critical areas.
 2. *Bank Hardening* – We recommend jurisdictions avoid allowing new development that requires bank protection now or is likely to in the future (consider channel migration, wind and wave action, and climate change), unless it addresses an imminent threat as an emergency activity (see Emergency Activities in this section below). Always look to alternative places to site a project so that no bank protection measures are needed. If measures cannot be avoided, require that a project proponent evaluate the effectiveness of bioengineering alternatives (also known as soft armoring) prior to proposing hard armoring. Follow bank protection recommendations in the [Washington State Integrated Streambank Protection Guidelines](#) (Cramer et al. 2002) when bank protection is unavoidable.
 3. *Clearing, Grading, and Filling* – We recommend jurisdictions acknowledge impacts of clearing, grading, and filling on riparian areas in their CAOs by limiting these activities to areas outside the RMZ (unless directly related to restoration) as they can negatively affect riparian areas. If a clearing, grading, or filling project must encroach in an RMZ, limit disturbance and minimize

⁹ As explained previously, many riparian areas had already experienced a substantial degree of degradation before laws like GMA, SMA, and VSP were passed, so while protecting what level of riparian functions and values remain is essential, protection alone will not be sufficient for meeting the needs of the state's fish and wildlife species.

effects to the greatest extent possible. Require that a qualified professional prepare an HMP describing how the project proponent will follow the mitigation sequence.

Jurisdictions that exempt small areas from filling or grading ordinances in riparian ecosystems should calculate cumulative impacts from these exemptions. They should also mitigate impacts and subsequently establish monitoring to ensure that mitigation measures are effectively negating potential losses to habitat function.

4. *Invasive and/or Noxious Plant Removal* – Many CAOs do not require a permit for control and removal of invasive and/or noxious weeds within riparian ecosystem. We support this when weed control efforts (1) employ hand weeding with light equipment; (2) use only Ecology-approved aquatic herbicides and adjuvants (a substance added to herbicides to improve application); avoid use of hazardous substances; and (3) do not result in soil compaction. Local governments should retain some oversight authority for more extensive invasive and/or noxious plant control projects to ensure adequate protections of riparian functions, especially water quality. Most communities issue an exemption letter or permit, which should include conditions to ensure impacts to fish, wildlife, and habitat are minimal.

It is important to note that even plants native to the region can, in certain circumstances, be detrimental to riparian areas. An example is in Puget Sound Prairies, where in the absence of periodic fire events (typically prescribed fire), common western Washington conifer species like Douglas fir outcompete native deciduous species (primarily Oregon white oak). In these circumstances, conifer removal and re-establishment of historical riparian conditions (oak and prairie vegetation) should occur under an approved HMP. WDFW regional [habitat biologists](#) can assist in preparing, reviewing, and implementing such a plan.

5. *Forest Practices and Conversions* – The state’s Forest Practices Act ([RCW 76.09](#) and [WAC 222](#)) regulates forest practice activities on forestland: We recommend that the proponent always contact DNR prior to conducting forest practice activities and seek technical assistance from a WDFW regional habitat biologist to ensure protections for Priority Habitats and Species. When conducting commercial forest practice activities, the forest practice rules—not the CAO—apply for protection of resources on site. Lands converted from forestry to another use require a special forest practice permit, and when converting land, local CAOs are applied. If conversion occurs, WDFW recommends timber harvests not be allowed within SPTH₂₀₀.
6. *Wildfire Hazard Reduction* – Wildfire is a concern in Washington, though the threat varies across the state. Local regulations to reduce wildfire hazards should be coordinated with a Firewise program in order to require landowners to consult with a Firewise professional (<http://www.dnr.wa.gov/firewise>) before removing trees or manipulating vegetation in an RMZ. Understanding the composition of historical forest stands and shrub-steppe can help ensure retention of riparian functions when carrying out wildfire hazard reduction activities. When fuel (vegetation) reduction efforts involve the removal of merchantable trees, the proponent should check with the local jurisdiction and DNR, which may require a permit for tree removal.
7. *Removing Hazard Trees* – Tree trimming or removal in RMZs is sometimes necessary to address public safety concerns but should be balanced with the potential impacts to riparian ecosystem function. Jurisdictions should define a “hazard tree” (sometimes referred to as a “danger tree”) as a threat to life, property or public safety, and require that the method of tree removal not

adversely affect riparian ecosystem functions if possible. Specifically, we recommend that any removal of hazard trees involve an avoidance and minimization of damage to remaining trees and vegetation within the RMZ. We further recommend that local governments require a qualified arborist to evaluate requests for hazard tree removal. The qualified arborist should be able to establish when a tree presents an imminent threat to life, property or public safety.

It is important to note that snags (dead trees) are a Priority Habitat feature for wildlife, and so should be preserved if not hazardous.

Some local governments use Forest Practice Rules ([WAC 222-21-010\[4\]](#)), which define a hazard tree as “any qualifying timber reasonably perceived to pose an imminent danger to life or improved property.” This applies to any tree within 1.5 tree-lengths of the structure. A DNR forester can verify during a site visit that a tree is a hazard based on this definition, and thus removing the hazard would not be subject to the Forest Practice jurisdiction or require a Forest Practice Application.

8. *Restoration and Enhancement* – We encourage local governments to include in their CAOs allowances for restoration and/or enhancement of the riparian ecosystem, including in-channel or streamside work, especially on lands set aside for conservation. To the extent possible, jurisdictions should promote incentives and set up a streamlined review process for restoration or enhancement projects to help facilitate project proponents not just meeting the minimum requirements of the local CAO, but instead going “above and beyond”. Significant resources are available to jurisdictions that address limiting factors in riparian areas or undertake high priority restoration activities that benefit salmon or other listed species (*see Chapter 4 for information on restoration*).
9. *Emergency Activities* – Local codes typically have provisions for emergency activities (e.g., bank stabilization to address imminent threats to homes) that provide relief from time delays related to procedural code requirements. Local regulations should distinguish the immediate need to permit an emergency activity from the need to compensate for its impacts after-the-fact.
10. *Educational or Recreational Areas* – Public access to shorelines is a priority use under the SMA and providing educational and/or recreational developments such as trails, viewing platforms, or similar facilities may also enhance the public’s understanding and appreciation of riparian areas, streams, and habitats. Thus, some focused use of the RMZ for educational and recreational activities may be desirable, if it does not create significant disturbances. Most CAOs include allowances for unpaved access to a stream for aesthetic or recreational enjoyment with defined limits on clearing to avoid impacts and minimizing soil, vegetation, and habitat disturbances: this is an allowance we support. That said, construction of trails could allow greater access for pets and other high intensity recreation, which may increase predation on, and/or disturbance of fish and wildlife species. Regulations should minimize impacts from recreational trails and interpretive facilities to the extent practicable, informed by PHS data and associated management recommendations.

3.2.2 *Project-specific Riparian Habitat Management Plans*

When reviewing proposed projects near streams, local governments typically require applicants to provide detailed site-specific HMPs (often called a Critical Area Report). Here we describe six aspects of Riparian HMPs that we recommend be addressed in CAOs:

1. When HMPs are required;
 2. Which additional critical areas must be delineated, and how;
 3. Which specific land use actions must be identified, and how;
 4. Mitigation requirements;
 5. Monitoring and Adaptive Management requirements; and
 6. Articulate who must prepare and review the HMP.
1. *When required* – We recommend jurisdictions require an HMP whenever someone proposes a land use activity in an RMZ (regardless of the jurisdiction’s regulatory RMZ delineation) or when a proposal likely could affect riparian or aquatic functions. In cases where there is less confidence in the spatial accuracy of the RMZ, consider requiring a Riparian HMP when impacts occur adjacent to the RMZ’s zone of influence.

Maps, [DNR’s stream layers](#), the [National Hydrography Dataset](#) (NHD), and other (e.g., local) stream layers are important for triggering HMPs. An HMP should be required whenever a stream is present near proposed development activities, including but not limited to subdivisions (plats, short plats, and large lot subdivisions), land/vegetation disturbing activities (e.g., clearing and grading, septic drain field siting), and stormwater routing.
 2. *Critical Area Delineation* – HMPs should have the extent of critical areas within and adjacent to a proposed project site identified, along with ecosystem functions that need protection. Follow the RMZ delineation procedure outlined in Chapter 2, along with locations of other critical areas on or near the site (e.g., wetlands, geologic hazards, frequently flooded, critical aquifer recharge areas; informed by Ecology). Also, identify salmon and other priority aquatic species that use the stream network in the immediate vicinity as well as up- and downstream. Likewise, HMPs should identify Priority Species that may use the riparian corridor and any other Priority Habitats to which the corridor is connected. Attach the delineation map (1) to the property’s title to inform future property owners of the site’s critical areas, and (2) use it to update the jurisdiction’s critical areas maps.
 3. *Land Use Action Identification* – A complete HMP should describe relevant management recommendations for Priority Habitats and Species found on or near the site. Include a map in the HMP showing the location of proposed land use actions. It should identify and quantify current and proposed disturbances to the RMZ and other FWHCAs.
 4. *Mitigation* – The HMP should have a description of the project proponent’s mitigation sequencing. It should describe in detail measures to avoid impacts and minimize unavoidable impacts (e.g., clustering, conservation easements, and seasonal construction restrictions). If mitigation or compensation is necessary, the HMP should identify ways to improve riparian ecosystem function by enhancing riparian corridor connectivity (e.g., removal of stream barriers) or by improving the quality of the riparian area (e.g., replacing invasive vegetation with appropriate native vegetation).
 5. *Monitoring and Adaptive Management* – The HMP should describe requirements for monitoring and adaptive management. In addition, it should identify measurable standards and expectations to monitor compliance (e.g., areal extent of vegetative cover, composition of riparian tree species, maximum invasive plant cover). The HMP should identify frequency of visits to monitor the site (e.g., at year 1, 2, 3, 5, 8, and 10) as well as measurable triggers for requiring more actions (e.g., maximum percent area coverage of invasive plants). The HMP

should specify who is responsible for preparing, reviewing, and submitting reports. Finally, if deemed necessary by the jurisdiction, the report should include a cost estimate for monitoring, and the project proponent should post a bond for this amount or more to allow for overages.

6. *Preparer and Reviewer* – A qualified professional biologist, botanist, or ecologist should prepare the HMP; additional expertise related to CMZs, unstable slopes, and wetlands may also be necessary. Additionally, an independent professional with similar qualifications should review the HMP. WDFW's regional habitat biologists can often serve in this role, especially for larger projects. USFWS or NOAA Fisheries should also review the HMP if the project might affect a federally listed fish or wildlife species.

3.3 RIPARIAN MANAGEMENT IN URBAN AREAS

Some people have raised questions about the applicability of RMZs to urban and urbanizing areas. These concerns generally fall into two categories: (1) the science on RMZs comes largely from agricultural and forestry settings, and so is perceived to be irrelevant to urban areas; and (2) there is a belief that the need to maximize density of development in urban areas is in direct conflict with the protection of riparian areas.

Concerns over the relevancy of literature on riparian functions to urban areas is largely unfounded. While most riparian ecosystem studies are from non-urban settings, the principles are the same. Functions of shade, bank stability, large wood recruitment, nutrient inputs, and pollutant removal operate similarly in urban areas as they do in other settings. However, within urban areas, these riparian ecosystem functions are often greatly diminished or even absent altogether.

The role that urban RMZs play in delivering habitat functions for aquatic and many terrestrial species is also like that in non-urban areas. Factors that may be different in urban areas are that urban riparian ecosystems may perform some functions at reduced levels due to their position in developed watersheds, which are often heavily degraded. However, intact RMZs in urban areas function as wildlife corridors that link habitat patches, which is critical for many species. In fact, sometimes RMZs in urban areas may be more important from a habitat standpoint, because within urban areas, adjacent uplands are often even more degraded than the RMZs, which then are often the only remaining areas where habitat functions are provided. Thus, a key element to maintain in urban RMZs is connectivity, both in and along streams.

Many Puget Sound salmon move through channelized streams, traversing heavily urbanized areas prior to reaching spawning grounds and as juveniles on a reciprocal journey to marine waters. Salmon must pass through a wide spectrum of development. For example, adults returning to spawn often start in urban cores (e.g., downtown Seattle), where streams are often channelized; then pass through areas with small lots and high urban density and into suburban creeks where larger lots allow for more riparian protection; and finally, to rural lots with less development and better ecosystem health. When juveniles make their journeys in reverse, they generally spending more time in each of these areas than their parents did, and yet because of their small size, they are also at much greater risk of not surviving any of them. While the decades-long decline of many of our native salmon stocks illustrate just how challenging this is, their persistence—especially the subspecies which are showing signs of improvement—shows us what is possible. Therefore, it is critical that the urban environment maintain and enhance the ability of different species and ages of salmon to not just survive, but thrive, while in these disturbed areas.

Many of the actions we recommend urban communities focus on are the same or similar to those appropriate in less densely developed areas. For example, it is critical to maintain connectivity through properly sized culverts such that all fish can pass through at all relevant life stages. Additional riparian function can be achieved through revegetation efforts using native plants and by improving connectivity between habitat patches. A landscape analysis can help identify existing connections to protect, as well as areas where restoring connectivity is a priority. On the other hand, some actions are particularly well-suited to urban jurisdictions, like standards for Low Impact Development (LID) and state-of-the-art stormwater management. Further, when changes are made to urban infrastructure, this may create opportunities to improve riparian functions while contributing to new or improved public open spaces.

Recommendations for urban riparian ecosystems:

1. Delineate urban RMZs to protect what areas remain and to highlight lost or degraded areas to target for restoration.
2. Quantify current conditions, with a goal of maintaining and improving functions through regulatory and voluntary means.
3. Identify and prioritize restoration opportunities and projects within the RMZ:
 - a. Protect riparian functions that remain, especially in places that are relatively high functioning; implement actions that enhance degraded functions (*see* Chapter 4).
 - b. Prioritize opportunities to maintain and restore in-stream and riparian connectivity.
 - c. Adopt a stormwater design manual equivalent to Ecology's most current manual for western and eastern Washington.
 - d. Manage stormwater by adopting Ecology's latest manual regarding LID for new development, redevelopment and retrofit projects.
4. When replacing or removing existing infrastructure within an RMZ:
 - a. Map RMZ to pinpoint the best sites to restore – consider connectivity and adjacency to other Priority Habitats;
 - b. Improve aquatic connectivity by replacing culverts and removing barriers to movement;
 - c. Revegetate with native plants and consider improvements for wildlife by integrating structures necessary for nesting, breeding, and foraging;
 - d. As infrastructure is remodeled or replaced, incorporate additional setbacks from streams;
 - e. Control access to RMZ to limit soil compaction;
 - f. Avoid operating equipment near the stream to reduce sedimentation and soil compaction; and
 - g. Avoid using chemicals in the RMZ which are not approved for use there by Ecology.

3.4 MANAGING WATERSHEDS

As described in Chapter 8 of Volume 1, land use activities in a watershed can affect the stream network, even when the riparian ecosystem itself is relatively undisturbed. "Watershed management" is a land management approach that seeks to minimize negative effects of upland land uses on aquatic systems, which include riparian areas. The remainder of this chapter focuses on key watershed elements important to managing and protecting functional aquatic systems. Many of the approaches we outline here are non-regulatory and can complement regulatory efforts;

as previously stated, we recommend cities and counties inventory current conditions of critical areas and, based on that inventory, develop watershed scale management plans accordingly.

Fully functional riparian ecosystems, in combination with targeted watershed protections, provide significant benefits to humans. These benefits, often described as ecosystem goods and services, include clean water; decreased flooding; increased nutrient cycling, sediment and pollutant filtering; reduced erosion; carbon sequestration; and cultural services such as recreational, spiritual, and other nonmaterial benefits. These services provide real but often unquantified economic benefits to individuals and society that largely go unnoticed until they are lacking.

3.4.1 *Watershed-Scale Recommendations to Protect Aquatic Systems*

To achieve desired ecosystem goods and services watershed managers should focus on influencing watershed processes that act upon water, wood, sediment, nutrients, vegetation, and pollutants at both the site- and watershed-scale. This section focuses on watershed-scale management.

Restore and Protect Watershed Processes – Efforts to improve watershed conditions should first focus on protecting and restoring watershed *processes* (e.g., natural disturbances) that create and retain habitat for fish and wildlife. Maintain the frequencies, magnitudes, and durations of natural disturbances (flood and fire being the most common) to the greatest extent that surrounding land uses can tolerate.

Manage Land for Stormwater – Stormwater runoff can change the timing, quality, and quantity of water provided to streams. Land uses should avoid/minimize changes to surface water flows. Protection and restoration efforts should focus on attenuating peak flows and reducing pollutants. Primary tools available to local governments include land use designations/zoning code, and stormwater regulations. See [City of Redmond Watershed Management Plan](#) (City of Redmond 2013).

Manage Land for Stream Temperatures – Reduced riparian vegetation cover, decreased streamflow, and simplified stream channels (e.g., increased width-to-depth ratio and reduced groundwater exchange) can lead to increased water temperature (Volume 1, Chapter 4). Modifications like these are often the result of land use activities such as riparian vegetation removal; water diversions; unmanaged livestock grazing; and stream channelization associated with roads, levees, and other forms of development. Identify and restore thermally sensitive stream reaches at the watershed scale to maintain optimal stream temperatures for sensitive aquatic species such as salmonids.

Restore and Protect Connectivity – Manage watersheds to avoid creating longitudinal (e.g., dams, road crossings), lateral (e.g., levees and roads/buildings that cutoff riparian areas and floodplains from their stream), and vertical (water withdrawals, reductions of floodplains) barriers to fish and wildlife movement and fragmentation of their habitat. This is especially important for highly mobile species that require a variety of habitat components across large areas. For example, where CMZs interact with floodplains, dikes and levees restrict the movement of the river or stream and also serve as a barrier for fish and many forms of wildlife.

Restoration to correct existing barriers to movement of water, wood, sediment, and species (e.g., removing blocking culverts) is a high priority with proven benefits for salmon. Connectivity to achieve nearly or completely contiguous RMZs is important to water quality and to achieve

connectivity among patches. Ensuring connectivity both for terrestrial and aquatic wildlife works towards a more interconnected and healthy riparian system.

Plan for Climate Change – Impending changes to aquatic systems caused by climate change increases risk to species already threatened, and riparian ecosystem protection is one of the most useful responses to ameliorate those risks. For example, because more intense rainfall events will lead to wider streams, larger culverts will be necessary to support fish passage. WDFW, in collaboration with the University of Washington’s Climate Impacts Group, created an [online tool](#) (UWCIG 2017) that estimates how much a stream’s channel width will increase with climate change in the years 2040 and 2080. Connectivity within the RMZ allows voluntary migration for species and helps minimize temperature change and increase off-channel storage of water to reduce low flows.

Conduct Monitoring and Adaptive Management – Monitoring and adaptive management are important elements to both site-scale and watershed-scale; this is addressed further in Chapter 5.

3.4.2 *Tools and Key References for Assessing Current Watershed Conditions*

Washington’s State agencies, including WDFW, have developed multiple tools to assist local government in assessing watershed conditions. Jurisdictions can utilize these resources—many available at no cost—to quantify changes in land cover, tailor planning for specific species, coordinate monitoring activities, inform restoration, and assess watershed health.

WDFW’s High Resolution Change Detection (HRCd) is a spatial dataset that characterizes changes in land cover. This tool allows jurisdictions to evaluate in specific ways how watersheds are changing at a sub-parcel scale over 2- to 3-year intervals. This dataset is currently available throughout the entire Puget Sound basin and in some Eastern Washington watersheds. HRCd data is available at www.pshrcd.com.

WDFW’s [Priority Habitats and Species](#) program has several resources of interest to watershed planners. In addition to this two-volume document on riparian ecosystems, readers will find useful ideas in [Land Use Planning for Salmon, Steelhead and Trout: A land use planner’s guide to salmonid habitat protection and recovery](#) (Knight 2009) and [Landscape Planning for Washington’s Wildlife: Managing for Biodiversity in Developing Areas](#) (Azerrad et al. 2009).

Since 2004, the [Pacific Northwest Aquatic Monitoring Partnership](#) has collaborated with West Coast federal, state, and tribal agencies to coordinate monitoring activities and develop common approaches. This partnership provides best practices, mapping tools, and protocols, and serves as a voluntary clearinghouse for a wide variety of monitoring projects.

Since 2009, Ecology’s [Watershed Health Monitoring Project](#) has been monitoring sites throughout the state to assess watershed health. This project’s protocols can be adapted by jurisdictions and scaled to watersheds of various sizes. Data is stored in the [Environmental Information Management database](#). This sophisticated database allows users to input and retrieve data via the web, reliably store it, and make it available for analysis. Quality assurance/quality control measures ensure data put into the database are of high quality.

Ecology’s [Puget Sound Watershed Characterization](#) is a Puget Sound-wide tool that compares areas based on their suitability and value for restoration and protection. This tool informs two fundamental questions: (1) where to focus protection and restoration on the landscape first, and

(2) what types of activities and actions (i.e., restoration, protection, conservation, or development) are most appropriate to that place. With insights gained by this tool, decision-makers can incorporate information regarding watershed processes to improve plans (e.g., comprehensive plans, subarea plans, CAOs, stormwater plans) and conservation efforts (e.g., in-lieu fee programs, open space tax credits, open space land acquisitions).

In 2016, the Washington Department of Commerce (Commerce) published [Building Cities in the Rain](#) (Ballash 2016) to help communities improve watersheds while redeveloping and revitalizing urban areas. The guidance describes an optional three-step process for prioritizing watersheds for stormwater retrofits in urban areas. Commerce's [Puget Sound Mapping Project](#) uses an interactive map to help users develop insights about how current and expected development patterns might affect the region's environmental health. The tool is designed to help decision makers consider information from the Puget Sound Watershed Characterization (described above) when making decisions regarding development projects, urban growth boundaries, and compensatory mitigation.

Finally, the University of Washington's [Climate Impacts Group](#) has developed a suite of tools, many in concert with WDFW, which may be useful for landowners and land use decision makers including climate trends, culvert design projections, and habitat connectivity.

CHAPTER 4. RESTORING RIPARIAN ECOSYSTEMS

4.1 INTRODUCTION

This chapter provides high-level guidance to landowners, land use decision makers, and conservation partners to promote restoration of riparian areas. Despite recent efforts to protect existing riparian systems, imperiled salmon stocks and other riparian dependent endangered species are not recovering as hoped (Table 4.1). Since non-indigenous settlement of Washington began in the 1800s, between 50 percent and 90 percent of riparian ecosystems have been lost or extensively modified (RCO 2019). While two subspecies (Hood Canal summer chum and Snake River fall Chinook) are moving towards recovery, most listed salmon in Washington are below recovery goals (Table 4.1).

The lack of recovery is also evidenced in the ongoing decline of salmon fishing, which affects the long-term health of Washington's tribes, Washington's economy, and our shared cultural heritage. The lack of salmon is one of the primary reasons Southern Resident Killer Whales are at risk of extinction, in addition to other impacts such as vessel disturbance and pollutants. (Lacy et al. 2017, Murray et al. 2019)

Given the extent of historical loss, WDFW recognizes that protection alone of remaining riparian ecosystems, will not recover salmon or the Southern Resident Killer Whale population. Therefore, WDFW recommends restoring and enhancing riparian ecosystems to achieve healthy, intact, and fully functioning riparian systems statewide. Continued investments in restoration will be required at all levels of government and in concert with Washington tribes.

Table 4.1. Non-statistical evaluation of natural origin (wild) fish that returned to spawn with consideration for threats and factors affecting health including habitat, harvest, and hydropower. (Adapted from RCO 2019; Data sources: WDFW, Indian tribes, NOAA).

Below Goal (Endangered Species Act-Listed Salmon in Washington)			Near Goal
Getting Worse	Not Making Progress	Showing Signs of Progress	Approaching Goal
Upper Columbia River Spring Chinook	Upper Columbia River Steelhead	Mid-Columbia River Steelhead	Hood Canal Summer Chum
Puget Sound Chinook	Lower Columbia River Chum	Lake Ozette Sockeye	Snake River Fall Chinook
	Lower Columbia River Coho	Lower Columbia River Steelhead	
	Lower Columbia River Fall Chinook	Snake River Steelhead	
	Lower Columbia River Spring Chinook	Puget Sound Steelhead	
	Snake River Spring Chinook		
	Snake River Summer Chinook		

4.2 RESTORATION ACTIONS

Although this section focuses on restoring riparian areas for the benefit of salmon, emulating historical conditions benefits many other aquatic and terrestrial species as well. WDFW is available to provide technical assistance and species-specific guidance for terrestrial species-focused restoration and recovery efforts. To recover salmon, we must protect all remaining existing riparian and watershed functions, while seeking opportunities to restore functions that have been lost over time. We provide the following information to assist the restoration community¹⁰ in understanding what is important to restore.

4.2.1 *Developing a Restoration Strategy*

Aquatic restoration strategies typically start with a clear set of goals and objectives. The selection of appropriate restoration strategies is informed by the political, social, and ecological context of the watershed, and bounded by the extent of opportunities and constraints. It is important in ecosystem restoration to consider the habitat attributes and scale necessary for a desired suite of species, be they aquatic or terrestrial. At a watershed scale, restoration efforts should focus first on projects that offer the greatest potential for success. The [Stream Habitat Restoration Guidelines](#) (Cramer 2012) suggest the following prioritization of stream habitat restoration strategies that are specific to instream related activities most often geared at anadromous fish:

1. *Protect existing habitat.* Protect areas that provide healthy, high-quality habitat functions (strongholds, refugia, and key sub-watersheds) to prevent further degradation. Secure, expand, and link protected areas.
2. *Connect habitat.* Connect and provide access to isolated habitat, including instream, off-channel, and estuarine habitat made inaccessible by culverts, levees, fragmentation, or other man-made obstructions.
3. *Restore habitat-forming processes.* Employ land use recovery and watershed restoration techniques to restore processes that create, maintain, and connect habitats (including restoring sediment dynamics, large wood dynamics, and flow regimes; avoiding/removing manmade disturbances within the riparian ecosystem; and maintaining water quality, floodplain connectivity, and channel evolutionary processes). Employ a combination of active or passive restoration techniques, as necessary. Active restoration involves accelerating processes or attempting to change the trajectory of succession; passive restoration simply involves ceasing environmental stressors such as agriculture, grazing, or timber harvest, and then allowing nature to take its course.
4. *Create new or enhance existing habitat.* Improve existing or create new habitat for specific species by installing instream structures such as large woody debris; reconfiguring channel shape, cross-section, or profile to reduce incision or restore flow; or constructing one or more new side channels.

In conjunction with other state agencies and partners, WDFW provides multiple technical guidance documents to help design and implement riparian restoration projects that have proven successful

¹⁰ Many watersheds in Washington have salmon recovery restoration goals that can be obtained from regional Salmon Recovery Boards or Lead Entities for Salmon Recovery. Lead Entities and Salmon Recovery Boards are in every region of the state, including those areas without salmon or other anadromous fish (https://www.rco.wa.gov/salmon_recovery/regions/regional_orgs.shtml).

in different types of landscapes, including on marine shorelines, and on river- and streambanks. These are part of a suite of Aquatic Habitat Guidelines found at <https://wdfw.wa.gov/licenses/environmental/hpa/application/assistance>. They include:

- [Water Crossing Design Guidelines](#) (Barnard et al. 2013)
- [Stream Habitat Restoration Guidelines](#) (Cramer 2012)
- [Integrated Streambank Protection Guidelines](#) (Cramer et al. 2012)
- [Land Use Planning for Salmon, Steelhead and Trout: A land use planner's guide to salmonid habitat protection and recovery](#) (Knight 2009)
- [Draft Fishway Guidelines for Washington State](#) (Bates 2000)
- [Draft Fish Protection Screen Guidelines for Washington State](#) (Nordlund and Bates 2000)
- [Marine Shoreline Design Guidelines](#) (Johannessen et al. 2014)
- [Your Marine Waterfront](#) (WDFW 2016)
- [Protecting Nearshore Habitat and Functions in Puget Sound](#) (AHGP 2010)

4.3 IMPLEMENTING RIPARIAN STRATEGIES THROUGH INCENTIVES

There are several types of conservation incentives available to individuals and local governments:

- *Financial assistance*: grant programs that provide funding for conservation activities
- *Tax adjustment*: tax reductions for landowners undertaking conservation activities
- *Technical assistance*: advice and/or hands-on help for landowners on tools or techniques
- *Recognition*: promotion of landowners who undertake conservation actions

Each of these will be described (and examples provided) in more detail, below.

4.3.1 *Financial Assistance*

State and federal grant funds are available for riparian ecosystem conservation and restoration projects on public and private lands through the Recreation and Conservation Office (RCO) and Salmon Recovery Funding Board. To access these funds and to learn more, go to <https://www.rco.wa.gov/grants/index.shtml>. Grant programs include:

- [Aquatic Lands Enhancement Account](#)
- [Washington Wildlife and Recreation Program](#) (WWRP; Riparian Protection, Critical Habitat, Natural Areas, and Urban Wildlife Habitat Categories)
- [Salmon Recovery Funding Board](#)
- [Estuary and Salmon Restoration Program](#)—a program of WDFW
- [Land and Water Conservation Fund](#)
- [Puget Sound Acquisition and Restoration](#)

Land trusts also help land owners conserve habitat for key aquatic and terrestrial species, often leveraging funds from foundations and other non-governmental sources; see www.walandtrusts.org for a county-specific list of land trusts.

For agricultural property owners, local conservation districts and the Washington State Conservation Commission (WSCC) can provide technical assistance to find an approach that works for the farmer and improves riparian ecosystem function. Technical assistance is also available

from the federal Natural Resources Conservation Service (NRCS), Washington State University Extension, and WDFW. Additionally, a host of state and federal financial incentives to expand and maintain riparian functions within the riparian management zone (RMZ) are available, some of which are listed below. For example, the Conservation Reserve Enhancement Program (CREP) provides funding to landowners for riparian preservation and is the most successful riparian buffer program in Washington. Since CREP's 1999 inception in our state, more than 900 miles of stream buffers have been planted, and as of October 2020, producers had over 13,500 acres actively enrolled in CREP. Contact your local conservation district or the RCO to learn more.

- [Conservation Reserve Enhancement Program](#) (NRCS)
- [Environmental Quality Incentives Program](#) (NRCS)
- [Conservation Stewardship Program](#) (NRCS)
- [Conservation Reserve Program](#) (NRCS)
- [Regional Conservation Partnership Program](#) (NRCS)
- [Agricultural Conservation Easement Program](#) (NRCS)
- [Agricultural Land Easements](#) (NRCS)
- WWRP [Farmland Preservation Grants](#) (RCO)

Timber landowners have access to a variety of forestry-oriented conservation incentive programs (see list, below) and can also receive technical assistance from DNR's Forest Stewardship Program (foreststewardship@dnr.wa.gov / 360-902-1428):

- [Forestry Riparian Easement](#) (DNR)
- [Rivers and Habitat Open Space Program](#) (DNR)
- [Healthy Forests Reserve Program](#) (NRCS)
- [Family Forest Fish Passage Program](#) (DNR)
- [Forest Legacy](#) (USFS)
- WWRP [Forestland Preservation Grant Program](#) (RCO)

4.3.2 *Tax Reduction Incentives*

Landowners can receive a substantial tax reduction by converting land into "open space" status because of the Open Space Taxation Act ([WAC 458-30](#)), enacted in 1970. Lands with riparian areas often qualify for this incentive; see your county assessor and local planning department for details.

4.3.3 *Technical Assistance*

Local governments and individual landowners who want to improve riparian habitat for a suite of species can request land use advice from a variety of sources, including:

- WDFW regional habitat and district wildlife biologists. Go to <http://arcg.is/1SgsHqk> to find the names and direct contact information for your local biologists, or call the regional office in your area:
 - Region 1 – Eastern: 509-892-1001
 - Region 2 – North Central: 509-754-4624
 - Region 3 – South Central: 509-575-2740
 - Region 4 – North Puget Sound: 425-775-1311
 - Region 5 – Southwest: 360-696-6211

- Region 6 – Coastal: 360-249-4628
- Salmon Recovery Lead Entities or Regional Fisheries Enhancement Groups
- Tribal natural resource departments
- Local [Conservation Districts](#)

4.4 SUGGESTED RESTORATION PRACTICES

The following section provides a series of suggested restoration practices promoted by WDFW, other state and federal agencies, and conservation partners. We encourage consideration of these activities and others within and adjacent to the RMZ, as delineated in accordance with our recommendations in Chapter 2. Further, it is not unusual to find other types of Priority Habitats (e.g., wetlands, shrub-steppe) adjacent to riparian areas. In such cases, restoration practices should not degrade or disturb the adjacent habitat, but rather—if feasible—improve it in addition to improving the riparian habitat. The same approach should be used where riparian-adjacent Priority Species areas are present.

Like most restoration practices, the ones recommended below can range in complexity, both biologically and technically, so landowners are strongly encouraged to seek technical assistance from WDFW and other experts before taking any action: This will help save money, time, and greatly increase the likelihood of success for any restoration activity. Landowners should also be aware that many of these activities may require permits^{11, 12} issued by one or more agencies such as WDFW for the [Hydraulic Code rules](#), and DNR for the [Forest Practices rules](#); as well as permits from the local jurisdiction.

1. Improve quality of vegetation for both aquatic and terrestrial wildlife by removing invasive species wherever present. Further, to avoid the likely return of invasive species, cleared areas should be replaced with native riparian vegetation: specifically, native vegetation that provides needed ecosystem functions as described in Volume 1 and throughout this document (e.g., shade, large wood, pollution removal).
2. Where riparian areas already possess some native vegetation, enhance them with a greater mixture of native plants that provide necessary habitat components (forage, cover, breeding, roosting, etc.) for a diversity of species and multiple riparian functions (e.g., streambank stability, wood recruitment, organic litter input, and pollutant removal). The specific mix of vegetation will vary by ecoregion and local needs, but likely includes conifers, grasses, and herbaceous plants.
3. Increase off-channel habitat and improve natural flow regimes by removing dikes or levees and restoring access to and within the floodplain.

¹¹ The Governor's ORIA Office provides additional assistance for general permitting questions (https://www.oria.wa.gov/site/alias_oria/347/Permitting.aspx)

¹² Larger projects may also trigger permit requirements with federal agencies, such as the U.S. Army Corps of Engineers (USACE).

4. In areas of incised channels, reintroduce beaver or construct beaver dam surrogates to store sediments, raise streambed elevation, raise water table elevation, and restore riparian vegetation.
5. Remove reed canary grass, which can greatly inhibit channel morphology and aquatic species movement. (Management techniques for reed canary grass vary and are often site-specific: contact your local WDFW regional habitat biologist for technical assistance.)
6. Through proper consultation with WDFW and tribal biologists, increase the presence of large wood in streams and rivers to improve habitat for salmon, resident fish species, and aquatic amphibians.
7. Increase connectivity through removal of non-fish passing culverts. If replacement culverts are needed, ensure they are adequately sized and climate-change-resilient; see WDFW's online resource on [Incorporating Climate Change into the Design of Water Crossing Structures](#) (Wilhere et al. 2016).
8. Reduce soil erosion by increasing vegetation complexity and density, excluding (or substantially minimizing) soil compacting activities, and implementing upland soil management techniques where applicable.
9. For agricultural operators: add and/or improve fencing structures to increase the amount of riparian area acreage from which livestock are excluded to reduce compaction, erosion, and overgrazing.

CHAPTER 5. IMPROVING PROTECTION THROUGH ADAPTIVE MANAGEMENT

5.1 INTRODUCTION

Adaptive management is widely recognized as an essential component of effective natural resource management because it provides a systematic process for continually improving policies and management through outcome-based learning. The adaptive management process is a continual cycle of planning, acting, monitoring, evaluating, and adjusting (Figure 5.1). This feedback loop provides information for making adjustments that focus on improving decisions in all phases of resource management. The utility of adaptive management programs should be considered by conservation practitioners, landowners, and land use planners to ensure that conservation actions achieve desired outcomes: in the case of this document, that means preserving, protecting, and restoring healthy, intact, and fully functioning riparian areas. In addition to improving ecosystem outcomes, adaptive management should improve clarity of regulations—resulting in increased transparency to all stakeholders.

All cities and counties are currently protecting critical areas, including riparian ecosystems, through a variety of regulatory and non-regulatory mechanisms. One regulatory challenge is understanding how well these mechanisms meet their intent of protecting ecosystem functions and values and how to make improvements where they are falling short. This chapter was written in collaboration with the Washington Department of Commerce (Commerce) and relies heavily on the Commerce’s 2018 update of the [Critical Areas Ordinance Handbook](#) (Bonlender 2018), with one exception, as noted.

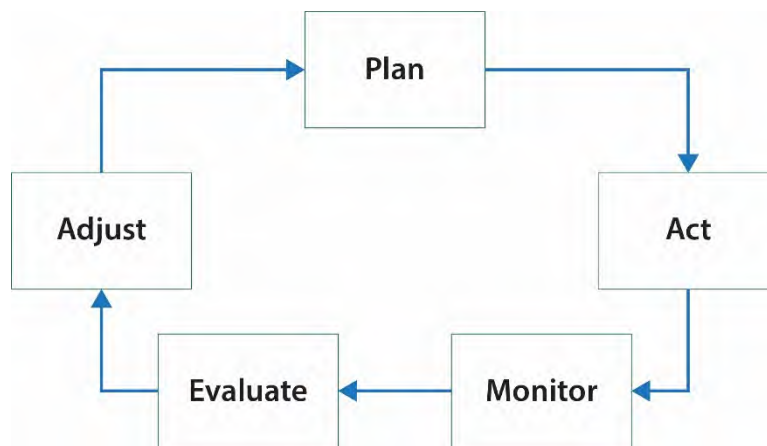


Figure 5.1. A simple depiction of the adaptive management cycle (modified from Bormann et al. 1994).

The process for monitoring we describe here supports both local and larger-scale actions that improve our collective efforts to protect riparian ecosystems throughout the state. For example, the Puget Sound Partnership (Partnership) uses “[Vital Signs](#)” of ecosystem health and recovery, such as riparian forest cover, to understand ecosystem condition, articulate shared goals and progress, and inspire action towards meeting those goals.

Adopting an adaptive management program can allow local governments to respond more quickly and meaningfully as new information become available. A willingness to address issues identified through this process is critical to the idea of adaptive management.

5.2 COMMON QUESTIONS ADDRESSED BY ADAPTIVE MANAGEMENT

Adaptive management does not have to be expensive or complicated to be useful. We believe local jurisdictions can maximize their investment in adaptive management by focusing on two types of monitoring related to their own regulatory process (explained in more detail in the next section).

We begin by discussing three basic types of monitoring because we have found it instructive to understand how different monitoring types can be hierarchically or sequentially staged, based on the types of questions they seek to answer: implementation monitoring, effectiveness monitoring¹³, and validation monitoring.

5.2.1 *Implementation Monitoring*

Implementation monitoring typically helps the permit issuer (permittor) answer the following questions about its permitting system, by looking at the outcomes of individual permits:

- Are permits consistent with regulations?
- Do permits contain all necessary conditions or provisions for a project?
- Does the permittor issue consistent permits (same requirements) for all permittees?

Implementation monitoring can also include:

- Permit *compliance monitoring*, which asks if the permittee followed or complied with each permit condition or provision and refrained from conducting unpermitted activities. Compliance monitoring usually takes place very soon after completion of permitted work.
- Keeping track of unpermitted activities; that is, finding changes in land use or management that require a permit but where no permit of any kind was issued.

Monitoring does not have to be complicated. Even if a city or county chooses to do only permit implementation monitoring, this will provide key information that can improve the permit process, and an individual landowner can check whether choices like enhancing native plantings produce the desired results.

5.2.2 *Effectiveness Monitoring*

In Commerce's 2018 Critical Areas Handbook, *effectiveness monitoring* is a form of long-term implementation monitoring. In other words, effectiveness monitoring looks at permit compliance as a while to determine whether permit conditions/provisions (e.g., buffer widths) are followed over time.

For the purposes of this document, we describe effectiveness monitoring a bit differently: Specifically, effectiveness monitoring is a way to determine whether permit conditions/provisions

¹³ As explained further in Section 5.2.2, we describe and use the term effectiveness monitoring somewhat differently than how it is described in Commerce's 2018 Critical Areas Handbook.

are working relative to intended environmental outcomes. For example, “Are permit conditions/provisions leading to the riparian function(s) (e.g., shade, bank stability) that they were intended to provide?” Effectiveness monitoring typically involves some on-the-ground measurement of environmental variables affected by land use activities.

5.2.3 Validation Monitoring

Research within the adaptive management framework is often referred to as *validation monitoring*. In the context of land use regulations, the questions relate to how management of critical areas (e.g., riparian) affects the specific environmental resource it was intended to protect (e.g., water quality, salmon). Validation monitoring may be beyond the fiscal means of most local governments. Moreover, it often involves questions that must be addressed over large spatial extents (e.g., at watershed or multi-watershed scale). In comparison, implementation and effectiveness monitoring are often tied to local jurisdiction’s regulatory processes at the site scale: For these reasons, the next two sections focus more on these two types of monitoring

5.3 RECOMMENDED IMPLEMENTATION MONITORING EFFORTS

We advise local governments to focus first on using implementation monitoring to evaluate their regulatory processes that affect riparian ecosystems. Implementation monitoring tracks execution of the permitting system from the perspective of both the permit issuer (permittor) and permit holder (permittee) (Figure 5.2). This effort can result in regular status reports that help demonstrate how well local governments and permittees are working together to meet resource objectives in a fair and consistent manner.

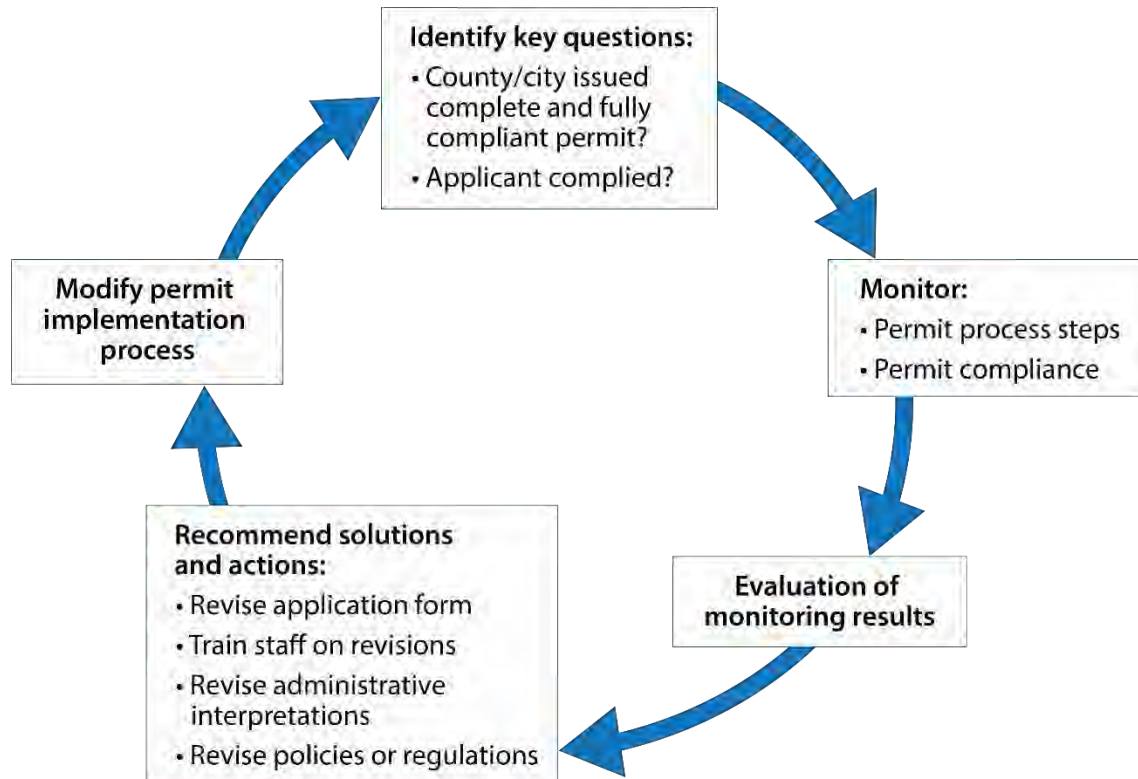


Figure 5.2. Depiction of the adaptive management cycle specific to permit compliance.

Implementation monitoring provides key information for permitting process improvement (**Error! Reference source not found.**2; Table 5.1). Even in situations where local governments cannot monitor all steps in their permitting process, monitoring any step—regulations to permit conditions/provisions, permit provisions to construction, construction to inspections, or inspections to enforcement—can provide valuable feedback about the quality of regulatory processes.

Table 5.1. Key questions for implementation monitoring during the Critical Areas permit review process.

Process Steps	Key study questions to evaluate permit implementation	Proposed metrics
Application	Was adequate information gathered from the permit applicant? Did the local government provide timely and necessary technical assistance to the permit applicant?	Number and percent of complete applications. i.e., include all information necessary to issue a permit. Number and percent by type of permit applications missing information
Permit	Do permit provisions follow the local government code?	Number and percent of permit provisions by type consistent with code.
Permit	Do permit provision identify intent of protection and how it can be accomplished? (e.g., area of tree retention, distance of structure from stream, clearing, grading, or storm water provisions, replanting requirements, extent of impervious surface.)	Number and percent of (complete) permits (i.e., include all provisions that enable a permittee to be fully compliant with the permit.) Number, percent, and type of missing provision/information
Permit (variance)	If a variance was granted, is the reason for the variance clearly stated?	Percent of variances by type justified by code or policy Percent of permits with variances by type.
Permit (mitigation)	If compensatory mitigation was required, were the unavoidable impacts clearly identified/quantified? Was the rationale clearly stated?	Number and percent of permits by type with unavoidable impacts Percent of permits by type with quantified mitigation requirements
Compliance	Post-Construction Visit: Did the permittee comply with the permit? (Requires field measurements of some or all the provisions in the permit. For riparian ecosystems, key provisions to inspect include RMZ width, retention of trees, replanting, structure distances from stream, area of impervious surface, and implementation of storm water provisions.)	Number and percent by type of provision that were out of compliance.
Enforcement	Are enforcement actions necessary to meet permit provisions and/or the regulations?	Number and percent by type of permit enforcement actions.

Because little or no fieldwork is required, the easiest and least expensive step to monitor is the link between regulations and permit provisions: that is, whether local land use regulations have been translated into permit provisions that can be understood easily by permittees. We recommend that some implementation monitoring become part of all local regulatory programs, even if it only on a relatively small subset of permits selected at random. A database for storing information on each

step (i.e., a permit tracking system—see Table 5.1, Figure 5.3) is a critical tool for creating a complete system of accountability.

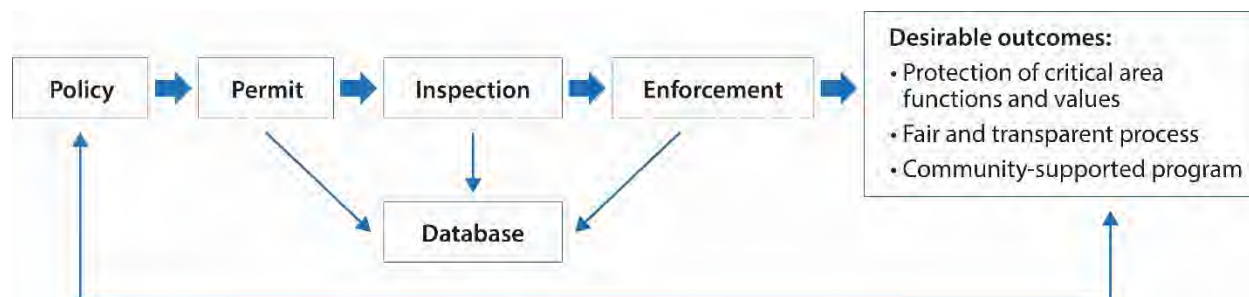


Figure 5.3. One system of permit accountability that includes implementation monitoring of internal permit processes, inspection for permit compliance, a database from which to judge outcomes, and a feedback loop connecting outcomes with policy intent.

Long-term implementation monitoring can help answer additional questions, such as: “Are rules/regulations intended to provide long-term protection of critical areas (e.g., RMZs) actually followed or maintained over time?” One way to answer this is by looking at changes in land cover, which describes the type and amount of vegetation, roads, and buildings occurring on the landscape. By comparing high quality aerial photographs taken of the same locations over time, change can be quantified and attributed to specific activities, both from natural disturbances (e.g., wildfires, river channel migration) and human activities (e.g., timber harvesting, residential subdivision construction, highway widening). In Section 5.5, we describe one such process WDFW developed and for which information for many parts of the state are already available.

5.4 EFFECTIVENESS OF REGULATORY PROTECTIONS OF CRITICAL AREAS

Where implementation monitoring has been successful, that is, either documenting a highly functional permitting process or improving poorly performing permitting process, we encourage additional effort on effectiveness monitoring. As described above, our primary goal for effectiveness monitoring would focus on understanding how well the permit conditions/provisions lead to measurable outcomes on the ground (e.g., protection/restoration of one or more riparian functions or values) over an extended period.

5.5 USING LAND COVER CHANGE TO UNDERSTAND LONG-TERM REGULATORY PROTECTION

High Resolution Change Detection ([HRCD](#)) is a tool that is useful for detecting changes in two specific types of land cover (tree canopy and impervious surfaces) over set time periods. Land cover change analysis like HRCD can show jurisdictions the degree to which critical area regulations are maintaining RMZs as intended. This information can then help shape if, where, why, and how adjustments to permitting processes should occur. By combining land cover change analysis with targeted questions about permitting processes, jurisdictions can begin to adaptively manage changes to their overall regulatory system.

Adaptive Management Framework in the Voluntary Stewardship Program

The Voluntary Stewardship Program (VSP) was authorized by the Legislature in 2011 through RCW 36.70A.705. The goals of VSP are to protect and enhance critical areas where agricultural activities are conducted, maintain and improve the long-term viability of agriculture in the State of Washington, and reduce conversion of farmland to other uses. The program provides counties with an alternative approach from traditional development regulations that require protection (and encourage enhancement) of critical areas at the individual parcel scale. Instead, VSP relies upon voluntary practices and incentive programs to protect (and enhance) at a watershed scale. Counties “opted-in” to VSP, and as of 2019, 27 of the state’s 39 counties are participating.

Under VSP, local workgroups created work plans that include benchmarks for protection and enhancement of critical areas designed to be achieved through voluntary and incentive-based actions. VSP requires monitoring and adaptive management to maintain and enhance critical areas, including riparian ecosystems, and directs workgroups to monitor at the watershed or sub-watershed scale. Key requirements for county-level programs include:

1. Establishing a durable system to track and report goals, benchmarks, and performance metrics.
2. Developing implementation and effectiveness monitoring programs and conducting monitoring on a pre-determined schedule.
3. Establishing an adaptive management program with (a) “triggers”; (b) subsequent actions to take; and (c) a process to review/update both the triggers and actions over time.
4. Reporting on the achievement of protection and enhancement goals and benchmarks at specified intervals.

Numerous counties have utilized WDFW’s recommended VSP Adaptive Management Matrix in approved VSP Work Plans. Examples include:

- Chelan County, Appendix I (Approved April 2017)
- Grant County, Tables 5-7 through 5-10 (Approved June 2017)
- Asotin County, Tables 5-3 through 5-5 (Approved May 2018)
- Okanogan County, Chapter 6 (Approved September 2018)
- Spokane County, Section 4 (Approved November 2018)

Jurisdictions can adapt matrices as templates for connecting goals, benchmarks, performance metrics, monitoring, and adaptive management for other uses beyond VSP. These matrices can be modified as frameworks to identify specific elements of any adaptive management plan.

The example in the following section is adapted from Commerce’s Critical Areas Handbook (Bonlender 2018). Chapter 7 of that document provides a number of similar monitoring program examples, nearly all of which were developed by cities or counties.

5.5.1 *Example: WDFW/Thurston County Shoreline Master Program*

In 2015, Thurston County and WDFW utilized a National Estuary Program grant to quantify shoreline vegetation, land cover change, and evaluate land use permit compliance. Specifically, Thurston County used WDFW’s HRCD data to monitor compliance within the County’s Shoreline Master Program (SMP) jurisdiction. This project developed a [protocol manual](#) for using HRCD for this purpose, available to all jurisdictions within the Puget Sound region.

One goal of the pilot project was to answer several related sets of questions:

For Thurston County:

- What land cover change is happening within designated SMP areas? What change is happening throughout the Deschutes River watershed (WRIA 13)?
- How does change known by permit records compare with detected changes by HRCD?
- What changes, if any, can be made to the land use permits or permitting process that could increase the relevancy or efficacy in utilizing the HRCD in compliance monitoring?

For WDFW:

- How well can HRCD detect changes relative to land use permit records?
- Using Thurston County's SMP area as an example test area, what land cover changes are happening which HRCD is not capturing?
- With the development of a HRCD user manual, can HRCD be successfully utilized by other entities in the absence of direct assistance by WDFW?

The pilot quantified increases in impervious surfaces and decrease in tree canopy within marine areas of the SMP jurisdiction and checked for relevant permits issued. It consisted of five phases:

Phase 1: Initial SMP Change Analysis: Staff from WDFW's Habitat Program and the County's Long-Range Planning Department intersected the HRCD dataset with the County's SMP area and tax parcel data within ArcGIS for three time periods of HRCD availability (2006 to 2009, 2009 to 2011, and 2011 to 2013). Staff compared known areas of change to those locations with the county's land use permit records to find locations of observed change via HRCD without any permit record. During this phase, land cover change statistics were also produced, including total area of change and discrete occurrences of land cover change events.

Phase 2: Learning What the HRCD Misses: Using the SMP area in the County, WDFW staff manually looked for land cover changes not captured by the HRCD analysis, to understand how accurate HRCD was in capturing all land cover change situations (rates of omission error).

Phase 3: Developing a Standardized Method for Utilizing the HRCD: A major goal of this project was to develop support materials for others to be able to utilize HRCD to answer land use management questions independent of WDFW staff assistance. Using lessons learned in Phases 1 and 2, WDFW and the County agreed upon a recommended method for applying HRCD to a specific management question, and collaboratively developed a "how-to" manual. In this phase, WDFW staff also developed a web-based service (<https://hrcd-wdfw.hub.arcgis.com>) where users can download the HRCD dataset, detail the methodology of HRCD construction, find WDFW contact information, and more.

Phase 4: Testing the Manual through Remaining SMP Analysis in WRIA 13: Using only the HRCD dataset and the manual produced in Phase 3, County staff examined land cover change within the remaining SMP areas within WRIA 13 successfully for the same three time periods that HRCD data was available and utilized in the earlier phase.

Phase 5: Training and Outreach: With the lessons learned and products derived from Phases 1 through 4 of the project, staff worked in conjunction with the [Coastal Training Program](#), managed by Ecology, to develop and deliver a workshop for planning staff within other state agencies, local

governments, and some non-governmental organizations. WDFW also used this opportunity to train internal staff on the benefits, limitations, and uses of HRCD.

The evaluators analyzed land cover change within Thurston County's SMP area between 2006 and 2013, pulling permit records from timeframes that corresponded with the available HRCD datasets. The project's findings were very helpful, not only because of the information collected, but also in providing proof of concept for several of the steps/tools.

For example: The utility of HRCD in analyzing patterns of land cover change in a specific geographic area of concern were well demonstrated. The HRCD analysis found that, from 2006 to 2013, less than half of one percent (0.39%) of the riparian area contained within the SMP had land cover change – approximately two-thirds of this was due to canopy loss, with one-third due to new impervious surfaces. The HRCD analysis did not find any permitted developments that were out of compliance, though it did find unpermitted events (e.g., tree removal) in each time period studied.

Furthermore, the HRCD dataset proved to be relatively simple to use. With the development of standard application methods, Thurston County was able to complete an analysis of their remaining SMP area without any further assistance from WDFW.

On the flip side, Thurston County found that comparing actual permit compliance with HRCD data was “tedious and difficult” because of limitations with the county's permit tracking database ([AMANDA](#)). For example, in many cases, land use permits did not include enough information to determine conclusively that a parcel with observed change via HRCD was out of compliance or determine that the parcel had a permit record during the study's timeframe in question.

Local governments can use HRCD analysis at the start to find land cover changes that are otherwise unknown; as they begin to understand patterns, HRCD analysis provides indications to identify locations that warrant closer investigation through other methods.

5.6 CONCLUSION

Implementation and effectiveness monitoring are important parts of adaptive management and can be undertaken relatively easily by local governments. Many of our riparian ecosystems are already degraded and stressed, so it is worth our while to investigate whether the actions put in place to protect them are being carried out as required and leading to the specific environmental responses that were intended. This is now more important than ever, because in spite of advances in science and efforts to improve regulatory processes, climate change and population pressures are increasingly confronting many parts of the state. Using monitoring and adaptive management to track successes and failures and then learning from both will make our challenges easier to overcome.

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Volume 1 serves as the primary source and citation for this document:

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GLOSSARY OF TERMS

Active channel: The active channel is defined by the lower limit of continuous riparian vegetation (Naiman et al. 1998) and may be delineated by absence of both moss on rocks and rooted vegetation (USFS 2008). The upper most elevation of the active channel is sometimes equated with the ordinary high-water mark.

Active floodplain: Located between the active channel and adjacent terrace or hillslopes (Fetherston et al. 1995; Harris 1987). Depending on the watershed, the flood return interval of the active floodplain varies between 1 and 10 years (Wolman and Leopold 1957; Ward and Stanford 1995; Lichvar et al. 2006; Williams et al. 2009; BLM 2015).

Adaptive management: The systematic acquisition and application of reliable information to improve management over time. It often includes treating management decisions as experiments in order to address critical uncertainties and learn more quickly from experience. It involves setting objectives, monitoring conditions, and adjusting management based on results. Hallmarks of a sound adaptive management program include: (1) adequate funding for monitoring and research, (2) a willingness to change course when pre-established triggers are reached, and (3) a commitment to gather data and evaluate conditions at appropriate spatial extents and time scales. *See Ecosystem-based management and WAC 365-195-920(2).*

Anadromous fisheries: The commercial, recreational or subsistence harvest of fish that are born in freshwater, rear at sea, and return to freshwater to spawn. Anadromous fisheries of Washington include salmon (Chinook, coho, chum, sockeye, and pink), steelhead, bull trout, coastal cutthroat trout, green sturgeon, white sturgeon, eulachon, longfin smelt, and Pacific lamprey.

Aquatic species: Wildlife species that live in marine or freshwater including fish, shellfish (e.g., clams, snails, mussels), amphibians (e.g., frogs, salamanders), reptiles (e.g., turtles), crustaceans (e.g., crayfish), insects (e.g., larval mayflies, stoneflies, caddisflies, dragonflies) and various other invertebrates.

Best Available Science: Information produced through a valid scientific process that WDFW or another local, state or federal agency has determined represents the best available science consistent with criteria set out in WAC 365-195-900 through 365-195-925. (Volume 1 of this document is an example of Best Available Science regarding riparian ecosystems.)

Biota: The animal and plant life of a region, habitat, or geological period.

Buffer: The area around a critical area that separates the critical area from incompatible uses. For example, a 200m buffer may be established around a heron-nesting colony (the critical area) to keep suburban land uses from disrupting the colony. *See WAC 365-190-130(3)(a).* Riparian ecosystems are both buffers (for instream habitat) and critical areas on their own merit.

Channel Migration Zone: The area within which a river channel is likely to migrate and occupy over a specified time period (e.g., 100 years).

Channel slope or gradient: The average steepness of a stream segment measured as its change in elevation divided by its length. Typically, a segment's gradient is considered low if less than 2%, moderate between 2% and 4%, and high if greater than 4%.

Classification (critical area): Defining categories to which critical areas are assigned. The Priority Habitats and Species (PHS) program provides WDFW's recommended classification scheme for Fish and Wildlife Habitat Conservation Areas. Classification precedes designation in counties' and cities' effort to protect critical areas. *See* WAC 365-190-040(4).

Complexity: The complicated state seen in dynamic environments that contain multiple components and processes that interact with one another in a web of interactions whose outcomes are often unpredictable. Complexity can be described with conceptual models; outcomes of well-understood complex phenomena can be partially predicted using computer models.

Connectivity: Landscape connectivity is the physical relationship between landscape elements. Functional connectivity describes the degree to which landscapes facilitate or impede the movement of organisms between areas of habitat.

Critical Aquifer Recharge Area: Areas with an essential recharging effect on aquifers used for potable water. One of five types of Critical Areas identified in the Growth Management Act.

Critical Area(s): Places that the Growth Management Act requires all counties and cities to designate and protect, specifically, (1) Wetlands; (2) Critical Aquifer Recharge Areas; (3) Fish and Wildlife Habitat Conservation Areas (e.g., Riparian Management Zones); (4) Frequently Flooded Areas; and (5) Geologically Hazardous Areas. In developing policies and regulations to protect the functions and values of critical areas, counties and cities are required to include best available science and give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries. *See* RCW 36.70A.172(1). The presence of a critical area may limit some land development options. *See* WAC 365-190-040(6).

Delineation (critical area): The act of applying definitions or performance standards in the field to identify the boundary of a critical area.

Designation (critical area): Assigning critical areas into established categories and specifying their general distribution, location, and extent. Designation can be made by maps (which are useful for public awareness and for identifying if a proposal may affect a critical area) and by performance standards or definitions (which allow for specific identification and site-scale delineation during permit review). WDFW's Priority Habitats and Species (PHS) program provides the agency's recommended designation maps and performance standards/definitions for Fish and Wildlife Habitat Conservation Areas. Designation occurs after classification in counties' and cities' efforts to protect critical areas. *See* WAC 365-190-040(5).

Disturbance regime: The frequency, magnitude, and duration of disturbance events.

Disturbance: A pronounced, temporary change in environmental conditions within an ecosystem. Disturbances often act quickly and can alter ecosystem composition, structure, and function.

Ecological (biological) integrity: Ability of an ecological system to support and maintain a community of organism that has species composition, diversity, and functional organization comparable to those of natural habitats within a region. An ecological system has integrity when its dominant ecological characteristics (composition, structure, function, and processes) occur within their historical ranges of natural variability. *See* Historical condition and Range of natural variability.

Ecosystem(s): A spatially explicit unit of the Earth that includes all the organisms, along with all components of the abiotic (chemical and physical) environment. Ecosystems have composition, structure, and functions.

Ecosystem composition (or ecological composition): All living (biotic) and nonliving parts of an ecosystem.

Ecosystem function(ing) (or ecological function): (1) The process or cause and effect relationship underlying two or more interacting components, e.g., terrestrial plant material as food/substrate for aquatic invertebrates. (2) The sum of processes that sustain the system. (3) The capacity of natural processes and components to provide goods and services that satisfy human needs, either directly or indirectly. Ecosystem functions can be conceived as a subset of ecological processes (*See Ecosystem process*).

Ecosystem process (or ecological process): Interactions among components of an ecosystem, biotic (living organisms) and abiotic (chemical and physical) components. Many processes involve transfer, conversion, or storage of matter or energy (*See Ecosystem function*).

Ecosystem structure (or ecological structure): The arrangement of and relations among the parts or elements (components) of an ecosystem.

Ecosystem-based management (EBM): Management driven by explicit goals; executed by policies, protocols, and practices; and made adaptable by monitoring and research; based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function. EBM acknowledges that humans are an important ecosystem component and focuses on managing human activities within ecosystems. EBM often involves balancing ecological, economic, and social objectives within the context of existing laws and policies.

Enhance: To improve a critical area's existing ecosystem processes, structure, and/or functions so that its ecological integrity is more like its historical condition.

Erosion: The loosening and transport of soil particles and other sediment by water. Terrestrial erosion includes raindrop splash erosion, overland flow sheet erosion, surface flow rill (shallow) and gully (deeper) erosion. Channel erosion includes streambank erosion and channel incision (gouging). Rill and gully erosion diminish the ability of the riparian area to trap sediment and pollutants and can often be avoided with intact riparian vegetation.

Fish and Wildlife Habitat Conservation Areas (FWHCA): A type of Critical Area specified in the Growth Management Act. The intent of FWHCAs are to maintain populations of species in suitable habitats within their natural geographic distribution so that (1) the habitat available is sufficient to support viable populations over the long term, and (2) isolated subpopulations are not created. FWHCAs come in a variety of types including waters of the state, places with which listed species have a primary association, habitats and species of local importance, and riparian ecosystems. *See WAC 365-190-130.*

Flow regime (stream): The distribution of stream flow through space and time. Flow regimes can be described by their magnitude (e.g., mean annual, hourly maximum), timing, frequency or return periodicity, duration, spatial distribution, and rate of change. The pathways that water takes to reach a stream (e.g., surface runoff) and within a stream exert a strong influence on the flow regime.

Function: Physical, chemical, or biological processes that occur within an ecosystem. WAC 365-196-830 says, “Functions are the conditions and processes that support the ecosystem. Conditions and processes operate on varying geographic scales ranging from site-specific to watershed and even regional scales.” See also Ecosystem function(ing) and Ecosystem process.

Habitat: The resources and conditions presented in an area that support the functional needs of a species (e.g., hiding, migration, resting, feeding, breeding, and rearing), and which are necessary for its survival and reproduction. Habitat is species-specific, scale dependent, and more than vegetation composition or structure.

Hazard Tree: A tree that a jurisdiction’s building official or other recognized professional (e.g., certified arborist, registered landscape architect, or certified forester) has determined poses a near-term hazard to public safety or to an existing permanent structure or public utility.

Herbaceous: Non-woody plants such as grasses and ferns.

Historical condition: See Ecological integrity and Range of natural variability.

Hydrology: Description of the properties, distribution, movement, and storage of water on and below the Earth’s surface.

Impervious surface: Ground surfaces that resist or prevent water infiltration, e.g., roofs of houses, roadways.

Imputed: estimated; a value assigned to missing data by inference from the values of data within the same dataset.

Infiltration: The rate or process by which water on the ground enters the soil.

Instream: Within flowing freshwater; also, the area waterward of the Ordinary High-Water Mark.

Large Woody Debris: Large dead woody material (such as fallen trees and branches) in various stages of decomposition that provide nutrient capital to forest and aquatic resources and serve as habitat in forest and riparian ecosystems. Large wood is usually defined as having diameter greater than 4 in (10 cm) and length greater than 6 ft (≈ 2 m).

Low Impact Development (LID): A storm water and land-use management strategy that tries to mimic natural hydrologic conditions by emphasizing pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation, and transpiration.

Mitigation: General category of measures that a proponent may take to avoid, minimize, and compensate for impacts.

Mitigation sequence: The stepwise process of protecting a critical area through, first (1) avoiding harm to the critical area to the maximum extent practicable, then (2) minimizing unavoidable harm to the maximum extent practicable, and finally (3) providing compensation for all unavoidable harm by restoring, creating, enhancing, or preserving the critical area’s ecological functions and values to replace those impacted or lost through permitted activities.

Monitoring: The process of observing and checking the progress or quality environmental conditions for the purposes of adaptive management. Often described as having three types – implementation, effectiveness, and validation.

Morphology (stream channel, aka fluvial geomorphology): A stream channel's shape and how it changes over time. Channel morphology is influenced by the abundance and variation in sediment sources, the ability of water to transport sediment downstream, and interactions of sediment with riparian vegetation and woody debris.

Off-Channel Habitat: Overflow channels, sloughs, alcoves, wetlands, and small streams found within the floodplains of larger river channels. Off-channel habitat consists of waters connected to and draining into rivers and streams by inundation during peak flow events (Smith 2005; WAC 222-16-031). Off-channel habitat provides habitat for salmonids and other aquatic species which often afford (1) spawning habitat that does not experience scouring high flows; and (2) summer rearing habitat that does not experience loss of stream flow.

Ordinary High Water Mark (OHWM): (1) That mark that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland (Washington Department of Ecology 2016). (2) That line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas (U.S. Army Corps of Engineers, 2014).

Organic litter: Plant, leaf, tree, or soil litter, and duff are dead plant materials that have fallen to the ground. In this document, organic litter is referenced as available for contributions to the stream system.

Passive Restoration: Allowing natural succession to occur in an ecosystem after removing a source of disturbance.

Population viability (local): The likelihood that a population of a species will persist for some length of time.

Precautionary principle: Erring on the side of not harming resources when faced with uncertainty, especially for potential harm that is essentially irreversible. Utilizing a precautionary approach in land use planning involves: (1) taking preventive action (avoiding impacts); (2) shifting the burden of proof to the project proponents; (3) exploring a wide range of potential alternatives; and/or (4) including multiple stakeholders and disciplines in decision making.

Priority Area: The area within a Priority Species' natural geographic distribution within which protective measures and/or management actions are needed to (1) support viable populations over the long term and (2) avoid creating isolated subpopulations.

Priority Habitat: A State of Washington habitat type with unique or significant value to many species; an area with one or more of the following attributes: (1) comparatively high fish and wildlife density; (2) comparatively high species diversity; (3) important breeding habitat; (4) important seasonal ranges; (5) important movement corridors; (6) limited availability; (7) high vulnerability to habitat alteration; or (8) unique or dependent species. Examples of Priority Habitats include but are not limited to instream, riparian, shrub steppe, Oregon white oak woodlands, freshwater wetlands, and marine nearshore.

Priority Habitats & Species (PHS): WDFW's primary means of transferring fish and wildlife information from resource experts to local governments, landowners, and others for the protection of fish, wildlife, and habitat. Includes endangered, threatened, sensitive, candidate, and vulnerable species and habitats deemed priorities of WDFW and reflective of best available science. *See* WAC 365-190-130.

Priority Species: A State of Washington fish or wildlife species requiring protective measures and/or management actions to ensure its survival. A Priority Species fits one or more of the following criteria: (1) is a state-listed endangered, threatened, sensitive, or candidate species, (2) has vulnerable aggregations, or (3) is of recreational, commercial, and/or tribal importance. Examples of Priority Species include but are not limited to steelhead/rainbow trout, bull trout/Dolly Varden, great blue heron, cavity-nesting ducks, sage grouse, fisher, orca, and elk.

Process: *See* Ecosystem process.

Protect: To prevent the degradation of existing ecosystem functions and values.

Range of natural variability (or Historical range of natural variability): Refers to the range of ecological conditions (components, structures and functions) in a time period before widespread anthropogenic changes.

Recruitment (wood): The process of wood moving from a riparian area to the stream channel. Sources of recruitment include bank erosion, windthrow, landslides, debris flows, snow avalanches, and tree mortality due to, for example, fire, ice storms, beavers, insects, or disease. Dominant factors include, but are not limited to, channel width, slope steepness, slope stability, forest composition and structure, and local wind patterns.

Refugia (singular Refugium): sites to which biota retreat, persist in and potentially expand from under changing environmental conditions (Keppel et al. 2012).

Riparian: An adjective meaning alongside a waterbody: stream, river, lake, pond, bay, sea, and ocean. Riparian areas are sometimes referred to by different names: riparian ecosystems, riparian habitats, riparian corridors, or riparian zones. Depending on the contexts, these terms may have somewhat different meanings.

Riparian area: A defined area encompassing both sides of a water body, composed of aquatic ecosystems (i.e., the river or stream), riparian ecosystem, and riverine wetlands. Riparian areas are three dimensional: longitudinal up and down streams, lateral to the width of the riparian ecosystem, and vertical from below the water table to above the canopy of mature site-potential trees (NRC 2002).

Riparian buffer: Buffer refers to its purpose, which is to reduce or prevent adverse impacts to water quality, fisheries, and aquatic biodiversity from human activities occurring upslope of the buffer. Riparian buffers managed specifically for pollutant removal may also be called a vegetated filter strip.

Riparian ecosystem: Riparian areas are transitional between terrestrial and aquatic ecosystems and distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of the ecosystem distinguished by gradients (i.e., riparian

zones) and portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., the Zone of Influence). Our definition of riparian ecosystem does not include adjacent waters (i.e., rivers or streams, but does include riverine wetlands) and recognizes the riparian zone as a distinctive area within riparian ecosystems.

Riparian Management Zone: A delineable area defined in a land use regulation; often synonymous with riparian buffer. For the purposes of this document, we define the RMZ as the area that has the potential to provide full riparian functions. In many forested regions of the state this area occurs within one 200-year site-potential tree height measured from the edge of the stream channel. In situations where a CMZ is present, this occurs within one site-potential tree height measured from the edges of the CMZ. In non-forest zones the RMZ is defined by the greater of the outermost point of the riparian vegetative community or the pollution removal function, at 100-feet.

Riparian values: The benefits that riparian ecosystems provide to society, including but not limited to flood damage reduction, water quality improvement, provision of harvestable populations of salmon, and provision of recreational opportunities. Riparian values have direct economic consequences to local communities through fishing opportunities, and flood and water quality protection, among others.

Riparian zone: A distinctive area within riparian ecosystems. The riparian zone contains wet or moist soils and plants adapted to growing conditions associated with periodically saturated soils. *See* Riparian ecosystem.

Risk: A situation involving exposure to danger, harm, or loss. Risk reflects the magnitude of the adverse impact and its probability of occurring. Risk is appropriately managed by applying the precautionary principle (especially for irreversible losses) and through adaptive management.

Salmonid: A family of fish comprised of salmon, trout and whitefish. Native salmonid species in Washington State include: Chinook Salmon (*Oncorhynchus tshawytscha*), Chum Salmon (*O. keta*), Coho Salmon (*O. kisutch*), Pink Salmon (*O. gorbuscha*), Sockeye Salmon/Kokanee (*O. nerka*), Steelhead/Rainbow Trout (*O. mykiss*), Cutthroat Trout (*O. clarki*), Bull Trout (*Salvelinus confluentus*), Dolly Varden (*S. malma*), Pygmy Whitefish (*Prosopium coulteri*), and Mountain Whitefish (*P. williamsoni*). This list does not include names of subspecies. (*See* anadromous fisheries).

Site class: The classification of a site based on the productivity of its dominant tree species. Site classes vary based on local differences in soil nutrients and moisture, light and temperature regimes, and topography. Site classes are typically described as most productive (I) through least productive (V).

Site-Potential Tree Height: The average maximum height of the tallest dominant trees for a given age and site class.

Stronghold: Habitat strongholds are refugia watersheds that contain high quality habitat with depressed or weak populations. The habitat in these areas has a high to very high potential to support these species. The population level in these areas is not considered to be a function of habitat, but other factors (USFS2001).

Structure: *See* Ecosystem structure.

Succession: Ecological succession is the process by which the biological community composition recovers over time following a disturbance event.

Uncertainty (scientific): The absence of information about the state of something or a relevant variable. Sources of uncertainty include, but are not limited to natural variation (i.e., because outcomes vary in difficult-to-predict ways through time and space), model uncertainty (i.e., we do not understand how things interact with each other), systematic error (e.g., poorly designed experiments or calibrated instruments), or measurement error. *See Risk.*

Values: The level of benefits that the space, water, minerals, biota, and all other factors that make up a natural ecosystem provide to support native life forms, including humans (Cordell et al. 2005).

Vegetative filter strips: A riparian buffer designed to capture nutrients, contaminant compounds, and sediment transported by run-off. Filter strips are sometimes synonymous with riparian buffers.

Water quality: Physical, chemical, and biological characteristics of water that describe its suitability to meet human needs or habitat requirements for fish and wildlife.

Watershed processes: The fluxes of energy (e.g., sunlight, wildfire) and materials (particularly water and sediment) that interact with biota (e.g., vegetative cover, salmon, beavers, soil microbes) to form a watershed's physical features and characteristics, which give rise to its instream physical and ecological conditions. These processes occur within a context that reflects the watershed's climate, geology, topography, and existing human land use. *See Ecosystem process.*

Watershed: A land area that drains to a common waterbody.

Wetland: Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support—and that under normal circumstances do support—a prevalence of vegetation typically adapted for life in saturated soil conditions. Examples include but are not limited to swamps, marshes, and bogs.

Zone of Influence: The portions of terrestrial ecosystems that significantly influence exchanges of energy (e.g., sunlight) and matter (e.g., large wood, sediment, nutrients) with aquatic ecosystems.

APPENDIX. SITE-POTENTIAL TREE HEIGHT MAPPING TOOL

The Site-Potential Tree Height (SPTH) Mapping Tool helps users find information they need to conserve, protect, and restore riparian ecosystems within a project site. The SPTH mapping tool works on personal computers (PCs) and mobile devices (tablets and smartphones).

SITE-POTENTIAL TREE HEIGHT MAP DATA

The SPTH mapping tool contains several GIS data layers, explained below:

1. Site-potential Tree Height at 200 Years (SPTH₂₀₀),
2. Imputed¹⁴ SPTH₂₀₀ Values for Urban areas,
3. Dryland Ecosystems – No SPTH Values, and
4. Other Lands – No SPTH Values.

Site-potential Tree Height at 200 Years (SPTH₂₀₀)

WDFW derived the SPTH₂₀₀ values from forest productivity site index information using Natural Resource Conservation Service (NRCS) soil polygons and its Soil Data Viewer tool for ArcGIS. The NRCS-provided forest productivity site index values, in feet, were for ages 50 years in Western Washington and typically 100 years in Eastern Washington. WDFW determined SPTH₂₀₀ values using tree site index equations. Each soil polygon has one or more tree species records with associated SPTH₂₀₀. When multiple tree species records with associated SPTH₂₀₀ are available, WDFW recommends using the largest SPTH₂₀₀ value of the tree species historically present at the site (such trees may currently be found on the site, but also may not). For example, if a project site contains mostly red alder but Douglas-fir is present (or was present prior to modern human alterations), use the Douglas-fir SPTH₂₀₀ for that soil polygon.

Imputed SPTH₂₀₀ Values

Four large urban areas (Seattle, Spokane, Tacoma, and Bellingham) lacked NRCS soil polygons; therefore, forest productivity information could not be mapped for most locations within those areas. Similarly, numerous soil polygons labelled as “Urban Land” lacked forest productivity information. For each of these four urban areas, WDFW calculated an imputed SPTH₂₀₀ by using an area-weighted average for 200-year site index values within a two-mile buffer around the perimeter. WDFW recommends the use of this imputed SPTH₂₀₀ as a guide for delineating RMZs in these urban areas. At the time of publication, WDFW had calculated imputed SPTH₂₀₀ information for those large urban areas. WDFW expects to continue to update the map.

Dryland Ecosystems and Other Lands

Not all soil polygons are forested, or have forest productivity information from NRCS; therefore, not all of them have associated SPTH₂₀₀ values. In addition, Benton, Franklin, Grant, and Adams counties had no forest productivity information in their NRCS soil polygons. These areas without SPTH₂₀₀ values were classified in one of two ways: as “dryland ecosystems”, or “other lands.”

¹⁴ Imputed: estimated; a value assigned to something by inference from the value of the products or processes to which it contributes.

- WDFW approximated the area contained within “dryland ecosystems” using the Arid Lands Initiative study area boundary (Arid Lands Initiative, 2014) and have developed associated process steps that we recommend be used to derive RMZ widths (Volume 2, Section 2.2.3).
- The “other lands” comprise the remaining soil polygons and are small and dispersed across the landscape. These polygons include the NRCS soil map unit name, if applicable, and often represent soils that do not support tree growth, such as beaches and wetlands, as well as certain types of heavily modified sites like gravel pits. Please consult with a WDFW regional habitat biologist on deriving RMZs for “other lands” and consider following a similar process for delineation in dryland ecosystems.

USING THE MAPPING TOOL

The mapping tool can be accessed from several locations:

- WDFW web site (<https://wdfw.wa.gov/species-habitats/at-risk/phs/recommendations>),
- Washington Geospatial Open Data Portal (<http://geo.wa.gov/>), and
- ArcGIS Online (AGOL) (<https://wdfw.maps.arcgis.com/apps/MapSeries/index.html?appid=919ea98204eb4f5fa70eca99cd5b0de1>).

The mapping tool consists of the statewide map with the four riparian datasets described above; user tools; and a sidebar explaining map contents, how to use the map, and links to supporting documents.

The four riparian datasets have unique colors indicating where the information occurs.

- Green: Area where SPTH₂₀₀ has been calculated.
- Orange: Areas where SPTH₂₀₀ values have been imputed.
- Pale brown: Dryland ecosystems where there is no tree height information.
- Beige: Places for which no SPTH site index information is available.

Tribal and publicly owned/managed lands federal and tribal lands are typically subject to different riparian regulations. Tribal, federal, and state lands are displayed in shades of grey. County-owned lands are shown in lavender, and city-owned lands are light blue.

The mapping tool contains the following tools (Figure A1):

1. **Zoom Slider:** zoom in or out on the center of the map.
2. **Home icon:** resets map to statewide extent.
3. **Target icon:** allows the user to zoom directly to their current location.
4. **Address Search:** zooms to a street address, place name, or latitude and longitude.
5. **Measurement:** use this to measure the distance between objects (e.g. edge of stream to another point), or to measure an area (square feet of an area surrounding a project site).
6. **Basemap Selector:** change the basemap to show a different view of the landscape: aerial imagery (default), topographic map, open street map, terrain with labels, and USGS national map.

7. **Legend:** displays the map layers currently visible. For example, map layers displayed at a site-specific scale will not appear in the legend when zoomed out to the statewide extent.
8. **Scale bar:** shows the scale that the map is zoomed to. At a statewide extent, the scale bar will show 0 to 60 miles. When zoomed to a scale where you can view the project area, the scale bar will show 0 to 100 feet or 200 feet.
9. **Coordinates:** latitude and longitude (decimal degrees) are shown where the cursor is located on the map.
10. **Panning:** move the map by placing the cursor over a desired location and dragging it to the center of the map display.

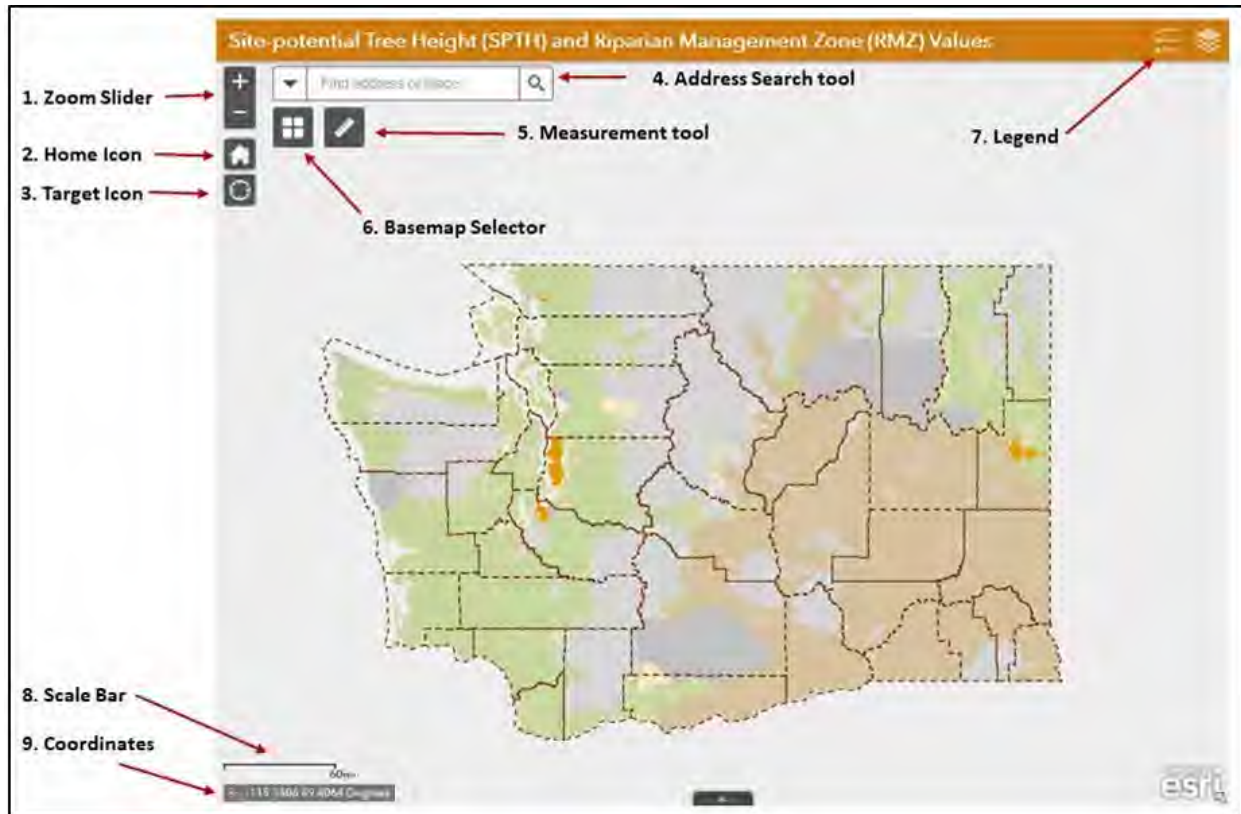


Figure A1. Tools available on the SPTH₂₀₀ and RMZ Online Map.

To zoom to a site location, use the Address Search tool or use a combination of the Zoom Slider and panning. (If using the Address Search tool, select the “ArcGIS World Geocoding Service” from the dropdown menu to the left of the search field for faster results.) Once the site is located, a click (on PCs) or tap (on mobile devices) of the cursor will open a popup window with information about that location. Be sure to review each window if multiple records are selected.

The NRCS soil polygons form a complex mosaic across the landscape, so you must zoom in close enough to clearly see your project site. Clicking (or tapping, on mobile devices) on the map when it is zoomed out will result in erroneous returns of the SPTH₂₀₀ values. Below is an example of using these tools to obtain riparian information at a project site.

MAPPING TOOL EXAMPLE #1

1. Start up the Online Map.
2. Type the project location into the Address Search tool (Figure A2). If the address is unknown, use a nearby place name or latitude and longitude.

This example uses 16018 Mill Creek Boulevard, Mill Creek, Washington.

3. Select the correct address from the drop-down menu or continue to enter manually. Click (on a **PC**) or tap (on a **mobile device**) the search button. The map will zoom to that location, shown as a small blue box and a popup titled "Search result" (Figure A3).

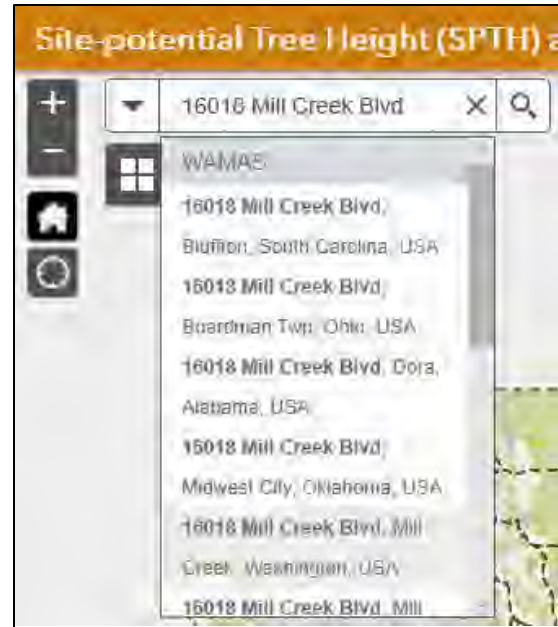


Figure A2. Using the Address Search tool.

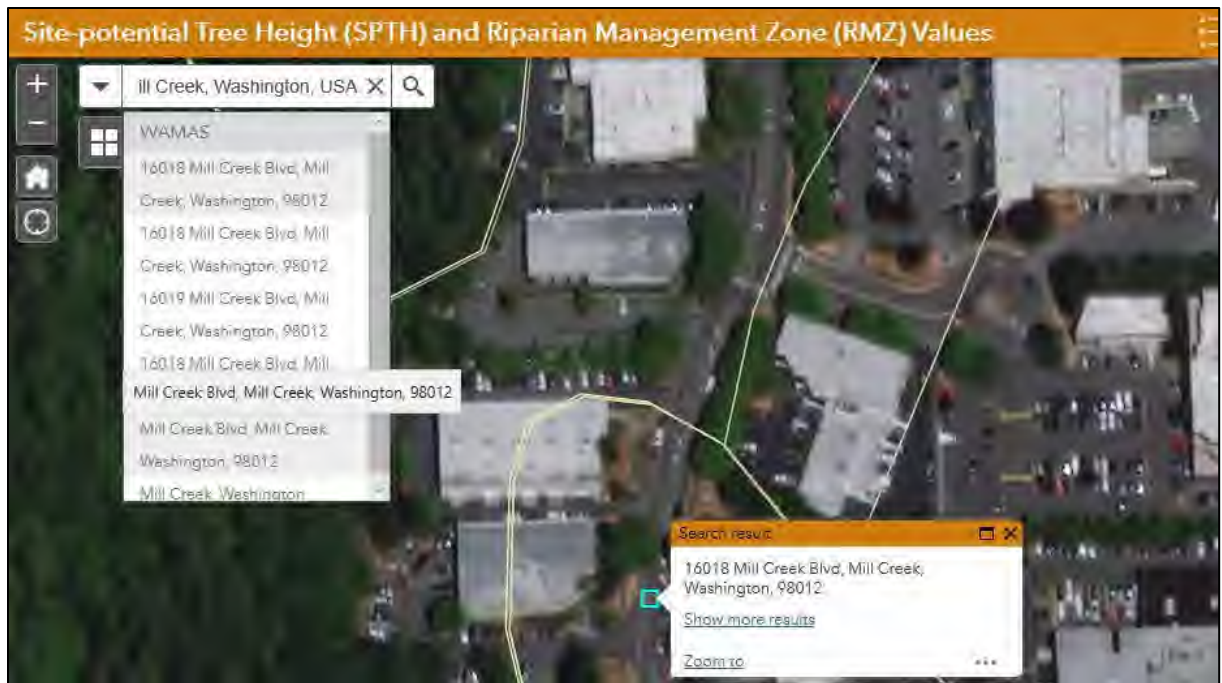


Figure A3. Zoomed in aerial image of the site address.

4. Click (or tap) on the “X” in the Address Search tool to close the popup. Zoom and pan until you can clearly see where the project site is on the landscape (Figure A4).

In this example, the project site lies in a wooded area to the west of the address selected in the previous screen. We panned west to center the map display over the project site. In this screen, you can see the outlines of the soil polygons.

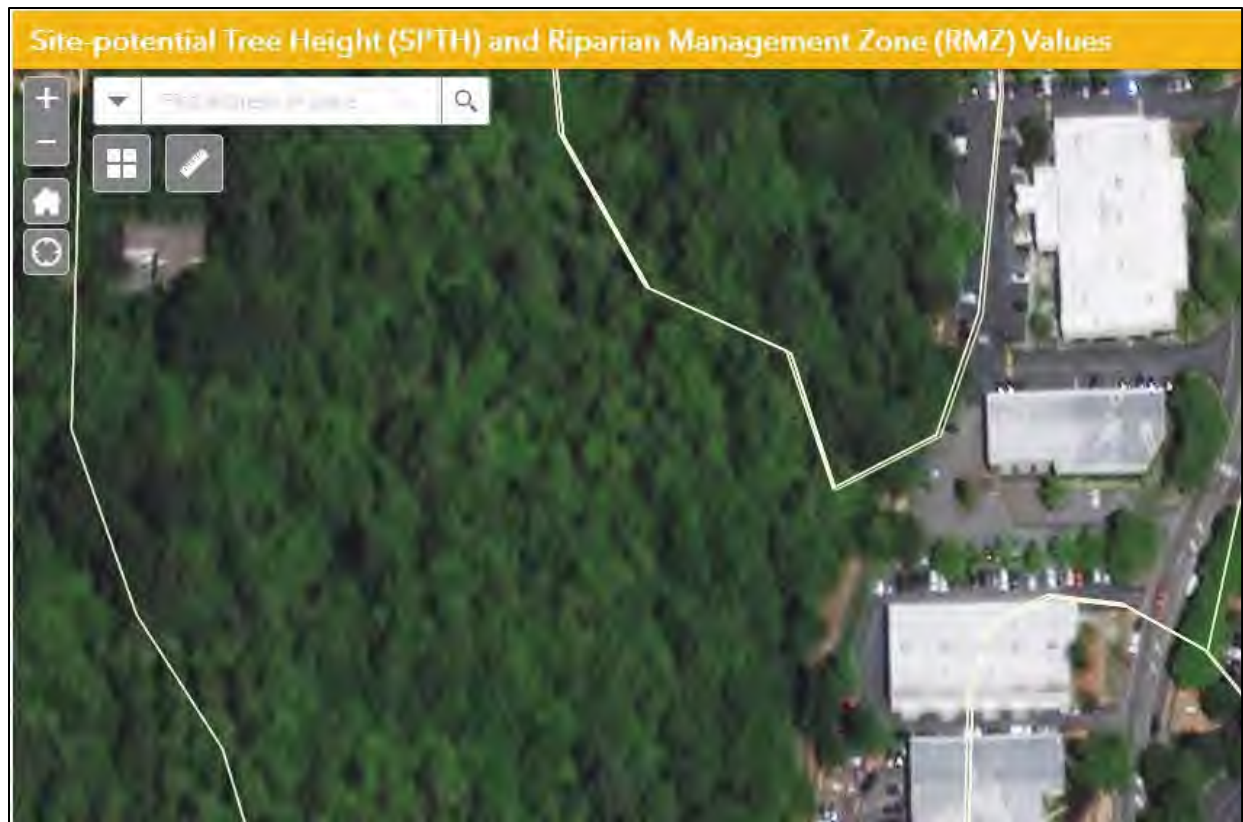


Figure A4. Adjusting the map display over the project site.

5. Click (or tap) near a stream on the project site. The outline of the soil polygon selected will turn blue, and a popup window will provide information about the $SPTH_{200}$ (Figure A5). On a PC, the popup should automatically show (1) the $SPTH_{200}$ in feet, (2) the species of tree it is based on, and (3) the reference study used to derive the height value. On a mobile device, tap the arrow on the right side of the popup to display this information.

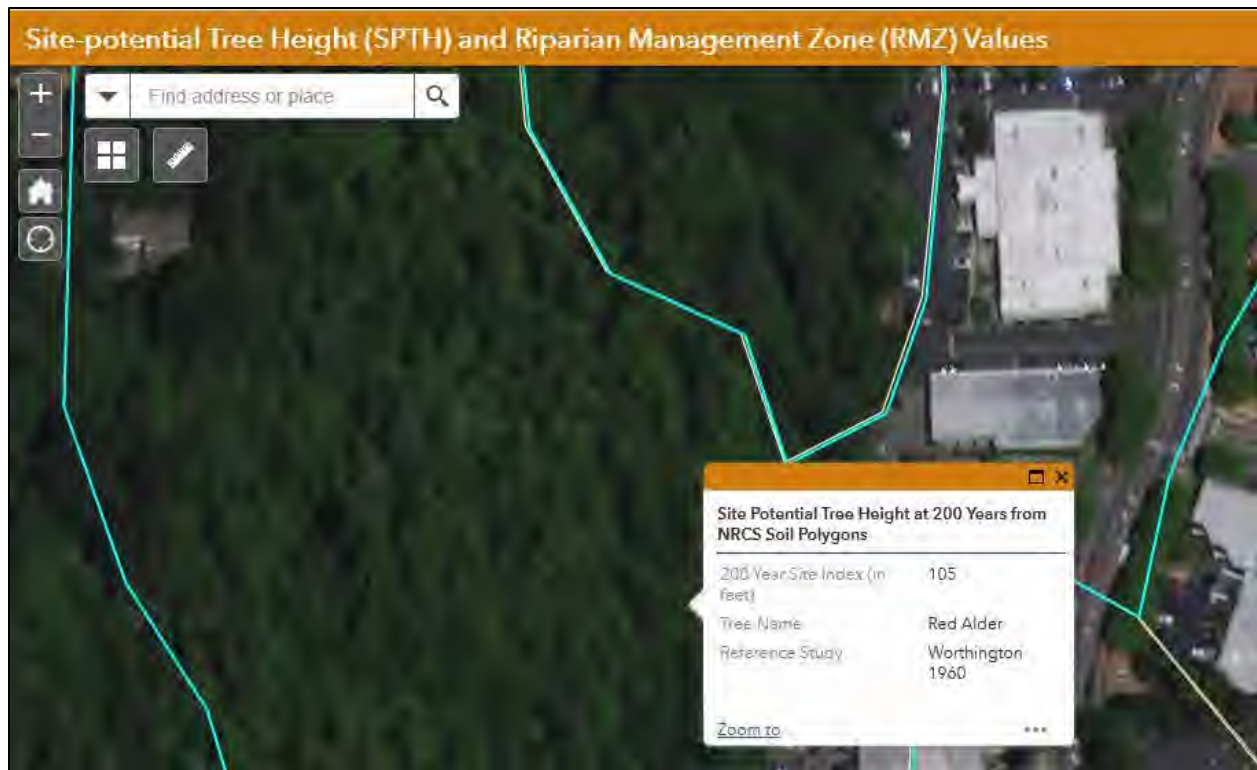


Figure A5. Bringing up the SPTH₂₀₀ information at the project site.

In Example #1, the soil polygon for the project site only showed one tree species: Red Alder. Sometimes soil polygons will list more than one tree species, as shown in Example #2.

MAPPING TOOL EXAMPLE #2

Example #2, the project site was at a different location. Steps 1-3 in Example #1 were repeated to zoom to the project site. For this site, the popup window for the selected soil polygon looked different:

- The upper left corner of the popup window says “(1 of 2)”; and
- There is a small arrow near the upper right corner of the popup window.

This means that this soil polygon has two different associated tree species. The first is Douglas-fir (see Figure A6a).

To view the information for the second tree species, click on the small arrow. The second tree species is western hemlock (see Figure A6b).

For project locations with multiple tree species, WDFW recommends using the largest SPTH₂₀₀ value, even if the largest tree species is not the most numerous (or even currently present) onsite.

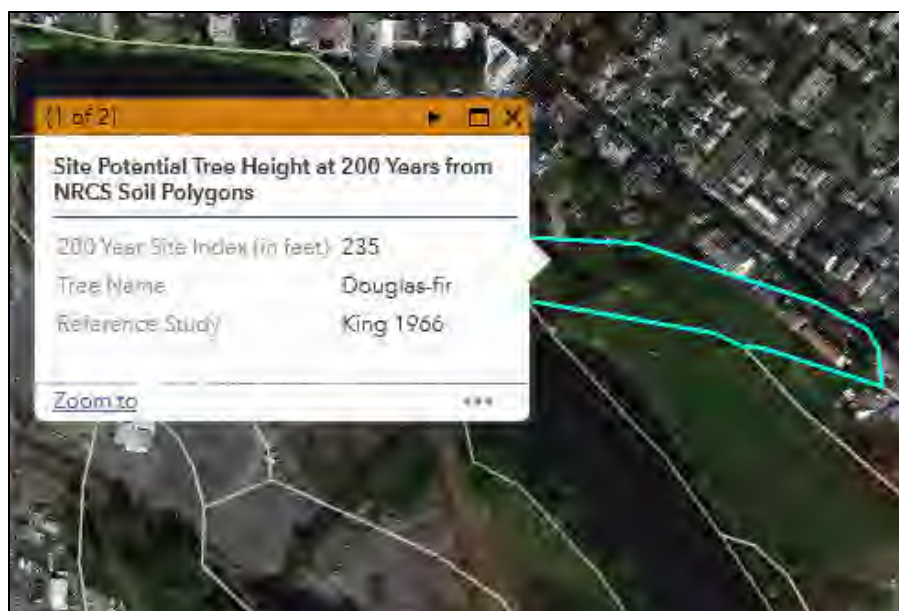


Figure A6a. SPTH information for the first of multiple tree species at a given site.

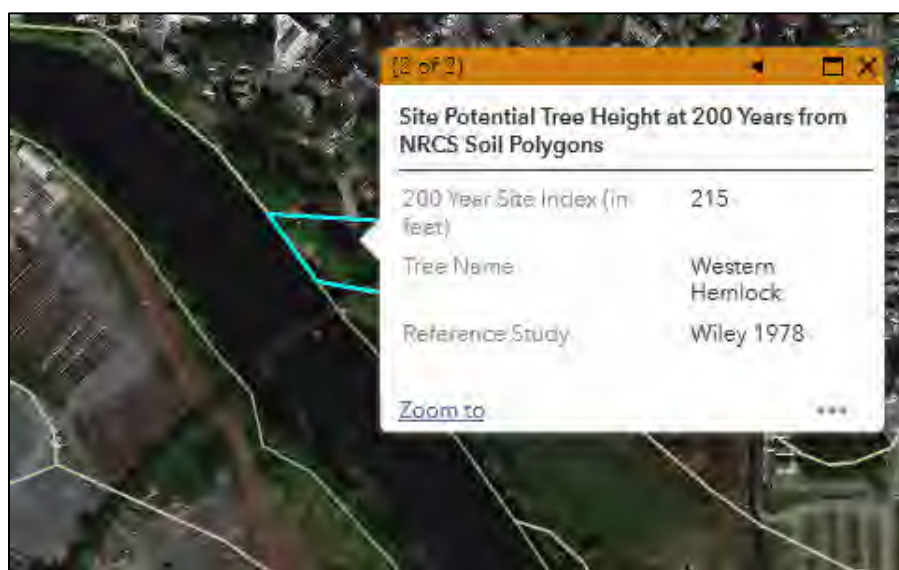


Figure A6b. SPTH₂₀₀ information for the second of multiple tree species at a given site.

APPENDIX REFERENCES: TREE SITE INDEX CURVES

The following twenty studies were used to determine $SPTH_{200}$ throughout the state:

- Alexander, R.R. 1966. Site indexes for lodgepole pine, with corrections for stand density: instructions for field use. Research Paper RM-24. U.S., Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- Alexander, R.R. 1967. Site indexes for Engelmann spruce. Research Paper RM-32. U.S., Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- Baker, F.S. 1925. Aspen in the Central Rocky Mountain Region. Bulletin 1291. United States Department of Agriculture, Washington, D.C.
- Barnes, G.H. 1962. Yield of even-aged stands of western hemlock. Technical Bulletin 1273. U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.
- British Columbia Forest Service (BCFS). 1977. Site index curves for cottonwood (as adapted by W.J. Sauerwein). pp. 852-853 in *Pocket Woodland Handbook*. U.S. Department of Agriculture, Soil Conservation Service, Portland, Oregon.
- Cochran, P.H. 1979a. Gross yields for even-aged stands of white or Douglas-fir and white or grand fir east of the Cascades in Oregon and Washington. Research Paper PNW-263. U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.
- Cochran, P.H. 1979b. Site index and height growth curves for managed, even-aged stands of Douglas-fir east of the Cascades in Oregon and Washington. Research Paper PNW-251. U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.
- Cochran, P.H. 1985. Site index, height growth, normal yields, and stocking levels for larch in Oregon and Washington. Research Note PNW-424. U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.
- Haig, I.T. 1932. Second-growth yield, stand, and volume tables for the western white pine type. Technical Bulletin 323. United States Department of Agriculture, Washington, D.C.
- Hegyi, F., J.J. Jelinek, J. Vizslai, and D.B. Carpenter. 1979. Site index equations and curves for the major tree species in British Columbia. Forest Inventory Report No. 1. Ministry of Forestry, Victoria, British Columbia.
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- Hoyer, G.D., and F.R. Herman. 1989. Height-age and site index curves for Pacific silver fir in the Pacific Northwest. Research Paper RP-418. U.S., Forest Service. Pacific Northwest Research Station, Portland, Oregon.
- King, J.E. 1966. Site index curves for Douglas-fir in the Pacific Northwest. Forestry Paper 8. Weyerhaeuser Company, Forestry Research Center, Centralia, Washington.
- Kurucz, J.F. 1978. Preliminary, polymorphic site index curves for western red cedar (*Thuja plicata* Donn) in coastal British Columbia. Forest Research Note No. 3. MacMillan Bloedel, Nanaimo, British Columbia.
- Meyer, W.H. 1961. Yield of even-aged stands of ponderosa pine. Technical Bulletin 630 (revised 1961). United States Department of Agriculture, Washington, D.C.

- Meyer, W.H. 1937. Yield of even-aged stands of Sitka spruce and western hemlock. Technical Bulletin 544. United States Department of Agriculture, Washington, D.C.
- Monserud, R.A. 1985. Applying height growth and site index curves for inland Douglas-fir. Research Paper INT-347. U.S. Forest Service. Intermountain Research Station, Ogden, Utah.
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EXHIBIT G

Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications



A Priority Habitats and Species Document of the
Washington Department of Fish and Wildlife



Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications

Published May 2018, updated July 2020

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Publication should be cited as follows:

Quinn, T., G.F. Wilhere, and K.L. Krueger, technical editors. 2020. Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications. Habitat Program, Washington Department of Fish and Wildlife, Olympia.

Example citation for chapter within publication:

Quinn, T., K.L. Krueger, and G.F. Wilhere. 2020. Introduction. Pages 1-14 *in* T. Quinn, G.F. Wilhere, and K.L. Krueger, technical editors. Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications. Habitat Program, Washington Department of Fish and Wildlife, Olympia.

Accessibility:

This document is available in alternative formats upon request. Please contact WDFW's ADA Program Manager at 360-902-2349, TTY (711), or ADAProgram@dfw.wa.gov.

Acknowledgements

Many people were involved with the creation of this document. WDFW would like to acknowledge the Washington Department of Ecology and US Environmental Protection Agency for the funds that made this document possible. Contract planning and budgeting for this work was led by Keith Folkerts. We appreciatively acknowledge the participation of our Technical Advisory Group:

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Steve Wondzell, PhD	US Forest Service

The scientific rigor of this document was improved through the peer review provided by the Washington State Academy of Sciences, with coordination provided by Dr. Robert Bates. Draft versions of this document were reviewed by numerous staff in state agencies, including the Department of Ecology, Department of Natural Resources, Department of Commerce, Recreation and Conservation Office, State Conservation Commission, and Puget Sound Partnership. These reviews improved the document and we appreciate the helpful feedback. We also appreciate the reviews by federal and tribal entities including EPA, NOAA Fisheries, Northwest Indian Fisheries Commission, Columbia River Inter-Tribal Fish Commission, Upper Columbia United Tribes, and individual tribes. We express our appreciation for all local governments and individuals who provided feedback during our public comment period. Finally, thank you to Peggy Ushakoff for creating graphics that help us better portray the science.

While we acknowledge and appreciate all review comments, WDFW bears sole responsibility for the content of this document.

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Leopard Frog *Lithobates pipiens*/Scott Fitkin, WDFW

Preface

This Priority Habitats and Species (PHS) document of the Washington Department of Fish and Wildlife (WDFW) is provided in support of the agency's mission to preserve, protect, and perpetuate the state's fish, wildlife, and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities. WDFW works cooperatively with land use decision makers and landowners to facilitate solutions that accommodate local needs and needs of fish and wildlife. One of WDFW's important roles in land use decision making is that of technical advisor: we provide information about the habitat needs of fish and wildlife and the likely implications of various land use decisions for fish and wildlife.

The nine chapters of Volume 1 are a partial update of a 1997 document entitled *Management Recommendations for Washington's Priority Habitats: Riparian*. This document, called *Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications* is a partial update because it addresses only aquatic species. Riparian needs of terrestrial species will be updated in the future. Until that update is complete, readers can consult the 1997 document, available at <http://wdfw.wa.gov/publications/00029/>, for information about riparian ecosystems and terrestrial species.

Priority Habitats are places that warrant special consideration for protection when land use decisions are made. For more information, see *Washington Department of Fish and Wildlife. 2008. Priority Habitat and Species List*, available at <https://wdfw.wa.gov/species-habitats/at-risk/phs>.

The PHS program provides land use decision support to clients such as local governments, tribes, government agencies, non-governmental organizations, and landowners. PHS consists of a PHS List, PHS Maps available at <https://wdfw.wa.gov/species-habitats/at-risk/phs/maps>, PHS Management Recommendations, and technical assistance from our regional habitat biologists.

This PHS document compliments a family of PHS documents including *Landscape Planning for Washington's Wildlife: Managing for Biodiversity in Developing Areas* and *Land Use Planning for Salmon, Steelhead and Trout: A land use planner's guide to salmonid habitat protection and recovery*, available at <https://wdfw.wa.gov/species-habitats/at-risk/phs/recommendations>.

List of Acronyms

BAS	best available science
BFW	bankfull width
CMZ	channel migration zone
DBH	diameter at breast height
DNR	(Washington) Department of Natural Resources
EPA or (US)EPA	United States Environmental Protection Agency
FEMAT	Forest Ecosystem Management Assessment Team
HCP	habitat conservation plan
IMW	intensively monitored watersheds
LWD	large woody debris
NOAA	National Oceanographic and Atmospheric Administration
NRC	National Research Council
PHS	Priority Habitats and Species
PNW	Pacific Northwest
RCW	Revised Code of Washington
RMZ	riparian management zone
SMA	Shoreline Management Act
SPTH	site-potential tree height
SPTH ₂₀₀	site-potential tree height at tree age equal to 200 years
TAG	Technical Advisory Group
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WNHP	Washington Natural Heritage Program
WSAS	Washington State Academy of Sciences



Bank of the Chehalis River/Kaysie Cox, WDFW

Chapter 1. Introduction

By: Timothy Quinn, Kirk L. Krueger, and George F. Wilhere

1.1. Document Description

Volume 1 is part one of a two-volume set. It contains reviews and syntheses of scientific literature for the purpose of informing the development of policies related to management of riparian areas and watersheds of Washington State. Volume 1 adds additional information to the science summarized in the PHS report titled *Management Recommendations for Washington's Priority Habitats: Riparian* (Knutson and Naef 1997).

Volume 1 was designed to answer the following three general questions:

- What is currently known about the key ecological functions of riparian areas?
- How do riparian areas and watersheds affect the freshwater habitats of fish and wildlife?
- How do human activities affect the capacity of riparian areas and watersheds to provide habitat for fish and wildlife in rivers and streams?

Volume 1 is intended to serve two goals. The first goal is to be a source of best available science (BAS) for understanding how riparian areas and surrounding



Chehalis River meander paths between 1938 and 2013/Ken Pierce, WDFW

watersheds affect ecological functions and aquatic habitats. The second goal is to provide a scientific foundation for management recommendations presented in Volume 2, which are consistent with Washington Department of Fish and Wildlife's (WDFW) mandate (RCW 77.04.012) to protect, preserve, and perpetuate Washington's fish and wildlife. Both goals also relate to WDFW's responsibility to support and provide technical assistance for conservation and protection measures necessary to preserve or enhance anadromous fisheries under the Growth Management Act (GMA; RCW 36.70A.172) and the Shoreline Management Act (SMA; WAC 173-26-221(5)(b)).

Volume 1 does not directly address instream flows as affected by water withdrawal for domestic and commercial uses, or instream water quality, both of which are regulated by the Washington Department of Ecology. However, because water quality is affected by land use, we discuss this issue in the context of riparian and watershed science. In addition, Volume 1 does not specifically address riverine wetlands, i.e., wetland associated with rivers and streams and commonly found in floodplains. Rather, riverine wetlands are usually considered part of riparian ecosystems, which are the focus of this document. Other specific wetland management guidance is available from Washington Department of Ecology (<https://ecology.wa.gov/Water-Shorelines/Wetlands>).

Volume 2 translates these science reviews and syntheses into land use guidance for local governments and other organizations to conserve watershed processes and riparian ecosystems in support of aquatic species and their habitats. The guidance presented in Volume 2 is not in and of itself "best available science." Rather, it represents the recommendations of WDFW as to how a local government could include the best available science in policies, plans, and regulations to protect riparian ecosystems and their associated aquatic habitats.

WDFW recognizes that natural resource management and land use policies must often balance competing ecological, economic, and social goals (Wilhere and Quinn 2018). In fact, one of WDFW's conservation principles is that management decisions should integrate ecological, economic, and social perspectives. This volume addresses only the ecology of riparian areas within the context of watershed conditions; it does not cover economic and social aspects. Determining an acceptable balance requires a political process involving stakeholders, local governments, tribes, and state agencies. Such a process would establish society's goals for freshwater habitats for salmon and other species of fish and wildlife, and lead to management for achieving those goals. This volume can help to inform that process.

1.1.1. Ecosystems

The ecosystem, a fundamental concept in natural resource management, can be defined as "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment" (Likens 1992). Throughout this document we use the term ecosystem composition to mean "the different parts (components) which something is made of" (Oxford Dictionary 2015). We define ecosystem structure as the "arrangement of and relations among the parts or elements of something complex" (Oxford Dictionary 2015). We define ecosystem function(ing) to include the first and second definitions of ecological function by Jax (2005): 1) the process, or the cause-effect-relationship underlying two or more interacting components, and 2) the sum of processes that sustain the system. Note that the definitions of functions we use here are broader and more inclusive than "functions" defined solely as ecosystem outputs that benefit humans, namely goods and services (Jax 2005; MEA 2005).

In this volume, we explicitly consider the composition, structure, and function of riparian ecosystems in the context of the surrounding watershed. This is especially important in light of the challenges of managing ecosystems sustainably and the risks associated with scientific uncertainty, i.e., the consequences of being wrong.

The composition, structure, and function of ecosystems describe the organization of biotic and abiotic elements and the processes occurring among elements. These concepts are closely related but not equally well studied nor understood. For example, describing an ecosystem's composition and structure is easier than describing its functions (Hunter et al. 1988; Noss 1992). Likewise, management objectives are often expressed in terms of composition and structure, not functions, because they are easier to characterize.

Composition and structure versus function have a chicken-and-egg relationship. That is, functions (processes) are in large part responsible for maintaining composition and structure, but some functions could not exist without an ecosystem's particular composition and structure. Myser (2001), for instance, argues that ecosystem structure can be defined as the minimal organization necessary for a function to operate. Others argue that managing for functions (Beechie and Bolton 1999) is likely to be more successful than managing for composition and structure because processes likely exert stronger influences on composition and structure than the other way around (Odum 1953), and processes are more directly affected by land use activities (Reid 1998). Furthermore, some land use laws or regulations stipulate no net loss of ecological functions, not no net loss of composition and structure (RCW 90.58, WAC 173-26-186, WAC 365-196-830), however, compliance is often determined through evaluating ecosystem composition and structure, not functions. Such conceptual ambiguity suggests that we consider the entire ecosystem, i.e., composition, structure, and functions, when studying riparian areas,

and furthermore, that land managers understand how composition and structure manifest ecological functions. The following chapters synthesize our review of the relationships among composition, structure, and functions of riparian ecosystems in the Pacific Northwest.

1.1.2. Riparian Ecosystems

WDFW has adopted the following conceptual definition of riparian ecosystems:

Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence).



Riparian ecosystem/Scott Fitkin, WDFW

Riparian ecosystems are sometimes referred to by different names: riparian areas, riparian zones, or riparian habitats. To compound confusion, the “riparian zone” is sometimes identified as a distinctive area within riparian ecosystems (Sedell et al. 1989; Naiman et al. 1992; Steiner et al. 1994). Some definitions include the adjacent waters whereas others do not. Unless stated otherwise, we consider riparian area, riparian habitat, riparian corridor, and riparian ecosystem to be synonyms. Furthermore, our definition of riparian ecosystem does not include adjacent waters (i.e., rivers or streams) and recognizes the riparian zone as a distinctive area within riparian ecosystems. The riparian zone contains wet or moist soils and plants adapted to growing conditions associated with periodically saturated soils.

Recent definitions reflect common conceptual understanding and identify similar composition, structure, and functions, including distinct plant communities and soil types; disturbance regimes unique to fluvial systems; gradients in soil, vegetation, and microclimate that manifest an ecotone between terrestrial and aquatic environments; and essential interactions between terrestrial and aquatic ecosystems. Riparian areas are the loci of terrestrial and aquatic interactions, however, the exact boundaries of riparian ecosystems can be difficult to delineate

because: 1) ecosystems are not uniquely identified entities (Karr 1996); 2) the environmental heterogeneity of riparian areas is expressed in a variety of plant life history strategies and successional patterns; and 3) some ecosystem functions depend on environmental setting (Naiman et al. 1998).

Following Naiman et al. (1998), our definition of riparian ecosystem includes the active floodplain, including riverine wetlands, and the terraces or adjacent uplands that directly contribute organic matter or large wood to the active channel or active floodplain (Figure 1.1 and 1.2). Terraces and adjacent uplands that contribute organic matter or large wood are located in the “zone of influence.” The active channel is defined by the lower limit of continuous riparian vegetation (Naiman et al. 1998), and it may be delineated by absence of both moss on rocks and rooted vegetation (USFS 2008). The upper most elevation of the active channel is sometimes equated with the ordinary high water mark. The active floodplain is located between the active channel and adjacent terrace or hillslopes (Fetherston et al. 1995; Harris 1987). Depending on the watershed, the flood return interval of the active floodplain varies between 1 and 10 years (Wolman and Leopold 1957; Ward and Stanford 1995; Lichvar et al. 2006; Williams et al. 2009; BLM 2015).

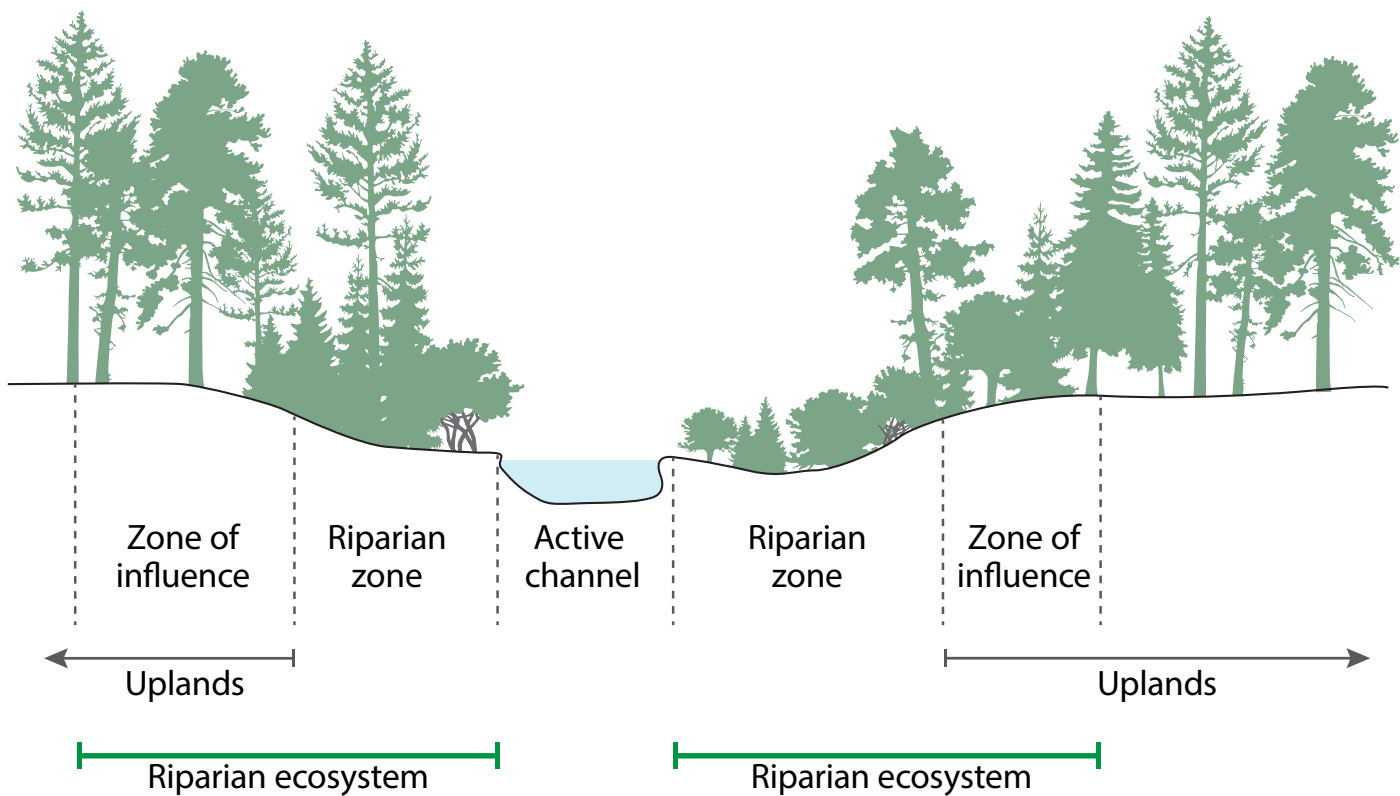


Figure 1.1. A generalized diagram of the riparian ecosystem. The NRC (2002) states that, "Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., the zone of influence)." The portion of the ecosystem characterized by moist soils and plants adapted to periodically saturated soils is the riparian zone. The width of the riparian ecosystem is typically based on riparian functions (i.e., wood recruitment to the stream in forested regions and the pollution removal function in dryland regions).

Riparian ecosystems are priority habitats in part because wildlife occurs more often and in greater variety in riparian areas than in any other habitat type. "Natural riparian corridors are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the earth" (Naiman et al. 1993). Although riparian ecosystems constitute a small portion of the surface landscape, approximately 85% of Washington's wildlife species are known to use riparian areas associated with rivers and streams (Knutson and Naef 1997). Of these, 170 species including 134 mollusks, 11 amphibians, 3 reptiles, 10 birds, and 9 mammals may be riparian obligates, i.e., require riparian habitat to survive (T. Quinn, unpublished). In addition, habitat for many upland and aquatic species is directly enhanced by

the presence of adjacent riparian areas. A principal reason for high fish and wildlife diversity is that riparian ecosystems are exceptionally productive. Riparian



Western Toad Anaxyrus boreas egg strings/Scott Fitkin, WDFW

ecosystems are characterized by the availability of water, milder microclimate, and relatively fertile soils. These factors enhance the productivity of plant communities and support a complex food web that includes a rich variety and abundance of fish, invertebrates, amphibians, plants, bacteria, fungi, reptiles, birds, and mammals (Cummins 1974; Johnson and Carothers 1982). It is not surprising then, that \$1.4 billion (57%) of \$2.5 billion spent to recover salmon in Pacific Northwest since 2000 has been directed at enhancing, restoring, and maintaining salmon habitat (e.g., large wood supplementation, riparian planting, fine sediment remediation, land acquisition) previously provided in large part by functioning riparian areas (NOAA 2015).

In addition to their essential role as fish and wildlife habitats, riparian areas provide other significant benefits to humans (Naiman and Bilby 1998; NRC 2002). Briefly, riparian areas help provide a variety of

ecosystem goods and services: provisioning services such as food and water; regulating services such as decreasing flood flows; supporting services such as nutrient cycling, sediment and pollutant filtering, and carbon sequestration; and cultural services such as recreational, spiritual, and other nonmaterial benefits (MEA 2005). These services provide real but often unquantified economic benefits to individuals and society; benefits that largely go unnoticed until they are lacking. According to the NRC (2002), protection and restoration of riparian areas should be a national goal because they have a major influence on achieving important national standards of the Clean Water Act, the Endangered Species Act, and flood damage control programs.

This document includes consideration of river-associated wetlands but does not consider other types of wetlands, which are covered by the Washington

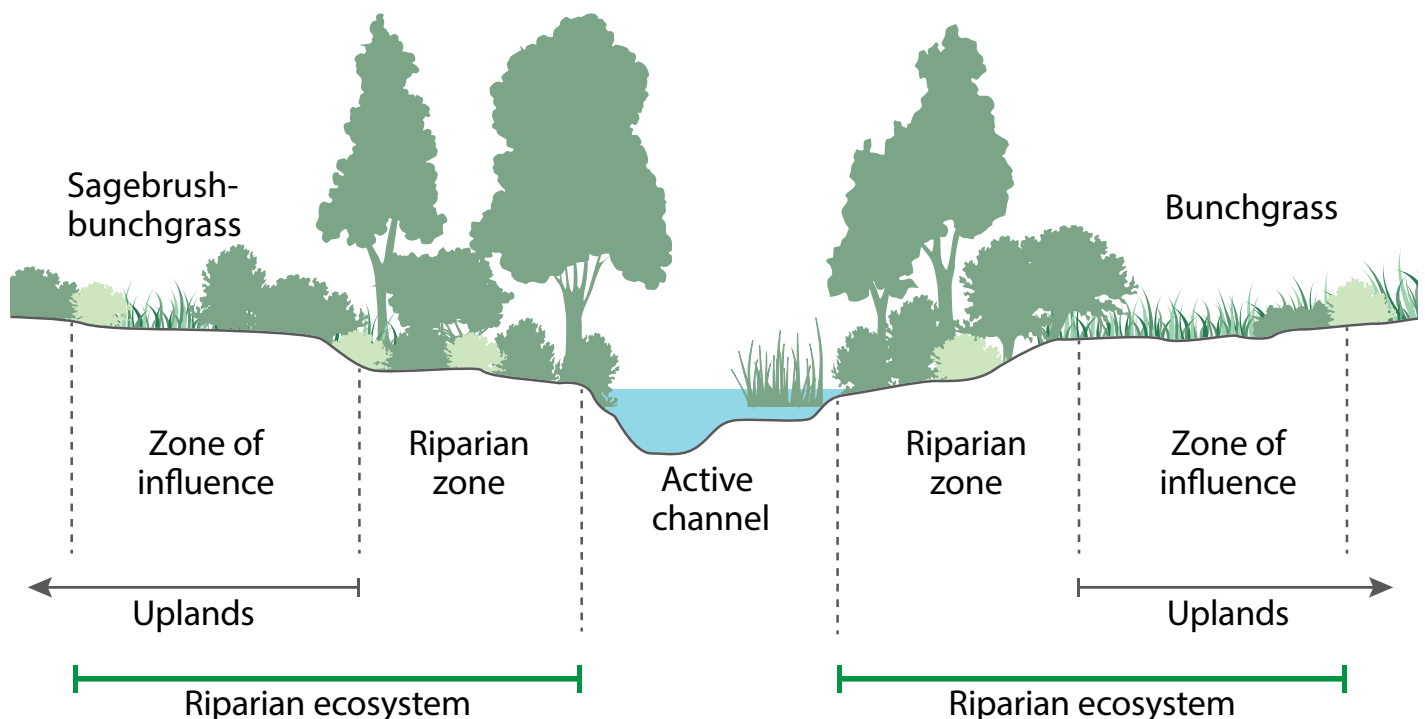


Figure 1.2. Dryland Riparian Ecosystem. The riparian ecosystem consists of two zones: riparian and zone of influence. The riparian zone extends from the edge of the active channel towards the uplands. This zone includes areas where terrestrial biota and soils are influenced, at least periodically, by surface or subsurface waters. Beyond this is the riparian "zone of influence." This includes areas where ecological processes significantly influence the stream (diagram modified from USFS 2004).

Department of Ecology, or areas bordering marine or estuarine (brackish) waters despite the potential applicability of this work to those environmental settings. A 2009 review of riparian functions of marine shorelines is available at <https://wdfw.wa.gov/publications/00693>.

1.2. Scope of Volume 1

1.2.1. Riparian Ecosystem Management

Riparian ecosystem management is often couched in terms of maintaining riparian functions thought to be important to fish and wildlife and their habitats (e.g., Bolton and Shellberg 2001, Everest and Reeves 2007). Some commonly identified riparian functions are described in FEMAT (1993) and the Forests and Fish Report (DNR 1999). The riparian ecosystem functions we discuss in this document, including some associated compositional and structural elements, are organized by chapter:

- Chapter 2. *Stream Morphology*—the interplay of water, sediment, and vegetation on channel form and riparian areas
- Chapter 3. *Wood*—effects of wood on channel morphology and habitat, and the recruitment of wood from riparian areas
- Chapter 4. *Stream Temperature*—effects of hydrology and shading on the thermal regime of streams
- Chapter 5. *Pollutant Removal*—the interception or filtration of fine sediments, excessive nutrients, pathogens, pesticides, and other contaminants in overland and shallow subsurface flows
- Chapter 6. *Nutrients Dynamics in Riparian Ecosystems*—dynamics and fate of the primary macro-nutrients: nitrogen, phosphorus, and carbon
- Chapter 7. *Riparian Areas of the Columbia Plateau*

- Chapter 8. *Watersheds*—relationship of watershed-scale management to the goal of achieving beneficial effects for fish and wildlife

Riparian functions are affected and in turn affect aquatic and terrestrial systems at multiple spatial scales. We focus much attention on riparian functions at the site (e.g., stream reach or land parcel) scale for three reasons. First, riparian areas are disproportionately important, relative to area, for fish and wildlife and other ecosystem services (Naiman and Bilby 1998; NRC 2002). Second, local governments and individual landowners, important users of WDFW's PHS guidance, typically manage at the parcel scale. Most land use activity, outside of public lands, occurs at the site-scale on ownership parcels that are relatively small compared to the watershed in which they occur. Third, effective and efficient conservation of fish and wildlife habitats requires management at multiple scales and thus good site-scale riparian management is an essential complement to good watershed management (Chapter 8), although approaches at different scales can vary dramatically.

1.2.2. Watershed Management

Even when all riparian functions are protected, rivers, streams, and riparian ecosystems are not immune to the effects of upland management. To varying degrees, riparian and stream structure, composition, and function reflect land uses and conditions throughout watersheds.

Regardless of its size, no ecosystem is entirely closed. Upslope activities can considerably alter the magnitude and timing of stream flows; the mobilization, routing, and storage of sediment, wood, and fine organic matter; and the quality of water, thereby influencing riparian ecosystem functions (NRC 2002; Figure 1.3). Thus, the management of riparian ecosystems at the site or reach scale should be considered just one important part, not

the sole requirement, of holistic watershed management for the protection of fish and wildlife and other values. We include Chapter 8, which focuses on watershed-scale issues that are important to the management of aquatic systems as a whole, with the intent of increasing

the effectiveness of collective riparian conservation efforts. This chapter provides a conceptual framework that identifies the key watershed processes and their primary influences by, on, and through riparian areas and adjacent watercourses.

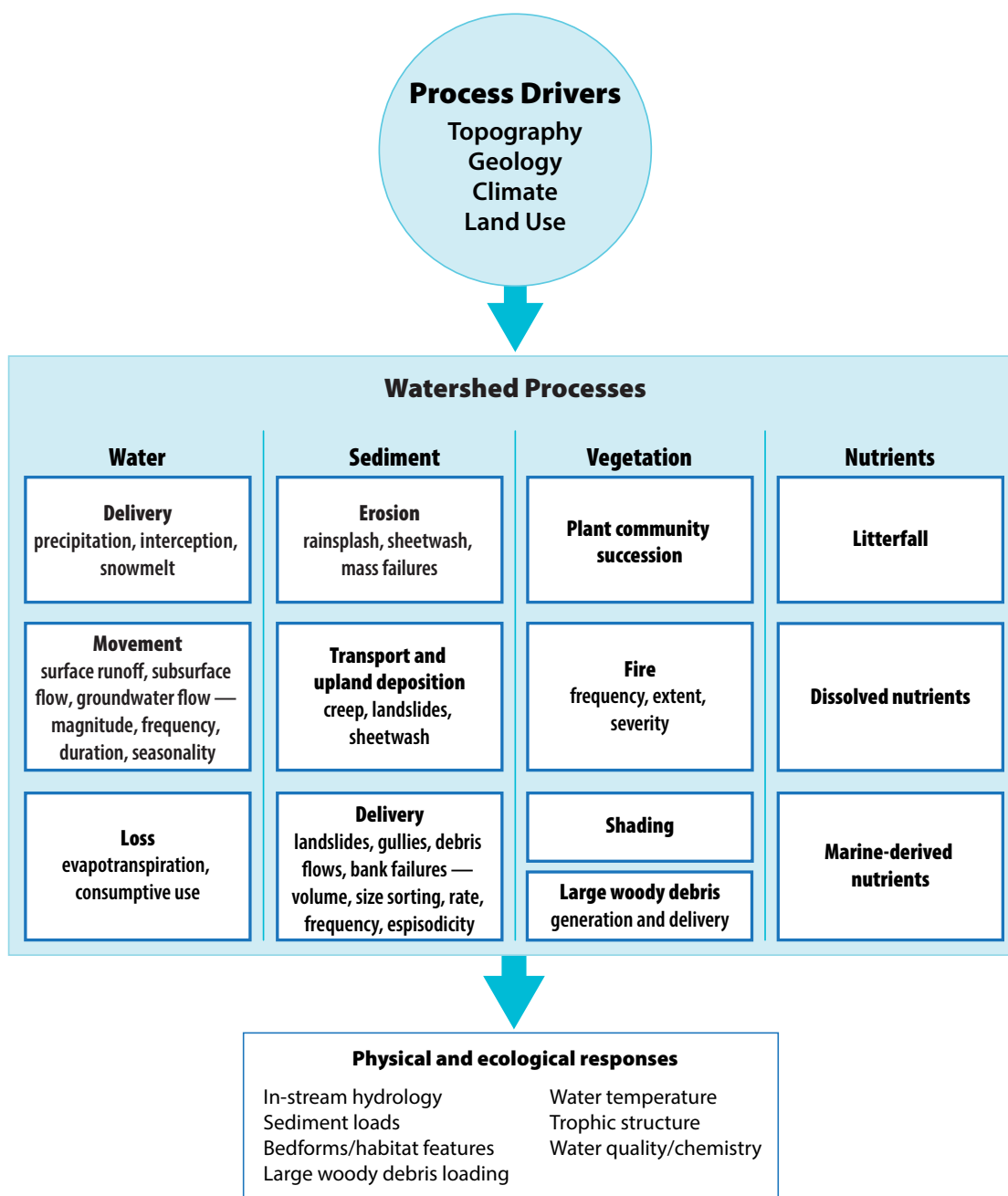


Figure 1.3. Conceptual framework for the hierarchical relationship of invariant, large-scale “process drivers,” the suite of watershed processes that are determined by these drivers, and the instream physical and biological responses to those processes. Multiple additional interactions between elements and levels are not shown on this diagram to emphasize the primary influences; but in any given setting, one or more of these secondary interactions may temporarily achieve equivalent importance. This framework embraces the definition of watershed processes from Stanley et al. (2011): “[t]he dynamic physical and chemical interactions that form and maintain the landscape and ecosystems.”



Devil's Club *Oplopanax horridus* is common in wet soils of western Washington riparian areas/Ned Pittman, WDFW

1.2.3. Science Synthesis

Chapter 9, *Science Synthesis to Management Implications*, of this volume summarizes important scientific finding from chapters 1-8 and provides a brief discussion of scientific themes that can inform thoughtful approaches to protecting aquatic systems.

1.2.4. Scope: Protection and Restoration

Protection and restoration of riparian ecosystems and watersheds are both essential for Washington's fish and wildlife, and especially for endangered and threatened salmonids. However, planning, management practices, regulations, and legal context for protection are different from those for restoration, and thoroughly covering both topics was beyond our scope. Thus, restoration is not explicitly incorporated in the scope of this document. Nevertheless, much of the science presented in this document can inform restoration activities. For instance, while this document does not review scientific literature on instream large wood placement, a common restoration activity, it does summarize large wood recruitment and reference conditions for the amount and size of instream large wood. Thus, the body of science that informs protection also helps to inform restoration, at least in terms of establishing resource goals and objectives.

1.3. Document Development

We employed the following approach to developing this document. We first established a Technical Advisory Group (TAG) of scientists from the region. Second, with guidance from the TAG, we conducted a literature review designed to inform the general state of knowledge regarding ecosystem protection and another literature review more focused on recent developments in riparian ecology and management. Third, we contracted with regional topic experts to author and co-author chapters. WDFW staff provided conceptual and technical guidance as possible. Finally, we subjected the draft final documents to several rounds of peer review. Each of these steps is discussed below.

1.3.1. Technical Advisory Group

The TAG helped provide overall science guidance, that is, contribute expertise and scientific perspective, provide important references and other sources of information, and review draft products. The TAG was composed of 13 individuals who were selected by virtue of their scientific expertise as opposed to affiliation with particular organization or stakeholder group. However, given the broad potential applicability of this document, it is conceivable that TAG members belong to one or more stakeholder groups. All TAG members were expected to attend three all-day meetings over the course of the project. Members of the TAG volunteered their time, except one who was paid a small stipend because she was employed by a non-profit organization. The first meeting was designed to introduce TAG members to the nature of the PHS update, to discuss different approaches to conducting a literature review and synthesizing new scientific information, and to

secure their ongoing commitment to helping WDFW meet high scientific standards. The second and third TAG meetings were designed to solicit review and feedback from TAG members on draft products. As part of their review process, we invited all TAG members to edit draft chapters and provide additional citations for WDFW's considerations. Although the TAG played a key role in advising WDFW on the science of riparian management and conservation, WDFW bears sole responsibility for the contents of this document.

1.3.2. Literature Review

We organized summaries around ecological functions including stream channel morphology, wood, pollution removal, nutrients, water temperatures, and watershed processes. Note that many of the issues we address here are directly or indirectly related to fish and wildlife habitats and other ecosystem services. We did not, however, explicitly consider cultural services that are important values for many stakeholders (e.g., spiritual, cultural and aesthetic values of riparian areas).

We enlisted the assistance of scientists with specific areas of expertise as technical advisors, authors, and informal and formal reviewers to help ensure that our summaries of pertinent scientific information were sufficiently accurate and inclusive. We were most interested in characterizing the state of knowledge and important, recent findings about each topic. That is, we tried to assess what we know, how well we know it, and what we do not know. The summary statements in each chapter are important to the development of management recommendations because they often identify important management challenges that are not well described in the published literature (e.g., the importance of habitat connectivity to fish population persistence). To this end, when appropriate, we encouraged authors to consider the broad body of scientific information and how it might be extrapolated to unstudied locales; in other words, to consider the

body of literature with regard to our ability to make reliable predictions.

Where information existed and as time allowed, we also attempted to summarize how riparian composition, structure, and functions differ among natural plant communities. In most cases, we used the broadest division called Major Vegetational Areas, which is made up of two groups in Washington State, i.e., Forested Regions and Steppe Regions (Franklin and Dyrness 1988). Regions can be further subdivided into forested zones (e.g., *Tsuga heterophylla* Zone) and steppe communities (e.g., shrub-steppe with *Artemisia tridentata*) that contain similar climax plant communities influenced by similar disturbance regimes. When information was available, for example, in the case of large wood in forested regions, we report that information at the finer division within the vegetation classification.

In addition, and as time and resources allowed, we summarized some potential effects of common land use activities on stream and riparian areas as a precursor to providing useful land use advice. We considered four general categories of land use: 1) urban, which includes commercial, industrial, urban, suburban, and rural development, 2) agricultural, which includes cultivated crops and grazing uses, 3) forestry, which includes timber management and associated activities such as

Chapter 9 summarizes scientific findings from chapters 1 through 8 and includes a brief discussion of scientific themes that can inform thoughtful approaches to protecting aquatic systems.

road building and maintenance, and 4) other activities (e.g., mining), which were not discussed due to the paucity of available research results.

We started this work by assembling topical literature reviews including Bolton and Shellberg (2001), Pizzimenti (2002), Bezener and Bishop (2005), Mayer et al. (2005), and Naiman et al. (2005). We compiled relevant literature cited in these review articles, from other reference materials we encountered, and from recommendations of TAG members. We also did an extensive literature search on computerized databases. We mostly focused our literature search on peer reviewed articles published after 1993, published in English, and conducted in proximity to Washington State. This last criterion was designed to focus on studies thought most relevant to Washington State's ecological conditions.



The North Fork Skokomish River runs through mature conifer forests of the Olympic National Park/Tim Quinn, WDFW

We also documented the type of review the study received according to RCW 34.05.271 (Appendix 1). Studies with no record of review were not considered further. As we (authors) reviewed the published literature, we noted important study findings that we believed would be especially useful for writing the PHS document. For empirical studies, our notes typically included the primary research questions or objectives, key results, management implications, and study limitations or assumptions. For literature reviews and syntheses, our notes summarized main conclusions by subject area. The intent here was to capture a sufficient level of detail for each paper so that we could use our collective notes as sources for writing the synthesis.

We found a massive quantity of literature related to riparian and watershed science despite focusing on information published after 1993. Due to the sheer volume of information, we could not cover all the literature in depth, so we covered those topics that were most relevant for management of riparian areas in Washington State. This document provides a comprehensive review on the current state of the science regarding certain riparian functions. Further, as described above, we enlisted the services of experts with specific areas of expertise as technical advisors, authors, and informal and formal reviewers to help ensure that our summaries of pertinent scientific information were sufficiently accurate and inclusive.

1.3.3. Peer Review

The peer review for Volume 1 consisted of a series of iterative steps, wherein we tried to gain as much agreement about the science synthesis as possible among those involved in the writing and reviewing process. Our intent was to provide the best available science. As described above, the TAG reviewed and often edited incomplete chapter drafts during the literature review and synthesis stage of the project. These draft syntheses were then given to topic experts to complete.

In cases, where WDFW lacked sufficient topic expertise, we provided stipends up to \$10,000 to outside authors (i.e., contractors) for completing a chapter. The steps involved in completion of drafts included adding one or more conceptual models describing the system and its functioning and a synthesis or summary of the important findings over the last approximately 20 years. These steps often entailed a series of editing and reediting by WDFW staff and contractors. Once completed by contractors and returned to WDFW, the drafts were reviewed a final time by TAG members. This last review by TAG members was to ensure that completion of the chapters was consistent with their earlier guidance and with their understanding of the literature. WDFW attempted to resolve all disagreement that occurred between contractors and TAG members and provided a written description of how those issues were resolved to both the contractor and the TAG. After final WDFW review, the document was submitted for review by the Washington State Academy of Sciences (WSAS).

We enlisted the WSAS to conduct the final, independent peer review of the PHS document. Modeled after the National Academy of Science, which is charged with providing independent, objective advice to the nation on matters related to science and technology, the WSAS provides expert scientific analysis to inform public policy making at the state level (WSAS 2015). The final peer review with the WSAS was also iterative. That is, WDFW in consultation with authors and TAG members, addressed WSAS comments, made appropriate changes to the document, and then discussed those comments with the WSAS in an attempt to resolve differences. This process proceeded until we reached agreement about scientific contents and conclusions.

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Chapter 2. Stream Morphology

By: Jane B. Atha, Mike Liquori, Kirk L. Krueger, George F. Wilhere, and Timothy Quinn

2.1. Introduction

The composition, structure, and functions of lotic systems are largely due to dynamic interactions of water, sediment, wood, and riparian vegetation. The nature of these interactions is affected by topography (e.g., channel slope), flow regime, sources and characteristics of sediment, the size, strength, and density of riparian vegetation (Naiman and Bilby 1998), and the actions of some animal species, most notably the American Beaver *Castor canadensis* and salmon. The influences of water and channel slope on sediment results in channel patterns (i.e., straight, meandering, braided) (Leopold and Wolman 1957) and geomorphic zones (i.e., source, transport, depositional) (Schumm 1977) that occur somewhat predictably from headwaters to river mouth. Furthermore, variation in fluvial processes (e.g., frequency and intensity of floods) and controls (e.g., lithology, large wood, riparian vegetation) result in a wide range of channel forms or reach types that are often described based on their bedform (e.g.,

slope, sinuosity, distribution of sediment sizes, etc.) (Montgomery and Buffington 1997). These channel forms can be useful descriptors of aquatic species' habitats. Tributary junctions (Kiffney et al. 2006), natural disturbances (Frissell et al. 1986), and artificial structures (Stanford and Ward 2001) can create discontinuities in these general patterns.

The composition and structure of riparian vegetation affects channel morphology, which in turn affects riparian vegetation (Hupp and Osterkamp 1996; Corenblit et al. 2007; Osterkamp and Hupp 2010; Gurnell 2014). Additionally, channel morphology and the processes that shape it can be impacted by human activities (e.g., levees, dams, Beaver trapping), usually resulting in loss of habitats, reduced habitat diversity, and diminished habitat functions for aquatic species. Management actions such as bank armoring, channelization, and riparian vegetation removal tend to reduce natural variability of geomorphic processes, often amounting to stream habitat degradation greater than the sum of its parts.



Yakima River/Justin Haug, WDFW

Knowledge of the fluvial processes that affect riparian and aquatic systems is important for making sound policy and management decisions. This chapter provides an overview of water and sediment in fluvial processes, their interactions with riparian vegetation, and potential alterations of fluvial processes by human activities. We first describe a general conceptual model for considering how physical processes affect channel morphology. Next, we describe stream flow and sediment processes in more detail. We then consider the watershed-scale context that directly influences fluvial processes. Lastly, we review impacts of human activities on stream functioning, introduce the “riverscape” concept for the management of fish habitats, and describe some physical stream habitat associations of herpetofauna. Some related topics are discussed in other chapters. For example, see Chapter 3 for a description of fluvial process interactions with large wood and Chapter 8 for a thorough examination of influences and management that occur at the watershed scale.

2.2. Conceptual Context

The concept of equilibrium is one of the most important ideas in fluvial geomorphology (Thorn and Welford 1994; Grant et al. 2013). The equilibrium concept posits that rivers tend to work toward long-term equilibrium (Gilbert 1877 as cited by Grant et al. 2013). *Dynamic equilibrium* describes a state of relative stability that results from the interaction of opposing forces (e.g., flowing water and substrate resistance). That is, over the long term and assuming that process drivers like climate and land use remain

unchanged (see Chapter 8), overall progression of the composition and structure of stream reaches in a watershed remains largely unchanged. A stream network may undergo significant changes during an extreme flood event, and yet return to equilibrium as smaller flows rework the sediment distributed by floodwaters to re-establish roughly the same relative abundance of stream reach types that existed prior to the flood event.

Lane (1955) conceptualized equilibrium within a stable channel as a balance among stream discharge, channel slope, sediment load, and sediment size (Figure 2.1). Lane’s conceptual model was described by Heede (1980) as:

$$Q_s D \propto Q_w S$$

where Q_s is sediment load (i.e., sediment discharge), Q_w is water discharge, D is sediment size, and S is channel slope.

What remains “in balance” over time are the processes of streambed degradation (erosion) and aggradation (sediment deposition). If an increase occurs in stream discharge, for instance, then the resulting increase in stream power can cause an increase in streambed degradation. The channel “adjusts” by decreasing channel slope, which reduces stream power and causes a return to the balance between degradation and aggradation. If a shift in stream discharge or sediment supply occurs, then the channel returns to equilibrium through adjustments in one or more other variables. However, persistent changes in one or more variables of sufficient magnitude may exceed a threshold that causes an abrupt shift to a new equilibrium state (Schumm 1979).

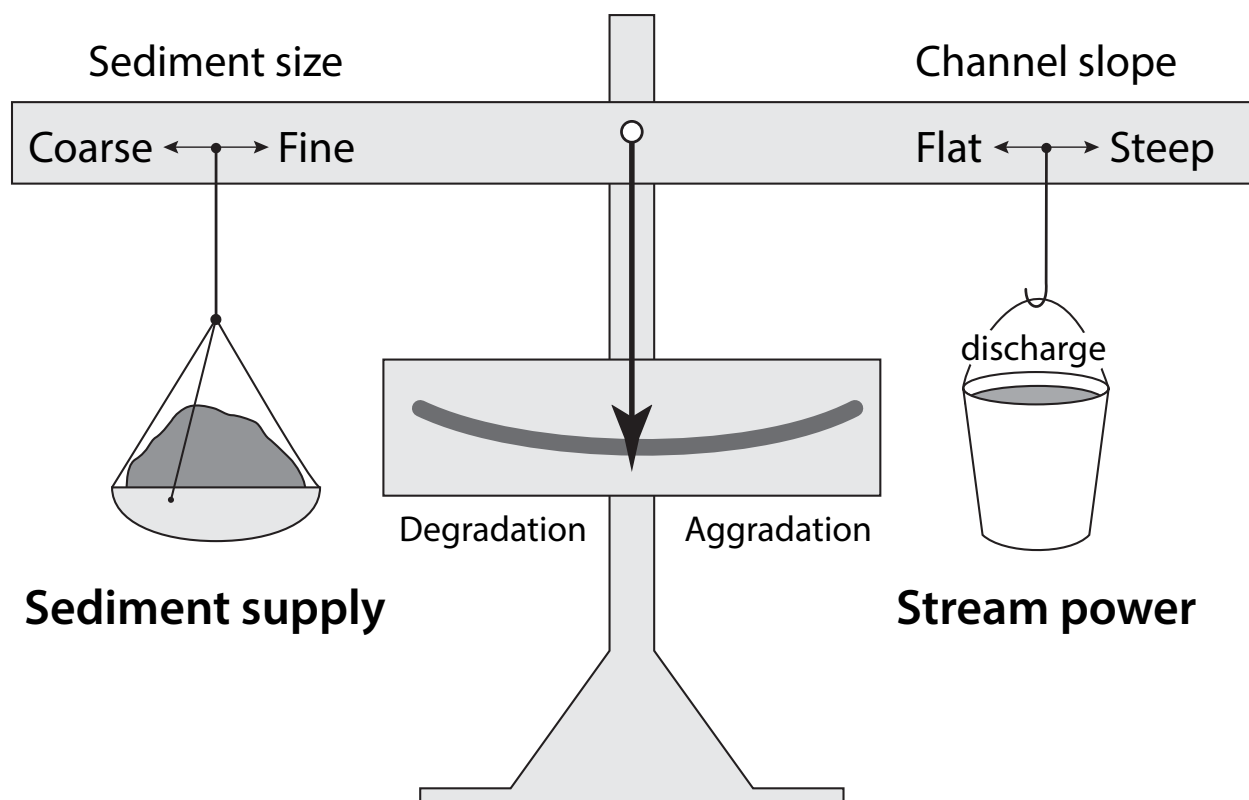


Figure 2.1. Lane's Balance illustrating the concept of channel adjustment (i.e., vertical aggradation or degradation of the streambed) in response to changes in water or sediment yield (from Dust and Wohl 2012).

While Lane's Balance is a useful conceptual model, it does not address complexity at the watershed scale nor the interactions between fluvial processes and riparian vegetation that affect channel morphology (Corenblit et al. 2007; Gurnell 2014) (Figure 2.2). These interactions are reciprocal and feedbacks exist between fluvial processes and vegetation composition and structure (Hupp and Osterkamp 1996; Osterkamp and Hupp 2010). Vegetation influences channel form and channel forming processes help shape riparian plant communities. Human activities that alter these interactions can cause significant changes to channel morphology and fish habitats.

Many geomorphic and ecosystem processes are coupled and occur in parallel at similar spatial and temporal scales. This results in mutual dependence between processes (Renschler et al. 2007). While such processes have received much attention from the scientific

community in the last fifteen years, a theoretical synthesis within a holistic conceptual framework is still needed to address how riparian management interacts with this complex system (Smith et al. 2002; Stallins 2006). Interdisciplinary research of these interactions could result in better predictability of impacts caused by management. From an ecosystem management perspective, the choice of spatiotemporal boundaries—often dictated by geomorphic processes—is of profound importance to conceptualization of the system and its ecologic processes (Post et al. 2007).

We frame the hydrologic and physical processes as they shape the riverscape from the context of equilibrium and mutual dependence among water, sediment, and vegetation.

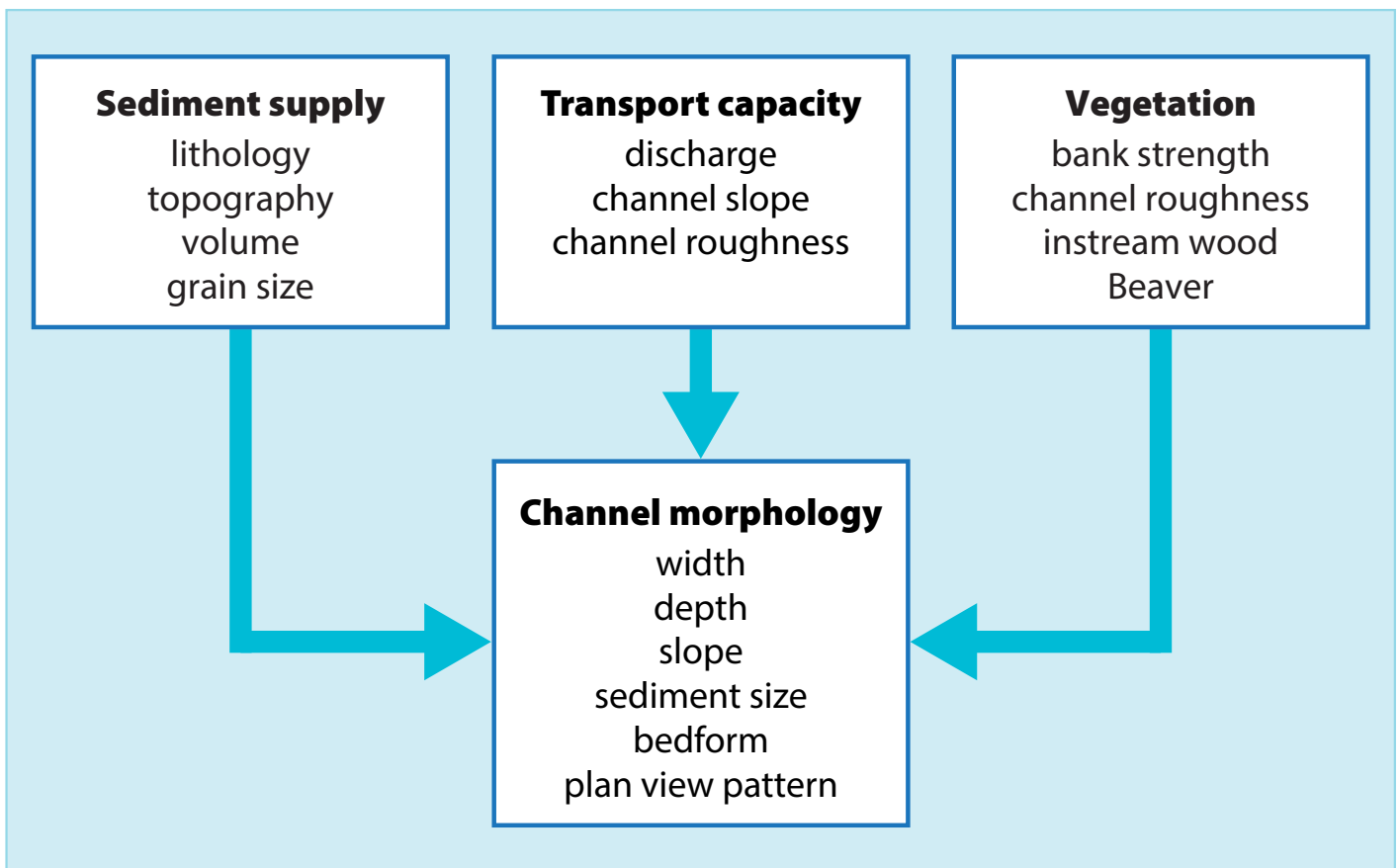


Figure 2.2. Influences on channel morphology (modified from Naiman and Bilby 1998).

2.3. Streamflow Processes

The pathways that water takes to reach a river exert a strong influence on the amount and timing of streamflow in the channel (Figure 2.3). Differences in the relative contributions of these pathways among locations and seasonal variability (e.g., presence or absence of snow) in environmental conditions produce a wide range of stream flow responses to precipitation events.

The fate of precipitation that is not lost through evaporation and transpiration is highly dependent on soil cover. Rain or melted snow that infiltrates the soil can flow downslope in the vadose zone (unsaturated),

above the water table as through flow, or below the water table as groundwater in the phreatic zone (saturated).

When precipitation rates exceed soil infiltration rates (Horton 1933) or when local soils are saturated (Dunne and Black 1970a, 1970b; Dunne 1978), water moves downslope as surface runoff. Surface runoff or overland flow remains outside the confines of a channel, and is most common where vegetation is sparse. Human activities that compact soil or destroy permeable, near-surface soil layers reduce infiltration capacity and promote overland flow. A second type of runoff, saturated overland flow, occurs at convergent zones (such as hillslope concavities) and is a combination of direct precipitation onto saturated areas and return flow from the subsurface as it becomes saturated (Wohl 2014) (Figure 2.3).

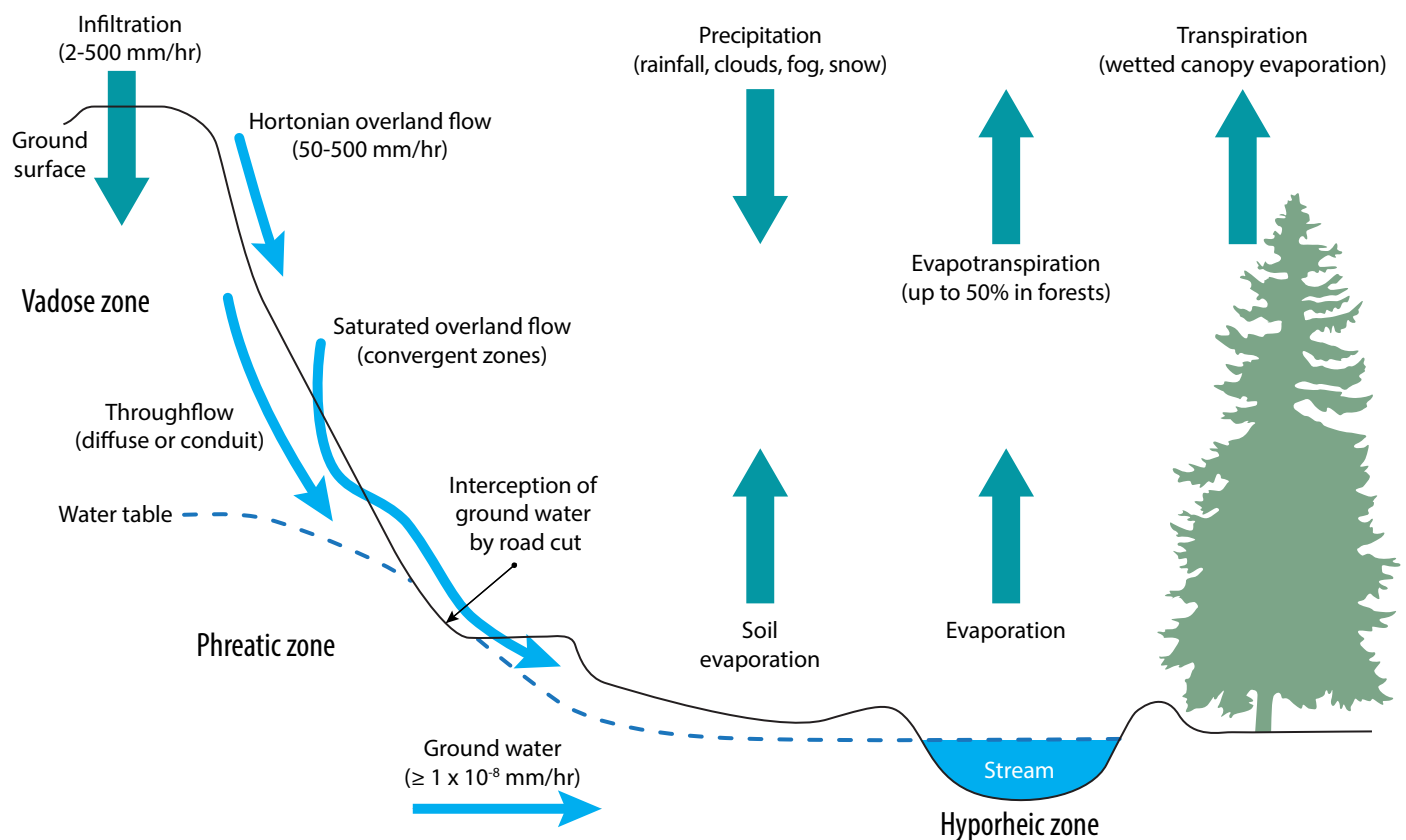


Figure 2.3. Illustration of different types and rates of downslope movement of water on a hillslope (modified from Ziemer and Lisle 1998, and Wohl 2014).

Runoff originates from variable source areas in response to precipitation and soil saturation conditions (Betson 1964; Hewlett and Nutter 1970). Conceptually, the amount of runoff within a single small drainage basin can be highly varied in space and time because many factors influence water infiltration and movement. Much of the variability in areas contributing water to the channel reflects the groundwater levels and activation¹ thresholds for lateral subsurface flow existing immediately after a precipitation event (McDonnell 2003).

Riparian vegetation influences preferential flow pathways in both surface and subsurface environments (Swanson et al. 1998; McDonnell 2003) and the manner in which surface flows create and maintain channel and floodplain morphology. During periods of active runoff, riparian areas quickly become saturated, and become

the first areas within the watershed to contribute runoff into the channel (McDonnell 2003). Riparian areas account for the majority of the runoff at the beginning of a flood event, whereas hillslopes contribute more as the runoff tapers off at the end of an event. Flow resistance provided by riparian vegetation and related organic material slows water velocities, reduces peak discharge, and lengthens a flood's duration (Tabacchi et al. 2000; Nilsson and Svedmark 2002).

In a reciprocal manner, stream hydrology plays a large role in shaping riparian vegetation communities. The rate at which the river water surface lowers after a spring freshet influences seedling germination and recruitment (Mahoney and Rood 1998). Thus vegetation species composition and age structure vary due to flow frequencies that determine sediment mobilization and effective discharge (Pike and Scatena 2010).

¹ Activation of subsurface water means that subsurface water is flowing, i.e., the velocity deviates significantly from zero. Activation threshold often refers to the amount of precipitation needed to activate subsurface flow.

Interactions between stream water and groundwater occur in the hyporheic zone. In other words, the *hyporheic zone* is the ecotone between a surface stream and deeper groundwater (Boulton et al. 1998). The extent of the hyporheic zone is determined by the volume of sediment stored within the channel and active floodplain (Moore and Wondzell 2005). Two-way exchanges of water occurring in the hyporheic zone are important in regulating hydrological, biogeochemical, and thermal processes (Krause et al. 2011), which strongly influence the volume, chemistry, and temperature of streamflow. Along this ecotone, upwelling subsurface water supplies the stream ecosystem with mineral nutrients while downwelling stream water provides dissolved oxygen and organic matter to organisms inhabiting the interstitial spaces of alluvial sediments (Boulton et al. 1998). The hyporheic zone can account for a fifth of the invertebrate production in an aquatic ecosystem (Smock et al. 1992). Water flows laterally from the hyporheic zone into alluvial sediment deposits, and can extend out more than 1.2 miles (2 km) in wide valleys and to depths of 33 ft (10 m) (Stanford and Ward 1988). Hyporheic flows can also affect riparian vegetation, although the interactions between riparian communities and hyporheic conditions are not well understood (NRC 2002).



Cape Creek, Lane County, Oregon/Jane Atha, WDFW

2.4. Erosion and Sedimentation Processes

2.4.1. Sediment Sources and Delivery

Sediment sources and delivery within a watershed can vary significantly depending upon geology, climate, landform, soil erodibility, vegetation, and the magnitude and frequency of dominant disturbances. Delivery of sediment to channels by surface erosion is generally low in undisturbed watersheds, but can vary greatly by year (Swanston 1991). Annual differences are caused by variation in weather patterns, changes in exposed surface area, and changes in the amount of erodible material. Sediment can move downslope in aggregates through mass wasting (mass movement, mass failure, or slope movement) categorized as landslides, debris flows, or heaves. Mass wasting events are typically seasonal as a function of soil moisture and freeze-thaw processes (Hales and Roering 2009). Soil on a hillslope will remain stable if the sum of the applied shear stresses does not exceed the sum of the shear strengths of slope materials (soils, roots, etc.). Mass wasting is initiated when shear stress on a material exceeds its shear strength threshold (Ritter et al. 2002). The volume of material generated from hillslope mass wasting events can be very large, and is often the predominant source of sediment and large wood delivered to streams in the Pacific Northwest (Swanson et al. 1982).

Sediment can also move downslope through gradual, diffuse processes such as rainsplash and rills that form from overland flow. Rainsplash takes place when raindrops loosen the soil particles making them more



Skagit Valley agriculture/Jane Atha, WDFW

susceptible to entrainment by overland flow (Furbish et al. 2009; Dunne et al. 2010). Overland flow can be concentrated into small, narrow, shallowly incised micro-channels that are carved into hillslope soils (Selby 1993). These channels, termed rills and gullies (with gullies being deeper) can form effective conduits for sediment erosion into stream channels (Wohl 2014).

Sediment delivered from riparian areas can be generated by mechanisms other than direct streambank erosion. Riparian sediment sources can be associated with treefall that results in the uprooting of trees (root throw; Hairston-Strang and Adams 2000; Liquori 2006). The primary causes of treefall include wind along newly created edges in riparian forest (Liquori 2006; Reid and Hilton 1998), undercutting streambank erosion, and large-scale disturbances such as fire or pest infestation. Root throw can provide direct sediment inputs to the channel (Lewis 1998; Reid and Hilton 1998; Gomi et al. 2005). Harris (1977) found that windthrow-related sediment production along a stream in coastal Oregon was responsible for 33 tons of sediment per mile of

stream per year (18.6 metric tons per kilometer per year) (as cited in Gomi et al. 2005).

Riparian vegetation can effectively trap and store sediment transported downslope from overland flow (Naiman et al. 2010). This topic is fully explored in Chapter 5, Pollutant Removal. Once the sediment is deposited in riparian areas, plant roots facilitate stabilization and continued storage of sediment (Allmendinger et al. 2005; Tal and Paola 2007).

2.4.2. Instream Sediment Transport and Deposition

Sediment that has entered the stream channel can be transported downstream as dissolved load, suspended load, or bed load. Dissolved load carries sediment within solution, which can be substantial in some rivers (Knighton 2014). The concentration of solute is highest in water entering the channel through subsurface pathways because slower rates of subsurface water

movement allow for longer reaction times with the surrounding environment. Solute concentrations through subsurface pathways tend to lessen with greater discharge (Wohl 2014). Suspended load refers to sediment carried as suspended particulates in the water, and originates predominantly from bank erosion and surface erosion from upland areas. The finest size fractions of suspended transport, known as wash load, are more likely to be supply limited, i.e., the amount in transport is limited by the amount available. In contrast, the coarser bed load, which consists of larger rocks that bounce along the channel bed, is typically limited by transport capacity of flowing water (stream energy). Bed load may not get suspended; it can roll and slide during low flows, saltate (bounce) at intermediate flows, and move as sheetflow during high flows (Wohl 2014). Bed load transport processes are surprisingly complicated because many factors, some of which interact, determine the threshold for movement. These factors include the range of sediment sizes, their spatial arrangement, and channel form within a reach (Knighton 1984).

Bedforms are bed undulations that result from sediment transport and deposition. Montgomery and Buffington (1997) classified stream channels based on common bedforms (i.e., cascade, step-pool, plane-bed, pool-riffle, and dune-riffle), their dominant sediment transport process, and behaviors of debris flows and instream wood. The role that sediment plays in aquatic habitat can differ dramatically among those classes. For example, sediment in headwater channels (often classified as cascade or step-pool) tends to be stored behind boulder and wood obstructions. In lower gradient channels, sediments become sorted into pools and riffles depending on instream wood load, gradient, and a wide variety of other factors (Benda et al. 2005; Gomi et al. 2005).

All bedforms are depositional features. Deposition occurs when the flow or shear velocity in the stream falls below the settling threshold velocity of the sediment particle. Settling thresholds are lower than entrainment

thresholds, and deposition can be localized or extended across a channel length depending on fluctuations in flow velocity (Wohl 2014). Riparian vegetation can be especially instrumental in facilitating deposition within channels and along banks (Tal et al. 2004). Establishment of riparian vegetation can initiate a positive feedback process as plants trap and stabilize sediments and organic matter that provides sites for germination of plants, which can then reinforce the development of floodplains, instream islands, and other landforms.

Erosional forces in the streambed can be increased due to topographic constrictions or locally steep gradients. Where hydraulic forces overcome surface resistance, channel incision can occur (Wells et al. 2009). Channel incision that occurs at the channel head, known as a headcut, results in vertical faces that separate upslope unchanneled environments from downslope channels. Headcuts that destabilize or incise an otherwise stable channel bed result in significant increases in sediment yield (Meyer et al. 1975; Bryan 1990). Headcuts can also occur as an upstream-migrating “step” in the channel bed that forms as a result of hydraulic scour, often from manipulations to the channel or flow conditions (e.g., culverts, diversions, etc.). This type of headcut can migrate upstream and change channel form for long distances.

Establishment of riparian vegetation can initiate a positive feedback process as plants trap and stabilize sediments and organic matter that provide sites for germination of plants, which can then reinforce the development of floodplains, instream islands, and other landforms.

A combination of field, experimental, and theoretical research has dramatically advanced our understanding of sediment transport dynamics as well as the role of vegetation in stream morphology. Sophisticated flume experiments and computational models have confirmed the importance and complexity of interactions among water, sediment, wood, and vegetation (Gurnell 2014). Recent modeling efforts have placed these phenomena on solid theoretical footings and have allowed researchers to explore scale dependence. We know much less about these interactions at small scales (single plant), however, understanding smaller scale phenomena is crucial to fully understanding longer-term and larger-scale geomorphic form and process (Gurnell 2014).



Bank erosion along the upper Chehalis River/Jane Atha, WDFW

2.4.3. Streambank Erosion

Streambank erosion is a geomorphic process that is integral to a watershed's natural disturbance regime and necessary for long-term ecological sustainability (Florsheim et al. 2008). Bank erosion is a key process for maintaining the structural diversity of aquatic and riparian habitats; it initiates community succession that promotes ecological diversity of riparian areas, and contributes coarse sediment to streambeds that is an essential habitat element for benthic invertebrates and spawning salmon. Bank erosion commonly occurs on the outside of river bends, but it can also occur in straight channels where changes in water or sediment supply cause channel incision. Instream large wood or mid-channel gravel bars that divert flows toward a bank (Florsheim et al. 2008) can also cause bank erosion. Local bank erosion is a naturally occurring process that is often indicative of a channel in dynamic equilibrium. Despite this fact, bank erosion at any scale is commonly misinterpreted as a sign of channel instability. Human disturbances can increase rates of bank erosion, and thus, understanding whether bank erosion is triggered by human activities or natural geomorphic processes is important for site-scale management (Polvi et al. 2014).

Two types of processes result in bank erosion: fluvial erosion and mass wasting (ASCE 1998). Fluvial erosion is the separation of sediments from a streambank's surface by the forces of flowing water. Fluvial erosion may destabilize riparian vegetation by exposing plant roots or undercutting vegetation (Florsheim et al. 2008). Fluvial erosion can eventually lead to mass wasting ("bank failure"). Mass wasting at streambanks is caused by scour of the streambed and bank toe that increases bank height and angle. When gravitational forces on the bank (weight of soil, water, and overlying vegetation) exceed the shear strength of the bank material, a portion of the bank collapses along a failure plane (Simon et al. 2000). Both types of bank erosion occur mainly during peak flows, but the association between flow magnitude and amount of bank erosion varies greatly among



Building in danger from streambank erosion on Newaukum River/Kaysie Cox, WDFW

watersheds. Wolman (1959, as cited in ASCE 1998), for instance, reported that significant bank erosion on a creek in Maryland occurred more than ten times per year during relatively small but frequent peak flow events. Studies of other alluvial systems have found that significant bank erosion was caused mostly by large floods with recurrence intervals of decades or more (ASCE 1998).

The stability of streambanks is influenced by soil characteristics, groundwater, and vegetation (Hickin 1984; NRC 2002). Mass wasting failure mechanics, for example, are quite different for cohesive and noncohesive soils (ASCE 1998). Adjacent surface waters or ground water affects pore water pressure, and positive pore water pressure destabilizes banks by reducing cohesion and friction amongst soil particles. Water in soil also adds mass, thereby increasing gravitational forces acting on a streambank. Bank failure often occurs shortly after flood waters recede because soils are at or near saturation and the laterally confining hydraulic pressure of the floodwaters decreases to zero (Rinaldi et al. 2004).

Vegetation may have mechanical and hydrologic effects on bank stability, and these effects can be stabilizing or destabilizing (Simon and Collison 2002; Langendoen et al. 2009; Pollen-Bankhead and Simon 2010). Soil is generally strong in compression, but weak in tension. Woody and herbaceous plant roots are strong in tension, but weak in compression. Consequently, the root-permeated soil of streambanks behaves as a composite material with enhanced strength (Simon and Collison 2002; Pollen and Simon 2005). However, the additional bank strength provided by roots is species dependent (Polvi et al. 2014). Simon et al. (2006), for instance, found that Lemmons's Willow *Salix lemmonii* provided an order of magnitude more root reinforcement of streambanks than Lodgepole Pine *Pinus contorta*. Dense root networks also physically restrain or bind soil particles. In addition, exposed roots on the bank surface increase channel roughness, which dampens stream flow velocities, thereby reducing fluvial erosion (Griffin et al. 2005; Gorrick and Rodríguez 2012). In fact, fluvial erosion of well-vegetated banks is 10 to 100 times less than erosion of unvegetated banks (ASCE

1998). Reduction of stream velocities by roots may also cause sediment deposition, which further stabilizes streambanks.

Vegetation has destabilizing mechanical effects as well (ASCE 1998; Simon and Collison 2002). The weight of vegetation adds a “surcharge”² load to soil. Hence, the weight of vegetation increases the vertical shear stress near a streambank and adds to the lateral earth pressure³ at the streambank surface, however, these effects can be minimal relative to soil’s weight (Simon et al. 2006). Additionally, tall, stiff vegetation may impose destabilizing forces on streambanks during windstorms (ASCE 1998).

The hydrologic effects of plants on streambank stability are those that influence soil moisture. Through canopy interception, vegetation reduces the amount of precipitation that reaches soil. Transpiration, which extracts water from the soil column within the root zone, creates negative pore water pressures (matric suction) that increase soil shear strength (Simon and Collison 2002). Plants destabilize streambanks by facilitating infiltration of water into soil via flow pathways (“macropores”) created by live and decayed roots. In addition, stemflow tends to concentrate precipitation around the base of stems, creating higher local pore water pressure. The net hydrological effect of vegetation can be significant. Simon and Collison (2002), for instance, found in their study conducted in northern Mississippi that following a very dry period the stabilizing hydrological effect of tree cover was two times greater (220%) than tree cover’s stabilizing mechanical effect. However, this result was reversed following a wet period; the stabilizing mechanical effect of tree cover was 159% of tree cover stabilizing hydrological effect.

The bank stability function of riparian vegetation has important implications for riparian area management. FEMAT (1993:V-27) created a generalized curve of root strength versus distance from channel based on expert opinion informed by scientific literature. The radius of Douglas-fir *Pseudotsuga menziesii* root networks are highly correlated with tree crown radius (Smith 1964).⁴ Hence, FEMAT (1993) assumed the contribution of root strength to maintaining streambank integrity declines at distances greater than one-half a crown diameter. Using linear regression, Roering et al. (2003) derived a power-law relationship for coniferous trees between root network radius and tree diameter. This relationship suggests that large diameter conifers (36 to 48 inches [91 to 122 cm] diameter breast height) have root network radii that measure 16 to 33 ft (5 to 10 m). Hence, in an undisturbed old-growth riparian forest, the full contribution of root strength to streambank stability is provided by trees within approximately 33 ft (11 m) of the streambank.

2.4.4. Lateral Channel Migration

Lateral channel migration affects sediment erosion and deposition, local topographic relief, flood inundation patterns, river planform, alluvial architecture, and riparian vegetation patterns, which in turn results in a complex arrangement of aquatic and riparian habitats across a river’s floodplain (Naiman et al. 1993). Lateral channel migration occurs through the processes of meander bend development, avulsions, and channel widening and narrowing (Rapp and Abbe 2003). These processes occur through fluvial erosion of intact bank material and mass failure of streambanks under gravity, followed by mobilization and transport of the disturbed material (Burckhardt and Todd 1998).

² A surcharge load is any load imposed upon the soil surface close enough to a streambank to cause lateral pressure to act on the bank. “Surcharge” denotes an extra force in addition to the weight of the soil.

³ Lateral earth pressure is the pressure (i.e., force per area) that soil exerts in the horizontal direction.

⁴ The ratio of root spread to crown width for small Douglas-fir and Western Hemlock (*Tsuga heterophylla*) (mean dbh about 13 inches [33 cm]) was reported by Smith (1964) to be about 1. Data in Eis (1987) for these same tree species suggest a ratio of about 2.

One mechanism of channel migration is meandering, which is one of the most common river-channel patterns (Güneralp and Marston 2012). Given time, and lacking physical obstructions, a natural unimpeded meandering channel can swing and shift across its valley in the downstream direction, completely disturbing the floodplain (Schumm 1977). The floodplains of meandering rivers are low-lying depositional features that store large volumes of sediment, and reflect the history of erosion and deposition of a river occupying the valley floor (Dunne and Leopold 1978). The time needed for a channel to migrate and occupy its entire floodplain is expressed as a “floodplain turnover rate,” which may take tens to thousands of years in western Washington. Beechie et al. (2006) found, for example, that braided channels in rivers of the Cascades and Olympic mountains had a turnover rate of 25 years. In contrast, O’Connor et al. (2003) estimated turnover rates for two large rivers on the Olympic Peninsula to be approximately 200 to 2000 years. The channel migration rates for the rivers in O’Connor et al.’s study ranged from 13 ft (4.0 m) to 42 ft (12.7 m) per year.

Sediment erosion and deposition patterns that result in channel migration are caused by complex flow patterns along meander bends. Water tends to develop a horizontal swirling flow as a result of greater roughness along the banks than in the center of the channel. This swirling flow, termed “helical flow”, is generated by the super elevation of the water’s surface as it flows along the outside of a bend (Callander 1978). Helical flow creates large cross-stream variation in velocity (Dietrich et al. 1984), and the reduced velocity and bed shear stress at the inside of a bend creates

pointbar deposition. In addition, pointbars deflect flow laterally toward the cutbank, creating topographically driven secondary flow that further induces an outward velocity shift toward the cutbank (Güneralp and Marston 2012).

Movements of individual meanders are described as: 1) simple migration (or translation), which is a downstream shift without significant shape change; 2) extension (or growth), where the amplitude of the bend extends by migrating across the valley; 3) rotation, in which the bend axis changes orientation; and 4) lobing and compound growth, where the bends become less regular and symmetrical (Hooke 1984). Individual bends along a meandering channel can have different styles and rates of migration, and typically deform and become asymmetrical with migration. Meander migration that increases the amplitude and tightness of bends can lead to a cutoff channel that creates a shorter flow path across the inside of a pointbar or a neck cutoff at the base of the bend. The increase in channel gradient from the cutoff causes it to become the main channel, and the longer flow path becomes a secondary or overflow channel on the floodplain. Secondary channels may function as side channels that are important rearing habitat for juvenile salmonids (Rosenfeld et al. 2008) or



Chehalis River meander bend/Jane Atha, WDFW



Mid-channel bar/Jane Atha, WDFW

oxbow lakes, which are habitat for amphibians (Henning and Schirato 2006). The increased habitat diversity for aquatic and riparian organisms can persist for decades to centuries depending on rates of sediment filling.

Another mechanism for channel migration is avulsion, which is the rapid abandonment of a river channel and the formation of a new river channel. Avulsions can occur with little erosion of the land between the old and new channel locations (Allen 1965; Butler 2004). An avulsion can cause rapid, dramatic shifts in channel location from one side of the valley bottom to the other, and can occur during a single flood event. Avulsions are often associated with aggrading channels, but this is not a necessary requirement (Tooth et al. 2007). Meander cutoffs, for example, are a type of avulsion not derived from aggradation. In the Pacific Northwest, wood jams often cause and mediate avulsions, acting to maintain a multiple-channel pattern. Wood jams can cause avulsions by plugging channels and diverting flow into a relict channel that then becomes the main channel (Collins and Montgomery 2002).

Along alluvial rivers, spatial and temporal patterns of riparian vegetation composition and structure are controlled by rates of channel migration and vegetation response to disturbance (Figure 2.4). As channels migrate laterally, pointbars create conditions for recruitment of early successional plant species. Over long periods, pointbar growth is followed by

the succession of terrestrial plant communities. Consequently, a pointbar may support a chronological series of successional stages arranged from youngest closest to the active channel to oldest farthest from the channel (Shankman 1993). A limited number of species consistently dominate the accreting edge of pointbar landforms, while progressively more species establish as the pointbar aggrades to a higher surface elevation (Meitzen 2009). Opposite these pointbars, eroding cutbanks expose and remove previously established mature vegetation, but also open edge habitat for colonization by new plant species. Kupfer and Malanson (1993) found that cutbank edge forests have higher stem densities and greater species richness than floodplain interior forests.

Lateral channel migration and related streambank erosion processes can pose risks to human communities located near rivers and large streams. Likewise, human actions intended to limit channel migration can degrade aquatic and riparian habitats. For these reasons, geomorphologists have developed protocols for determining the channel migration zone (CMZ). A CMZ includes the outer extent of historical channels, plus the area where future channel migration could occur over some time period (e.g., 100 years). CMZ delineation considers the historical migration zone, i.e., the area encompassing all historical channels; the avulsion hazard zone, i.e., areas not in the historical record that are at risk of avulsion; and the erosion hazard area, i.e., the area at risk of bank erosion from stream flow or mass wasting over the time horizon of the CMZ (Rapp and Abbe 2003). The CMZ typically encompass floodplains and some portion of terraces (landform remnants of the former floodplain). The CMZ also includes channels and terrace banks that are at risk of mass wasting due to erosion of the toe.

Lateral channel migration produces a spatially dynamic riparian ecosystem. Because the riparian ecosystem (i.e., the riparian zone and zone of influence) is defined by proximity to water, as the active channel moves back

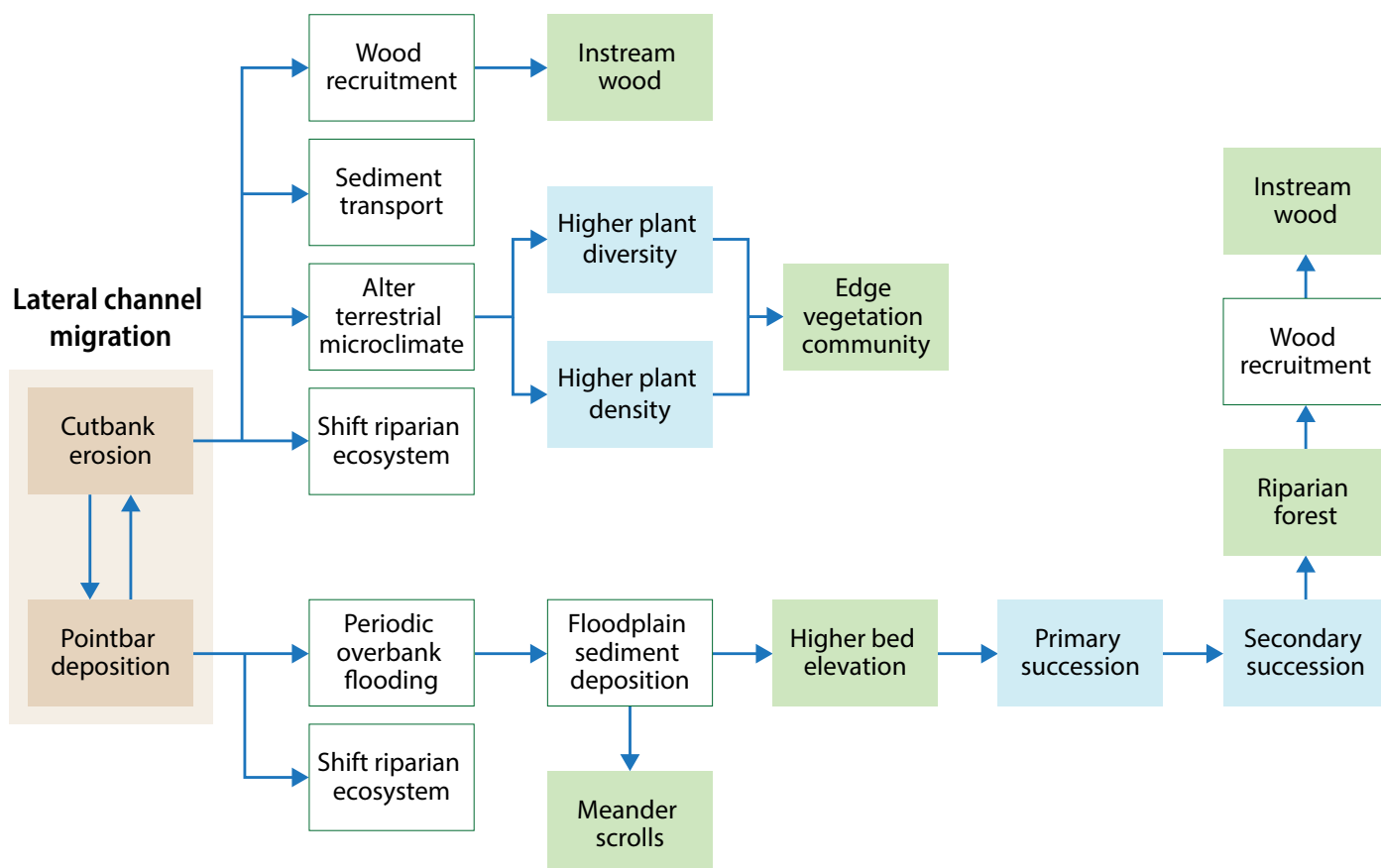


Figure 2.4. A conceptual model of lateral channel migration processes and riparian forest responses (modified from Meitzen 2009). Arrows indicate the hypothesized directions of causal relationships. Brown boxes represent proximal processes leading to channel migration. White boxes are secondary processes. Green boxes depict structures. Blue boxes are biological responses.



Chehalis River meander paths between 1938 and 2013/Ken Pierce, WDFW

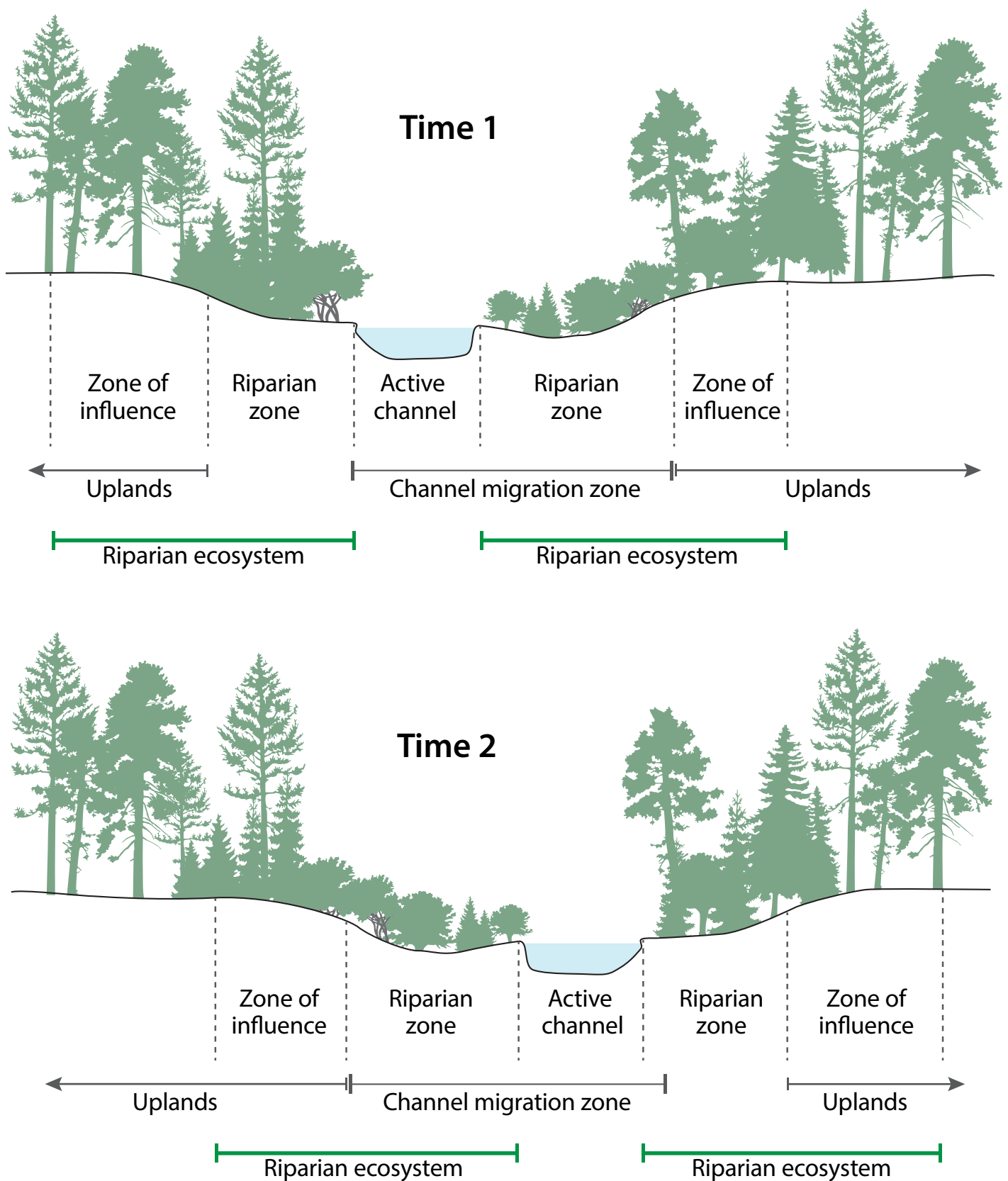


Figure 2.5. Spatial relationships between the riparian ecosystem and channel migration zone (CMZ) over time. As the active channel moves laterally within the CMZ the riparian ecosystem moves with it. Time 1 and time 2 could be separated by days or centuries.



Quinault River/Jane Atha, WDFW

and forth across the CMZ, the riparian ecosystem moves with it (Figure 2.5). Consequently, over long periods of time, a riparian ecosystem will occupy different parts of the CMZ. Furthermore, when an active channel reaches the outside limit of its CMZ, the riparian ecosystem lies outside and adjacent to the CMZ. Hence, to maintain riparian ecosystem functions, management must anticipate and protect future locations of the riparian ecosystem.

2.5. Disturbances

2.5.1. Geomorphic Process Domains

The spatial variability of sediment sources and the varying capacity of water to transport sediment result in a mosaic of different channel forms within a watershed. Channel forms

can be described by attributes such as bed and bank sediment size distributions, pool and riffle depths, bankfull widths, gradient, and sinuosity. The classification of channel forms has been refined over the last 30-40 years beginning with Schumm (1977), who distinguished a headwater production zone, mid-basin transfer zone, and downstream depositional zone. This longitudinal arrangement is also reflected in more recent work that defines geomorphic *process domains*. Process domains characterize differences in the types and frequency of disturbance events, and provide a way to represent spatial differences in disturbance regimes (Montgomery 1999).

Six common geomorphic process domains have been identified for forested watersheds of Washington State: hillslope, unchanneled hollows, debris-flow channels, bedrock-fluvial channels, coarse-bed alluvial channels, and fine-bed alluvial channels (Montgomery et al. 1996; Sklar and Dietrich 1998; Montgomery 1999). These process domains are important to distinguish since they

each function differently in terms of sediment dynamics and transport capacity. Note that although geomorphic process domains often occur in a regular longitudinal sequence, there are many exceptions in Washington State where this is not the case.

Hillslopes are unchannelized and are typically dominated by diffusive transport or rain-facilitated transport of sediment downslope. Unchanneled hollows are hillslope concavities that serve as sediment storage sites and source zones for hillslope mass movement (Dietrich and Dunne 1978; Montgomery et al. 2009). Debris-flow channels are dominated by mass wasting sediment dynamics but channel geometry may still be influenced by fluvial processes. Bedrock-fluvial channels have underlying exposed bedrock that limits boundary erosion. In these channels, overlying alluvium is transported by scour during higher flows, and transport capacity exceeds sediment supply, resulting in exposed bedrock. Coarse-bed alluvial channels are dominated by unconsolidated gravels, cobbles, and boulders and are more likely to be supply limited, rather than stream energy limited. Lastly, fine-bed alluvial channels have non-cohesive sand-sized sediment and are more likely to be transport limited by flow energy rather than sediment supply (Wohl 2014).

Using process domains, it is possible to identify within a watershed where different geomorphic processes, disturbance regimes, and responses to disturbance dominate, and predict riparian vegetation dynamics (Naiman et al. 2000; Polvi et al. 2011). Channel

morphology correlates well with bed gradient and sediment supply (Montgomery and Buffington 1997). The differences in the balance of hydraulic forces and available sediment among these channels likely lead to differences in overbank processes that can affect vegetation establishment, growth, and mortality. For example, in higher gradient channels, energy is expended on transporting sediment downstream and is not available to reshape the riparian area.

2.5.2. Natural Disturbance Regimes

From an ecological perspective, disturbances are relatively discrete disruptive events that change the physical environment or resource availability (Pickett and White 1985); thereby creating opportunities for other species to become established (Nakamura and Swanson 2003). Natural disturbances result in dynamic habitats of varying physical conditions that allow for a variety of species to coexist. Community succession theory recognizes that large-scale disturbances, such as low frequency, high magnitude floods, continually reinitiate community succession in riparian areas (Pickett et al. 1987; Corenblit et al. 2007). The cycle of disturbance and succession occurring throughout a watershed maintains compositional and structural diversity in aquatic and riparian ecosystems. Disturbances that influence streams and riparian areas include wildfire, floods, landslides, tree infestations by insects, and human-induced disturbances such as residential development, timber harvest, and road construction.

Disturbances are relatively discrete disruptive events that change the physical environment or resource availability, and are essential for developing habitat to support native biota.

Disturbance processes are essential for developing the range of habitat conditions necessary to support native biota (Swanson et al. 1998; Tabacchi et al. 2000). For example, the coarse sediments and large wood delivered to streams via mass wasting are thought to be essential components of freshwater salmonid habitats (Reeves et al. 1995). A natural disturbance regime can be characterized by frequency (how often), magnitude

(how big), duration (how long), and predictability. Wildfires of a given magnitude, for example, occur with a particular statistical probability in the absence of human manipulation of a watershed (Agee 1993). In general, smaller, frequent, and varied disturbances increase the heterogeneity of channel forms, leading to an environment that is more diverse and species rich (Kauffman and Martin 1989; Malanson 1993; Tabacchi et al. 2000; Everett et al. 2003). For example, the dynamics of stream channels that result from frequent, low intensity wildfires determine short-term patterns such as seed germination and animal foraging behavior (Hughes 1997). The influence of moderate and frequent disturbances such as fire (Wright and Bailey 1992) or insect-induced tree mortality (Mattson and Addy 1975) may lead to minor reductions in the riparian canopy, but more diverse habitat conditions that are generally beneficial for salmonids (Naiman and Bilby 1998). By contrast, disturbances that are large and infrequent tend to lead to widespread alterations that have larger and longer-lasting physical impacts. Large disturbances could cause a geomorphic threshold to be exceeded, and the resulting fluvial response could manifest a new geomorphic state with different physical conditions that support a different biological community (Hughes 1997).

Human activities can either dampen or amplify disturbance processes. While natural disturbance processes are ongoing, they are modified by human alterations (e.g., dams eliminate or dampen flood flows and land management can reduce the frequency and severity of fires). Too little or too much disturbance may have detrimental impacts on the physical structure of streams and riparian areas. For example, too little flooding can lead to cementation of the streambed or loss of riparian vegetation, especially in arid regions. Conversely, too much flooding caused by land cover change, for example, can lead to less habitat complexity due to excessive scouring of the channel. The past and current management of a site—and of its greater watershed—may alter the natural disturbance regime resulting in ecosystem states that did not exist historically.

Process domains within a watershed exhibit different disturbance regimes which manifest different aquatic and riparian ecosystems. Disturbances, and where they occur within a watershed, play key roles in structuring ecosystems. Important advances have shifted focus from single channel reaches and disturbance events to processes occurring at larger geographic extents over longer periods of time, that establish linkages between watershed-scale conditions and natural disturbance regimes (Naiman and Bilby 1998; Nakamura and Swanson 2003).

2.5.3. Human Alteration Impacts

Thus far, this chapter has largely focused on the hydrologic and geomorphic processes and their interactions with riparian area vegetation as they naturally occur within a watershed. However, human influences on channel form are ubiquitous, and therefore should be considered in management of riparian areas.

How a channel responds to human alterations of the landscape or riparian areas depends on its sensitivity and resilience (Brunsden and Thornes 1979).



Narrow riparian buffers along Badger Creek/Jennifer Nelson, WDFW

A sensitive channel reach changes in response to human alterations. A resilient channel reach also changes in response to human alterations but will return to its prior condition at some later time. The idea that some parts of a river are more or less sensitive or resilient is critical to predicting channel adjustments. For example, stream reaches with high transport capacity may adjust relatively quickly to an increase in upstream sediment yield but a similar change in sediment yield may cause significant changes in channel morphology in reaches with low transport capacity. The shape, hydraulics, and natural disturbance regime of a reach may indicate its sensitivity to anthropogenic disturbance. For example, a channel that is degrading (lowering bed elevation) may be more sensitive to riparian large wood additions than a channel that is in equilibrium. In addition, sensitivity to changes in hydrology is inversely proportional to channel gradient (Wohl et al. 2007). Hence, managers should anticipate that high gradient streams will be more sensitive to changes in stream flow than lower gradient streams. Other drivers such as the flow regime or controls such as lithology might also be used to determine a reach's sensitivity and resilience, and thereby inform management decisions.

Forestry

An extensive body of scientific literature documents the effects of forestry on stream channels (see Foley et al. 2005; Scanlon et al. 2007; and Wohl 2013 for thorough reviews). Cutting of trees and road building associated with forestry can greatly increase sediment yields and affects water yields over multiple decades as vegetation recovers (Wohl 2014). Impacts from road networks—for logging and otherwise—are numerous and are discussed below. Changes in sediment supply and water yield due to logging can alter the streamflow, stream chemistry, and channel morphology of a stream reach (Liquori et al. 2008). In addition, the resilience of channels in response to such alterations can be quite variable. For example, Madej and Ozaki (1996) found that channel recovery (defined as returning to a former bed-elevation) after a sediment wave following extensive logging in Redwood Creek basin, Northern California varied from 8 years in one creek to 15 years in another. A third channel had not yet recovered.



Clearcut hillside/Jane Atha, WDFW

There is substantial agreement among scientists as to the potential magnitude and consequences of peak flow changes due to forestry. Grant et al. (2008) assessed the effects of forestry on peak flows and consequent channel response in the Pacific Northwest in a state of the science report. Their findings, primarily synthesized from long-term monitoring, show that responses are complex, and vary with runoff type (snowmelt, rainfall or rain-on-snow), local hydrology, harvest treatment, and channel type. The authors generally noted that geomorphic changes from harvest-related peak flow effects are limited to low-gradient channels (below 2% grade) and are generally minor as compared to other anthropomorphic impacts. Other literature reviews (e.g., Liquori et al. 2008; Grant et al. 1999) had similar conclusions.



Big Beef Creek, Kitsap Peninsula/Ned Pittman, WDFW

The degree to which forestry practices alter water and sediment yields depends on where the logging occurs within a drainage basin. In one study, logging at lower elevations in snowmelt-dominated basins of southwestern Canada caused little to no change in peak flow because of relatively small snowpack, whereas in the higher elevations the peak flow changed significantly (Whitaker et al. 2002). Similarly, characteristics such as climate, topography, and soils also determine landscape sensitivity to forestry. Several studies have shown that mean annual precipitation is a reasonable indicator of impact (e.g. Anderson et al. 1976; Coe 2006; CBOF-TAC 2008). A road network may deliver 20% of sediment to stream channels in areas with 22 in (500 mm) per year average precipitation compared with 50% of the sediment when precipitation exceeds 118 in (3,000 mm) per year (Coe 2006). In areas of high topographic relief, it is particularly challenging for researchers to differentiate channel adjustments induced by logging from change that would have occurred without interference (Marston 2008).

Conversion of riparian areas from forest to other land uses can cause channel narrowing and deepening (Anderson et al. 2004; Sweeney et al. 2004; Faustini et al. 2009). Furthermore, streams without riparian forests often exhibit channels with less wood that are narrower, deeper, have fewer obstructions, less variability in active channel width, higher proportions of run and glide habitats, and lower habitat diversity (Jackson et al. 2014).

Road Infrastructure

Road networks are similar to stream networks in that they are often widely distributed, transport energy and material across a landscape, and have a high edge length per unit area enabling interaction with adjacent hillslopes (Jones et al. 2000). Stream networks and road networks commonly occur in similar densities in wet-climate forested mountains where logging has occurred (Wemple et al. 1996).

The biggest impact of unpaved roads on aquatic systems is sedimentation. Road construction and maintenance disturbs a layer of soil on the road tread, adjacent drainage ditch, and cutslopes that becomes easily eroded material (Megahan 1974). In conjunction with other loose material on roads, higher erodibility increases the total sediment yield from a road segment (Luce and Black 1999). In managed forests of Washington State, unpaved roads and trails are the most significant management activity that affects

sediment production and delivery into streams (Lewis 1998; Gomi et al. 2005; CBOF TAC 2008). Roads can initiate mass movements that tend to result in longer runoff zones and more sediment than their naturally occurring counterparts do (May 2002). Sediment generated from roads can be delivered to streams via ditches and gullies below cross-draining culverts that concentrate and route runoff. Road sediment production varies substantially with the type of surfacing material, road slope, mean annual precipitation, geology, traffic type and volumes, and road area (Cafferata and Munn 2002; MacDonald et al. 2004; Coe 2006). Roads and water crossings with improper design or maintenance are often the most significant sources of erosion and sediment delivery to streams in forested watersheds (Madej 2001; Cafferata and Munn 2002). Jones et al. (2000) found that unpaved roads continue to contribute sediment fines to channels long after harvested vegetation has reestablished.

Agriculture

Agriculture, in the form of livestock grazing or crop production, can reduce and alter vegetation cover, compact soils, and reduce water infiltration. It can also increase runoff and sediment yield, and cause associated changes in streamflow, channel morphology, and channel stability.

Cattle grazing can severely degrade riparian areas particularly through vegetation reduction and trampling of streambanks. Grazing animals can create ramps

along streambanks and trails along the floodplain that enhance localized erosion (Trimble and Mendel 1995). Grazing-disturbed streams are usually characterized by a lack of overhanging banks, wide and shallow channels, smaller pool area, high sediment yields and turbidity, steep gradients, and channel beds typified by long stretches of glides or runs. Along streams with enclosures that kept cattle out of riparian areas, Magilligan and McDowell (1997) found that channel widths became narrower due to increased roughness by grassy riparian vegetation, which ultimately traps sediment leading to width reductions. The channel narrowing effects of grassy vegetation were also reported by Sweeney et al. (2004) and Allmendinger et al. (2005).

A common effect of planting crops is increased sediment yield and associated changes in channel pattern and stability (Wohl 2014). The magnitude of these changes is dependent on the type and extent of crops, as well as the topographic and soil characteristics at a site. Numerous case studies indicate that soil erosion from conventional agriculture exceeds rates of natural erosion by up to several orders of magnitude (Montgomery 2007).

Urban/Suburban

Research on the effects of urbanization on sediment yield and channel response date back almost 50 years and is global in reach (Wolman 1967). The results of this research draw similar conclusions regarding the sequence of changes that occur within a drainage basin, with differences occurring only in the magnitude and timing (Chin 2006).

Erosion rates can reach up to 40,000 times pre-disturbance rates on land surfaces cleared for building that remain bare for up to a year (Harbor 1999). Construction sites can dramatically increase sediment yield from an urbanizing basin (Fusillo et al. 1977). For example, sediment production from Issaquah Creek

Understanding a channel's state of equilibrium (or disequilibrium) and its potential future states is critical for restoration and protection of salmon habitats.



Mill Creek, Walla Walla, Washington/Jane Atha, WDFW

watershed in western Washington had two- to five-fold increases when only 0.3% of its 55.6 mi² (144 km²) drainage area was under construction (Nelson and Booth 2002). Upon completion of construction, sediment yield usually decreases to negligible amounts as urbanizing areas are stabilized beneath roads, buildings, and lawns.

Research on the effects of urbanization on hydrology and flooding is also extensive, and dates back at least 50 years. Collectively, this research clearly shows that urban development, and associated increases in impervious surfaces, leads to larger and more frequent floods (Leopold 1968). The key metrics of change are peak discharge, lag time, flood frequency, and total runoff or water yield. Morphological adjustments have been studied in response to hydrologic changes, with most studies showing increases in channel width (Chin 2006).

Stream Channel Modifications

Humans have been directly altering stream flow and channel form for centuries (Poff et al. 1997). Flow

regulation, through dams, reduces the size and variation of annual peak flows (Williams and Wolman 1984), increases minimum flows (Hirsch et al. 1990), shifts the timing of seasonal flows, and can alter diurnal flow fluctuations if the dam is used for hydroelectric power generation (Magilligan and Nislow 2001).

Dams can have dramatic effects on aquatic and riparian systems (Nilsson et al. 1997; Nilsson and Berggren 2000; Katz et al. 2005; Merritt and Wohl 2006). Dams disconnect the channel from the floodplain by reducing peak flows. This decreases or eliminates freshly scoured surfaces necessary for seedling establishment in riparian areas. Flow regulation can disrupt downstream transport of seeds to germination sites, and seedlings established on gravel bars may die from prolonged submersion when managed flows are higher than natural flows. Changes in sediment size distributions and moisture content can also adversely impact riparian vegetation. The cumulative effects on riparian communities downstream of dams can result in fewer plant species and lower plant density (Jansson et al. 2000).

Humans regularly alter channel form through dredging, channel straightening, removing instream wood or Beaver dams, building check dams, extending channel networks via canals, burying or laterally shifting inconvenient channels, and simply reconfiguring a channel to be more esthetically pleasing. (Wohl 2014). Levees are a direct form of channel alteration particularly ubiquitous in lowland rivers. Levees are mounds built parallel to stream channels that limit overbank flooding, and are also known as dikes or embankments (Petroski 2006). Levees severely reduce or eliminate channel-floodplain exchanges, facilitate higher magnitude floods, and exacerbate flooding in downstream areas without levees. Disconnection between the channel and floodplain reduces deposition of sediment and organic matter in floodplains, leading to loss of habitat, reduced animal abundance, and lower biodiversity in riparian areas (Hohensinner et al. 2004).

Lastly, humans can indirectly and severely alter channel form by introducing invasive, exotic species to riparian areas. Invasive plants may displace native riparian plants and thus impact streambank resistance to erosion and overbank sedimentation dynamics (Graf 1978; Allred and Schmidt 1999). Invasive riparian plants can also change patterns of water uptake and transpiration which in turn alter streamflows, subsurface water tables, nutrient cycling, and the quality and quantity of aquatic habitats (Schilling and Kiniry 2007; Hultine and Bush 2011).

2.6. Fish and Wildlife Habitat

2.6.1. Fish

The fisheries and fish ecology literature are replete with studies that report relationships between fish and physical habitat conditions. Such studies demonstrate the profound importance of instream conditions for fish and they have helped guide habitat management and restoration. For example, Nickelson et al. (1992) found seasonal differences in the use of pool and riffle habitat by juvenile Coho Salmon *Oncorhynchus kisutch* and suggested that additional pool habitats might improve their survival. Such correlative approaches have been expanded by considering shifts in habitat use within species and differential habitat requirements among species in attempts to identify optimal habitat type configurations (Rosenfeld 2003; Bain and Jai 2012). However, the success of such approaches has been limited by high spatiotemporal variability in, for example, habitat-density relations among streams (Dunham and Vinyard 1997; Dunham et al. 2002) that can be due to biotic and abiotic factors. Further, population statistics such as density can be a poor indicator of habitat quality (Van Horne 1983).



Juvenile Chinook Salmon *Oncorhynchus tshawytscha*/David Price, WDFW

Recent scientific advances regarding the protection and restoration of fish habitats (and habitats for other vagile aquatic species) include the following: 1) acknowledgement of the importance and frequency of fish movement (Schlosser 1991, 1995; Gowan et al. 1994), 2) greater acknowledgement of the importance of habitat heterogeneity and spatial variability in fish-habitat relationships (Torgersen et al. 2006), and 3) the concept of riverscapes (Ward 1998; Fausch et al. 2002; Allan 2004), which describes a dynamic mosaic of habitat types and environmental gradients that are characterized by high connectivity and complexity.

The riverscape concept expands on the classic stream continuum concept of Vannote et al. (1980) mostly by explicitly incorporating spatial and temporal heterogeneity, discontinuities, and connectivity between stream reaches (longitudinal), the stream and uplands (lateral), and the stream and groundwater (vertical). Fausch et al. (2002) provide several principles for effective research and management given the riverscape concept. These include: 1) conduct research (and management) at appropriate scales for the question, 2) the importance of physical and ecological processes are revealed at different spatiotemporal scales and processes will interact among scales, 3) rare or unique features can be very important, and 4) unintended consequences of habitat degradation propagate in all directions, including upstream. Cumulatively, these principles and the vast research that supported their development suggest that the spatial extent and temporal duration of research and management must be matched to the scales at which populations of species use habitat and at which suitable habitat conditions are created and maintained. Further, they emphasize the importance of maintaining and restoring longitudinal and lateral connectivity of stream systems (Sedell et al. 1989) to allow for proper functioning of habitat forming processes and maintenance and restoration of supplementary and complimentary habitats to account for expected variability in local suitability.

Conducting research and management that incorporates the riverscape concept is challenging because it often requires study at large spatial and long temporal extents as well as monitoring biotic and abiotic processes at fine spatial and temporal resolutions. Perhaps the best examples of such work in Washington are the Intensively Monitored Watersheds (IMW) projects that are designed to assess the efficacy of stream restoration for increasing the freshwater survival and production of salmon (Bilby et al. 2005). The IMW projects are conducted at the spatial extent of watersheds and over the course of several salmon life cycles. Important physical and ecological processes are monitored within and among individual stream reaches with the intent of identifying rare features and measuring changes in habitat complexity and connectivity (Bennett et al. 2016). This approach should yield reliable inferences regarding the efficacy of restoration efforts that can be used to inform decisions via adaptive management (Bennett et al. 2016).

2.6.2. Amphibians and Reptiles

Amphibians are less conspicuous inhabitants of instream habitats than fish, but in much of the Pacific Northwest, particular groups of stream-breeding amphibian species that include giant salamanders (*Dicamptodon* spp.), tailed frogs (*Ascaphus* spp.), and torrent salamanders (*Rhyacotriton* spp.) dominate fishless headwater

The riverscape concept expands on Vannote et al.'s (1980) classic stream continuum concept by including lateral and vertical connectivity and incorporating spatial and temporal heterogeneity.



*Coastal Tailed Frog *Ascaphus truei* in metamorphosis/Marc Hayes, WDFW*

streams. Headwater streams represent a large majority (up to 80%) of the overall stream network based on its length (Meyer and Wallace 2001). Stream-breeding amphibian dominance in headwaters partly reflects the flow conditions in headwater habitats and the suitable physical conditions those flows create. Amphibian abundance is highest in step-pool and cascade reach morphologies characterized by armored beds, stable bedforms, refuge spaces amongst coarse bed material, and reduced tractive forces as a result of tumbling flow (Dupuis and Friele 2006). For example, torrent salamanders, the only stream-breeding amphibian group that does not attach their eggs to rocky substrates, deposit and conceal them in the lowest flow headwater ends of streams and their tributaries; higher flow habitats will dislodge or damage their eggs. In contrast, giant salamanders and tailed frogs, which glue their eggs to coarse rocky substrates, use concealed oviposition sites in stable step structures typically found further downstream in the headwater network (Hayes et al. 2006). Stream-breeding amphibians seem to become less abundant below headwater streams at least in part because substrate and flow conditions that provide either oviposition or refuge sites become less frequent (Brummer and Montgomery 2003). Other conditions, such as predation by fishes, also play a role.

The freshets (high water events) in larger streams or rivers that have an alluvial floodplain, when coupled with wood, are also critical to both creation and maintenance of off-channel amphibian habitats (Amoros and Bornette 2002). Off-channel habitats comprise among the most important lowland stillwater habitats representing key breeding and rearing areas for the largest group of native amphibians (stillwater breeders) (Richter 2005) and the garter snakes (*Thamnophis* spp.) that feed on them. Such off-channel habitats are also critical rearing and foraging habitat for native turtles (Holland 1994).

2.7. Conclusions

The interactions of water, sediment, wood, and riparian vegetation create complex channel morphologies and diverse aquatic habitat conditions. Reach-scale differences in sediment erosion, transport, and deposition result in a mosaic of aquatic habitat conditions within and among stream reaches.

Understanding a channel's state of equilibrium (or disequilibrium) and its potential future states is critical for restoration and protection of salmon habitats. Consistent with the idea of process domains, not all stream reaches within a watershed are equally sensitive or resilient to human land uses or other anthropogenic disturbances. Describing a channel's historical range of natural variability can aid in understanding a reach's potential response to human disturbance. A historical perspective may also aid in identifying biological communities that are in most need of habitat restoration (McDonald et al. 2004; Brierley and Fryirs 2009). By adopting a historical perspective, we may be able to move closer to the ecosystem composition and structure, and the resulting habitat heterogeneity, essential for fish and wildlife.

Historically, disturbance and successional processes were key drivers for the creation of aquatic habitats (Reeves et al. 1995). Now and into the future, both natural and anthropogenic disturbances will affect the creation, maintenance, destruction, and recreation of aquatic habitats. Management may most reliably result in high quality habitat when it emulates historical disturbances and their effects on a watershed (Poff et al. 1997). An idea offered by Naiman et al. (2000) is to base management on historical patterns of watershed conditions and natural disturbances. If flooding was a major natural disturbance in a watershed, then with empirical data and/or models on the extent to which flooding has affected the watershed, one could describe the dynamic equilibrium conditions of channels and floodplains over time, and then tailor riparian management to the unique conditions of that watershed. If wildfires followed by landslides were the historical disturbance pattern in a watershed, then watershed-scale, long-term forest management plans

might schedule timber harvests such that historical natural patterns are partially emulated (Reeves et al. 1995; Bisson et al. 2009). Emulating flood or wildlife disturbances for the benefit of salmon and other aquatic species will be a much more complicated project in residential (i.e., rural, suburban, urban) areas.

The importance of riparian ecosystems in maintaining channel, off-channel, and floodplain habitats is increasingly well supported by the scientific literature. In particular, the importance of longitudinal, lateral, and vertical connectivity to the quality of habitat conditions and the importance of riparian vegetation to stream channel stability are increasingly emphasized. Management of riparian ecosystems should consider connectivity among the geomorphic process domains, the influences of natural disturbance, the historical range of natural variability, and the inextricable influence that riparian vegetation has on geomorphic processes.



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2.8. Literature Cited⁵

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School of Bull Trout Salvelinus confluentus/William Meyer, WDFW

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Chapter 3. Wood

By: George F. Wilhere and Anne Marshall

3.1. Introduction

The scientific study of wood in rivers and streams began about 50 years ago (Gregory 2003) and the vital ecological role of instream wood has been known for at least 40 years (Swanson et al. 1976). Over that 50 year period, the substantial quantity of research on instream wood has motivated numerous authoritative reviews of the scientific literature, such as Bisson et al. (1987), Maser et al. (1988), Gurnell et al. (1995), Bilby and Bisson (1998), Gurnell et al. (2002), Naiman et al. (2002a), and Hassan et al. (2005). A comprehensive, in-depth review of the ecology of wood in aquatic ecosystems is provided by Gregory et al. (2003). Although we have a solid understanding of wood's role in aquatic ecosystems and the pathways through which wood enters and moves through a stream network, some important questions remained unanswered.



Wood, rocks, and roots – roughness elements that enhance habitat diversity by increasing hydraulic complexity/Jane Atha, WDFW

This chapter focuses on the roles and recruitment of wood in aquatic ecosystems. It does not cover stream restoration using large wood. For information on that, see Dominguez and Cederholm (2000), Reich et al. (2003), Bisson et al. (2003), Carah et al. (2014), and Roni et al. (2014). For information on riparian forest management see Boyer et al. (2003) and Spies et al. (2013).

3.2. The Ecological Role of Instream Wood

Wood plays critical roles in the composition, structure, and function of riparian and aquatic ecosystems. In forested regions, wood is an important determinant of channel form and dynamics, especially in small streams (Montgomery and Buffington 1997; Bilby and Bisson 1998). However, the importance of wood's effects differs with channel dimensions, slope, sediment supply, and stream discharge (Gurnell et al. 1995). Large wood causes widening and narrowing, deepening and shallowing, stabilization and destabilization at different points along a stream or river channel (Swanson et al. 1976). The many effects of large wood create a variety of channel morphologies—dam pools, plunge pools, riffles, glides, undercut banks, and side channels—which provide a diversity of aquatic habitats. Pools are deposition sites for sediment and fine organic matter. Sediment is essential substrate for salmonid spawning, and stored sediments become mobilized over time to replenish downstream spawning areas.

Sediment and fine organic matter deposits are productive areas for invertebrates and are important food production sites for juvenile salmonids (Bisson et al. 1987). Pools provide rearing habitats and essential refuge from high flows for fish and other aquatic fauna. Instream large wood provides fish with cover from predators, and by increasing a water body's effective space, wood structures may increase fish densities (Bisson et al. 1987).

3.2.1. Small Wood

Wood is often divided into large and small size categories. Large wood is usually defined as having diameter greater than 4 in (10 cm) and length greater than 6 ft (≈2 m) (Bilby and Ward 1991; Schuett-Hames et al. 1999).¹ Small wood² consists of branches and other woody material not classified as large wood. Small wood plays essential and unique roles in lotic ecosystems. For instance, accumulations of small wood enhance a stream's retention of leaves and particulate organic matter (Gregory et al. 1991), which are vital food sources for many aquatic invertebrates. Small wood also effects channel morphology. Plunge and dammed pools are often associated with accumulations of small wood, and large wood with dense accumulations of small wood retain sediment significantly more frequently than large wood with sparse small wood accumulations (Bilby and Ward 1991).

Small wood exerts tremendous effects on hydrology and channel morphology through actions of the American Beaver *Castor canadensis* (Naiman et al. 1988). Beaver dams can store large quantities of sediment, reduce channel incision, remove excess nutrients from water, increase water retention and base flows, reduce peak flows, and by spreading flow events over longer periods,

increase groundwater recharge, and increase the salmonid habitat capacity of small streams (Pollock et al. 2015). Beaver dams consist mainly of mud and small wood. Published information on small wood sizes in dams of Beaver is lacking. However, Beaver most often forage on trees ranging from 1.2 - 3.2 in (3 - 8 cm) in diameter (Collen and Gibson 2001), and a large proportion of woody stems used as food are also used in dam construction (Barnes and Mallik 1996). In Maryland, Bliersch and Kangas (2014) found that 98% of sticks (i.e., small wood) in a Beaver dam were less than 4 in (10 cm) in diameter and that 46% of those sticks were probably placed in the dam by Beaver. The other 54% of sticks in the dam were due to passive capture of transported wood. For more information on the role of Beaver and Beaver dams in aquatic ecosystems, see Pollock et al. (2015).

3.2.2. Roles of Instream Large Wood

The main role of large wood in aquatic ecosystems is large roughness elements (Bisson et al. 1987) (Figure 3.1). Roughness elements are obstacles in a channel that deflect flow and change its velocity. The size, shape, and strength of large wood make it very effective at redirecting hydraulic forces and the flow of materials (Figure 3.2), such as sediment and fine organic matter. Instream large wood increases hydraulic complexity, i.e., creates a wider range of flow velocities, which causes pool formation, streambed scour, sediment deposition, and channel migration. The net result is a diversity of aquatic habitats.

¹ Large wood is also known as large woody debris (LWD) or coarse woody debris. There is no universal definition of LWD. Another definition is greater than 4 in (10 cm) in diameter and greater than 3 ft (≈1 m) in length. The system of measurement used effects the size of large wood. The definition using English units (4 in wide and 6 ft long) results in a piece of smaller volume than the definition using metric units (10 cm wide and 2 m long).

² Small wood is also known as small woody debris or fine woody debris

The influences of instream large wood on aquatic ecosystems are a function of wood size relative to channel size. For instance, as much as 80% of pools in small streams can be associated with wood (Montgomery et al. 1995); however, the frequency of wood-associated pools decreases with increasing stream size (Bilby and Ward 1989, 1991; Montgomery et al. 1995). The latter relationship is due to the increased capacity of larger streams to transport large wood downstream.

In low order streams, “key pieces” of large wood affect channel morphology. Key pieces are defined as large wood that is independently stable within the bankfull channel (i.e., not held or trapped by other material) and have the potential to retain other pieces of large wood (WFPB 2011). Key piece size increases as channel width increases (Table 3.1). In large rivers, wood influences channel morphology through tangled accumulations of wood known as woody debris jams.

Stable structural features can promote channel stability (Sullivan et al. 1987). In large rivers, for instance, woody debris jams contribute to floodplain stabilization by initiating the formation of mid-channel bars that eventually become forested islands (Fetherston et al. 1995; Abbe and Montgomery 1996). In small streams, persistent large wood structures trap sizable amounts of sediment thereby increasing channel stability (Figure 3.3). Of all structures capable of storing sediment (i.e., wood, boulders) in small non-fish-bearing streams of northwest Washington, 93% were composed of large wood (Grizzel and Wolff 1998). Thirty to 80% of a stream’s drop in elevation can be influenced by large wood (Keller and Swanson 1979), and log steps can reduce average channel gradients by 8 to 22% (Heede 1972). Reducing channel gradient dissipates stream power which mobilizes less sediment and increases sediment storage which can subsequently increase channel stability.

Table 3.1. Minimum volume of large wood key pieces for different channel widths. Example dimensions for key piece length and diameter yield minimum volume. Diameter is measured at piece midpoint. One meter is approximately 3.3 ft.

Bankfull width (m)	Minimum volume (m ³)	Example dimensions (m)	
		Length	Diameter
0-5 ^a	1	2.5	0.71
5-10 ^a	2.5	7.5	0.65
10-15 ^a	6	12.5	0.78
15-20 ^a	9	17.5	0.81
20-30 ^b	9.75	17.5	0.84
30-50 ^{bc}	10.5	17.5	0.87
50-100 ^{bc}	10.75	17.5	0.88

^a WFPB (2011), ^b Fox and Bolton (2007), ^c Must have an attached root wad.

Studies where wood has been experimentally removed from streams further reveal the significant role of large wood for storing sediment. For instance, Bilby (1981) measured a 72% reduction in sediment storage following removal of large wood from 575 ft (175 m) of streambed. Beschta (1979) observed a similar effect after woody debris dams were removed from a moderate gradient headwater stream in western Oregon where 6,500 yd³ (5,000 m³) of sediment was lost from 820 ft (250 m) of streambed over a period of about 10 months.

Large wood can also cause transient channel instability. Keller and Swanson (1979) and Nakamura and Swanson (1993) describe stream reaches where large wood caused local erosion that increased channel width by more than 50%. In one case a woody debris jam increased channel width by 230%. These two studies also describe reaches where large wood caused lateral migration of the main channel and formation of side

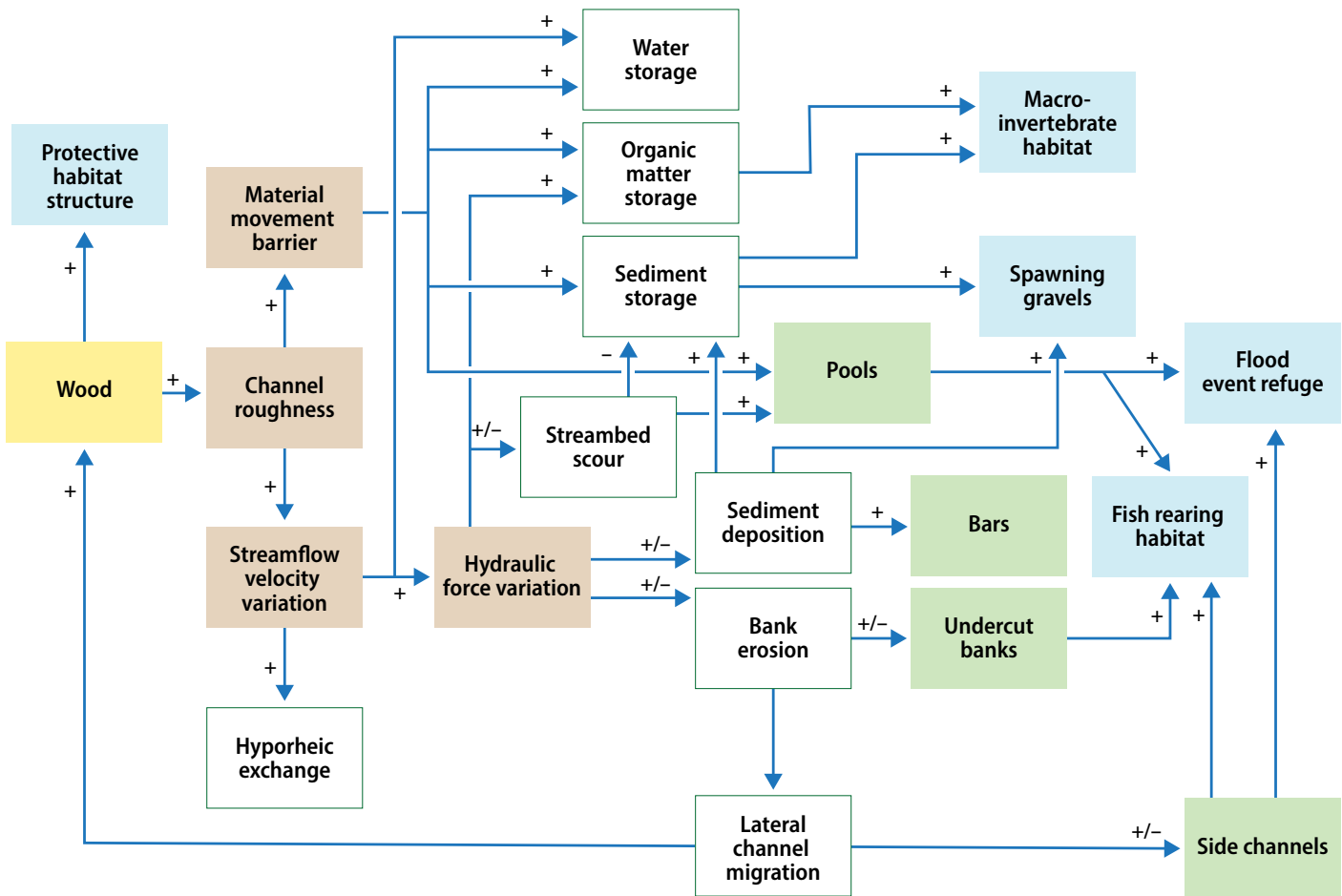


Figure 3.1. Conceptual model depicting the effects of wood on fluvial systems and fish habitats. Arrows indicate the hypothesized directions of causal relationships; pluses and minuses indicate the hypothesized slope of each relationship. Brown boxes represent direct effects of wood on fluvial processes. White boxes are secondary processes. Green boxes depict channel structures. Blue boxes are habitat features. Diagram does not include most feedback loops.

channels. Over time, these types of disturbances create a shifting mosaic of aquatic and riparian habitats. Wood influences nutrient dynamics in two major ways: wood contains nutrients that are released through decomposition, and large wood influences the rate and timing of organic materials transport (Bilby 2003). The latter is the more important effect. Instream large wood traps and retains organic matter, such as leaves and other plant detritus, which are essential to the aquatic food web. Trapped organic materials are food sources for aquatic microorganisms, such as bacteria and certain fungi, and invertebrates, such as insects, crustaceans, and mollusks.



Figure 3.2. Sediment and nutrient storage and gravel bar formation behind large wood/Jane Atha, WDFW



Figure 3.3. Large wood altering channel morphology by creating dam pool, step drop, and plunge pool/Jane Atha, WDFW

The relationship between instream large wood and nutrient storage is well established. Larger quantities of wood per unit area in small streams lead to higher rates of storage of fine organic matter (Bilby and Likens 1980; Bilby and Bisson 1998; Brookshire and Dwire 2003). The mass of coarse particulate organic matter in streams in the McKenzie River watershed of Oregon was positively related to amounts of instream wood (Naiman and Sedell 1979). Bilby (1981) reported dramatic increases in downstream export of fine particulates during periods of high discharge following woody debris removal.

Carcasses of adult anadromous salmon provide nutrients to aquatic ecosystems (Cederholm et al. 1989; Reimchen et al. 2003). On the Olympic Peninsula, a positive correlation was observed between the number of Coho Salmon *Oncorhynchus kisutch* carcasses retained in streams and the amount of large wood in the stream (Cederholm and Peterson 1985).

By creating dams, instream large wood regulates water flow and storage. For example, surface water volume increased by 168%, five years after restoration of instream large wood in a coastal Oregon stream (Crispin et al. 1993), and third-order streams in Indiana with woody debris dams held surface water 1.5 to 1.7 times

longer than those with minimal large wood (Ehrman and Lamberti 1992, cited by Gurnell et al. 1995). Hydrological effects such as these may alter high flow events by reducing peak discharge and increasing the event's duration (Gurnell et al. 1995). Pools created by woody debris dams raise the water table in adjacent streambanks (Gurnell et al. 1995), and that affects riparian vegetation composition. For instance, at some sites, wet riparian soils may be maintained through seepage from pools, and wet soils are more suitable for Red Alder *Alnus rubra*, Red Cedar *Thuja plicata*, and Alaska Yellow Cedar *Chamaecyparis nootkatensis* than other tree species. Red Alder is known to contribute enormous amounts of beneficial nitrogen to soils and streams (Naiman et al. 2002b).

The hyporheic zone is the saturated sediment beneath stream channels and riparian areas where groundwater and instream water mix. Large wood diverts surface water flow into the hyporheic zone, and by trapping and storing sediments, large wood increases the volume of the hyporheic zone (Naiman et al. 2000). Greater hyporheic exchange can also reduce a streams thermal sensitivity (Chapter 4).

3.3. Recruitment of Instream Large Wood

The quantity of instream large wood is determined by the processes of wood recruitment, decomposition, and transport (Figure 3.4). "Recruitment" refers to the process of wood moving from the terrestrial environment to the stream channel. "Transport" refers to wood import to, movement within, and export from stream reaches. For comprehensive reviews of the dynamics of instream large wood, including decomposition and transport, see Benda et al. (2003), Bilby (2003), Gurnell (2003), and Piegay (2003).

3.3.1. Wood Recruitment Mechanisms

Large wood recruitment is often caused by bank erosion, windthrow, landslides, debris flows, snow avalanches, and tree mortality due to fire, ice storms, insects, and disease (Swanson et al. 1976; Maser et al. 1988). At any given site, more than one mechanism may contribute to recruitment. However, the dominant mechanism is determined by channel morphology, slope steepness, slope stability, forest composition and structure, and local wind patterns (Murphy and Koski 1989; McDade et al. 1990; May and Gresswell 2003; Johnston et al. 2011; Benda and Bigelow 2014). In large low-gradient rivers, for instance, wood is commonly recruited via bank erosion. Steep-sloped riparian forests along confined streams can recruit instream large wood via several mechanisms; however, landslides and windthrow are the dominant recruitment mechanisms in such settings (Nakamura and Swanson 1993; May and Gresswell 2003). Fox (2001) reported that smaller channels are likely to obtain a significant proportion of instream large wood by stem breakage and individual tree mortality due to insects or disease because smaller streams recruit less wood through lateral bank avulsion. Beaver recruit small wood to small, low-gradient streams (Pollock et al. 2003).

Instream wood originating from bank erosion increases as channel confinement decreases (Murphy and Koski 1989; Nakamura and Swanson 1993; Martin and Benda 2001; Johnston et al. 2011). In relatively unconfined third-order channels surrounded by mature and old-growth forests in British Columbia, bank erosion was the dominant route of large wood delivery, especially in wider channels (Johnston et al. 2011). Along Alaska's southeastern coast, bank erosion dominated large wood recruitment in alluvial channels, while windthrow was dominant in bedrock channels (Murphy and Koski 1989). Over a 63 year period, the Queets River (bankfull width = 420 ft [128 m]) recruited 95% of wood pieces

≥ 3 ft (1 m) in diameter through bank erosion that occurred as its channel meandered across its wide floodplain (Latterell and Naiman 2007).

The relative importance of each instream wood recruitment mechanism is highly variable (Table 3.2). Johnston et al. (2011) found tree mortality was the most common recruitment mechanism followed by (in descending order) bank erosion, windthrow, and landslides. In contrast, Murphy and Koski (1989) found that tree mortality was the third most common mechanism, and their rank ordering was bank erosion, windthrow, tree mortality, and landslides. Johnston et al. (2011) found that windthrow contributed 4% of instream large wood, but May and Gresswell (2003) found windthrow contributed 59%, on average. Benda et al. (2003) found that landslides contributed, on average, 17% of instream wood volume, but at the site-level, the contribution from landslides ranged from 0 to 66%. In the Oregon Coast Range, 65% of instream pieces of large wood and 46% of wood volume in a fourth order stream were delivered by landslide or debris flow (Reeves et al. 2003).



Large wood suspended over water creates a refuge for fish from avian predators/Jane Atha, WDFW

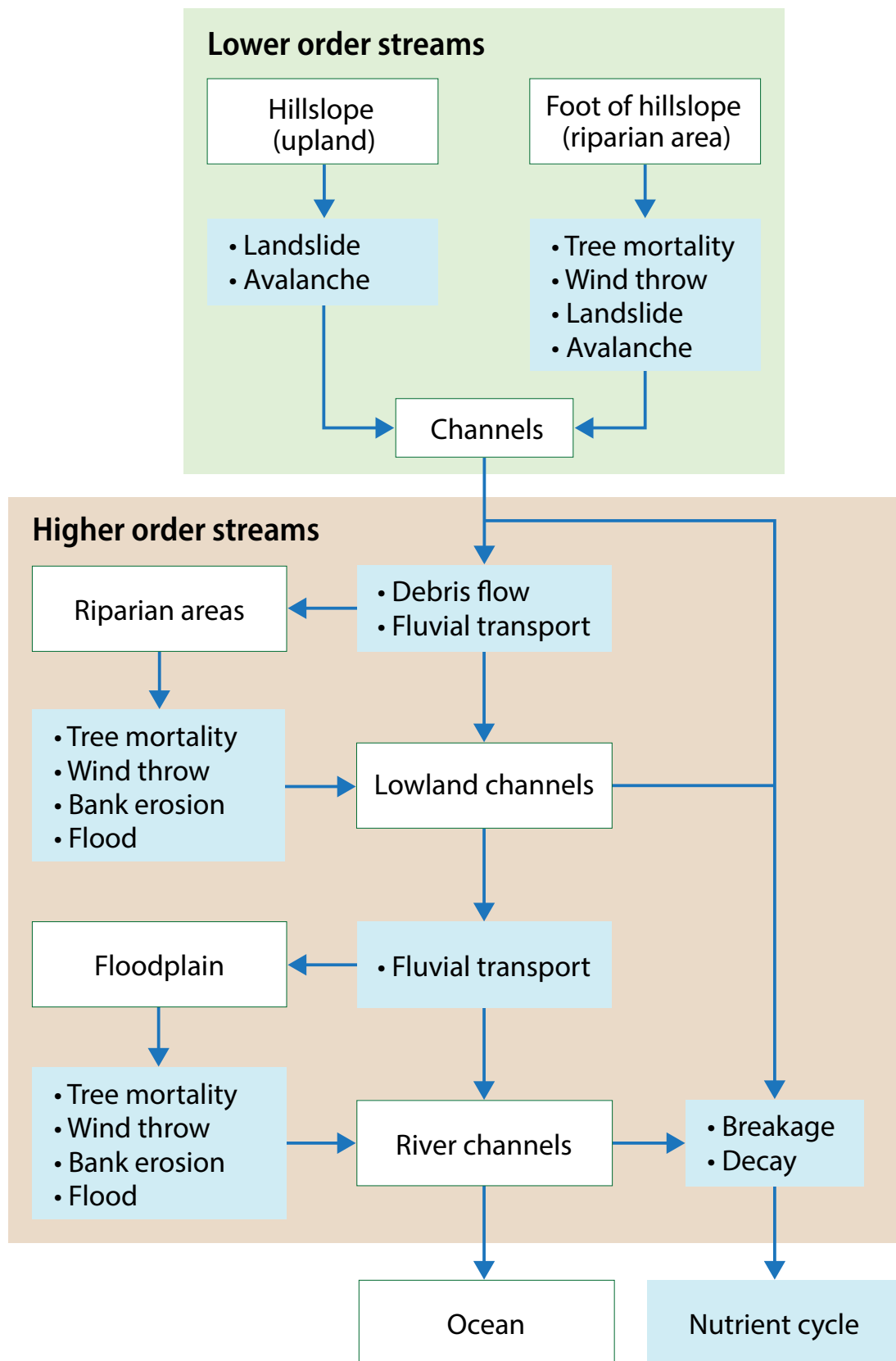


Figure 3.4. Wood recruitment mechanisms and wood transport pathways (adapted from Hassan et al. 2005). Lower order streams are first and second order headwaters. White and blue boxes are ecosystem structures and processes, respectively.

Table 3.2. Mean percentage of instream large wood contributed by various recruitment mechanisms in unmanaged old-growth conifer forests. For Johnston et al. (2011), stem breakage could be lumped with the windthrow or tree mortality categories. One meter is approximately 3.3 feet.

		Southeast Alaska ¹	South & Central British Columbia ²	Coast Range Oregon ³	Northern California ⁴
	Stream length (m)	10,280	8,129	3,220	4,470
	Wood units	% of wood pieces	% of wood pieces	% of wood pieces	% of wood volume
Recruitment mechanism	bank erosion	42	18	6	29
	windthrow	33	4	59	--
	tree mortality	22	65	6	53
	stem break	--	12	--	--
	landslide	3	1	29	17

1 = Murphy and Koski 1989, 2 = Johnston et al. 2011, 3 = May and Gresswell 2003, 4 = Benda et al. 2003

A site's recruitment mechanisms determine the magnitude and timing of wood recruitment events. Recruitment can be continual or episodic. In large, meandering rivers wood may be recruited through continual bank erosion. Soil creep along the eroding base of a hillslope may also contribute to continual wood recruitment. However, most wood recruitment occurs through episodic events such as floods, landslides, debris flow, or windstorms. For example, if a 100-year flood causes a river to migrate across its floodplain, then a huge volume of wood that would have taken decades to be recruited under smaller flows could be recruited overnight. In smaller confined streams, the main recruitment mechanism may be windthrow, which can recruit wood incrementally (single tree per event) or catastrophically (100s of trees per event).

3.3.2. Recruitment Distances

Forests adjacent to streams provide the majority of large wood delivered to stream channels (Murphy and Koski 1989; McDade et al. 1990), however, trees far removed from riparian areas may also be delivered via landslides (Reeves et al. 2003) or channel migration (Latterell and

Naiman 2007). Johnston et al. (2011) found that mean recruitment distances were greatest for wood entering by way of landslides, followed by (in descending order by distance) windthrow, stem breakage, falling of dead trees, and bank erosion.

Source distances are affected by channel geomorphology. The source distance of instream large wood differed significantly ($P < 0.05$) when comparing alluvial streams to colluvial channels draining steep hillslopes in Oregon's Coast Range (May and Gresswell 2003). In this study, 80% of wood pieces and total wood volume originated from forests within 160 ft (50 m) of colluvial channels confined by steep hillslopes, whereas in unconfined alluvial channels, 80% of instream large wood originated from within 98 ft (30 m) of the channel (May and Gresswell 2003). Along steep second growth redwood forests in northern California, landslides resulted in recruitment distances extending over 197 ft (60 m) (Benda et al. 2002). In the Oregon Coast Range, large wood from pristine steeply sloped conifer-deciduous forest was delivered to a fourth order stream by landslide or debris flow from distances of more than 295 ft (90 m) upslope of the channel (Reeves et al. 2003).

Table 3.3. Recruitment distances of instream large wood from unmanaged old-growth conifer riparian forests.

Location	Stream order or width	Maximum recruitment distance	Dominant recruitment process	Recruitment from intermediate distances	Source*
Southeast Alaska	second- to fifth-order	> 100 ft > 30 m	bank erosion	99% of pieces from < 100 ft (30 m). 45% of pieces from within 3 ft (1 m) of streambank. Average tree height = 130 ft (40 m)†.	1
Western Oregon & Washington	first- to third-order	180 ft 55 m	not reported	50% of pieces from within 33 ft (10 m) of streambank; 85% from within 100 ft (30 m); 90% from within 128 ft (39 m), horizontal distance. Average tree height = 189 ft (57.6 m).	2
Northern California	45-55 ft 14-17 m	180 ft 55 m	variable	90% of wood from < 100 ft (30 m), slope distance. Longer recruitment distances due to landsliding.	3
Coast Range Oregon	second- and third-order	230 < d < 262 ft 70 < d < 80 m	windthrow	In alluvial stream 80% of pieces from ≤ 100 ft (30 m). In colluvial streams ≈50% of pieces from ≤ 100 ft (30 m). For both types ≈75% of volume from ≤ 165 ft (50 m).	4
Coast Range Oregon	fourth-order	> 300 ft > 90 m	landslide & debris flow	About 65% of pieces and 46% of wood volume were from upslope sources by landslides or debris flows.	5
Olympic Peninsula	sixth-order	> 1,475 ft > 450 m	channel migration	95% of wood from < 870 ft (265 m). 50% of pieces from within 300 ft (92 m).	6
Southeast Alaska	16-94 ft 5-30 m	115 < d < 130 ft 35 < d < 40 m	variable	96% of all large wood from within 65 ft (20 m) and 89% of from within 33 ft (10 m). Average tree height = 74 ft (22.6 m).	7
South & Central British Columbia	3-55 ft 1-17 m	425 ft 65 m	tree mortality	90% of large wood pieces and volume delivered to stream channels from within 33 and 30 ft (10 and 9 m), respectively. Average tree height = 120 ft (37 m).	8

* 1 = Murphy and Koski 1989, 2 = McDade et al. 1990, 3 = Benda et al. 2002; 4 = May and Gresswell 2003; 5 = Reeves et al. 2003, 6 - Latterell and Naiman 2007, 7 - Martin and Grotefendt 2007, 8 - Johnston et al. 2011.

† Tree height from Spence et al. (1996).

Source distances are affected by tree size. In one study, source distances for approximately 90% of instream large wood from mature and old-growth conifer riparian forest in western Washington and Oregon were within 85 and 130 ft (26 m and 40 m) of the streambank, respectively (McDade et al. 1990). The difference in source distances was largely attributed to taller trees in old-growth riparian forest (mean height = 189 ft [58 m]) compared to trees in mature riparian forest (mean height = 157 ft [48 m]). Likewise, recruitment distances measured in Alaska (e.g., Murphy and Koski 1989; Martin and Grotefendt 2007) are generally shorter than

those measured in Oregon (e.g., McDade et al. 1990; May and Gresswell 2003) because trees of the same species are generally shorter in Alaska than in Oregon (Table 3.3). Johnston et al. (2011) also found that large wood source distances increased with increasing tree height. For a more thorough discussion of factors affecting source distances see Benda and Bigelow (2014).

The stereotypic recruitment function describing the amount of instream wood versus recruitment distance is nonlinear (Figure 3.5). That is, areas closer to the

stream channel provide relatively more wood than areas farther from the stream channel. In southeast Alaska, for instance, 100% of large wood was recruited from within 98 ft (30 m) of the streambank, but 45% of large wood originated from within 3.3 ft (1 m) (Murphy and Koski 1989). Likewise, in a study from Oregon and Washington, 100% of large wood with an identified source was recruited from within 180 ft (55 m), but 50% of large wood with an identified source originated from 33 ft (10 m; McDade et al. 1990) (Table 3.3). The shape of the wood recruitment function, and in particular, the shape under different watershed and site-level conditions, is an important question for riparian forest management.

Although most wood is recruited from areas close to a stream (Table 3.2), areas farther from a stream cannot be discounted, especially along larger alluvial streams. Along a fourth order stream in Oregon, the sources for 65% of large wood originated on hillslopes prone to landslides and lay beyond 295 ft (90 m) from the stream channel (Reeves et al. 2003). In Washington, 50% of large wood in a fifth-order river was recruited by lateral channel migration from forests on floodplains and fluvial terraces that lay beyond 300 ft (92 m) from the riverbank (Latterell and Naiman 2007).

3.3.3. Wood Recruitment in Intensively Managed Forests

An important question for riparian area management is how does wood recruitment in second-growth or intensively managed forests differ from recruitment in unmanaged, “natural” riparian forests? The answer to this question is essential for understanding the effects of contemporary forest management on fish habitats, however, useful answers are difficult to obtain because forest practices today are much different from those of the past.

The current conditions of instream wood and riparian areas in second-growth forests are the result of past management, and over the past 100 years management practices have changed dramatically. In the early 20th century splash dams were built on small streams to sluice logs downstream (Bisson et al. 1987), a practice that flushed naturally occurring large wood from the channel. During the 1950s and 1960s wood was routinely removed from streams to “improve” fish passage (Sedell et al. 1988), and this practice continued until the 1980s (Bilby 1984). Until the 1970s, logging to the streambank was common in Oregon

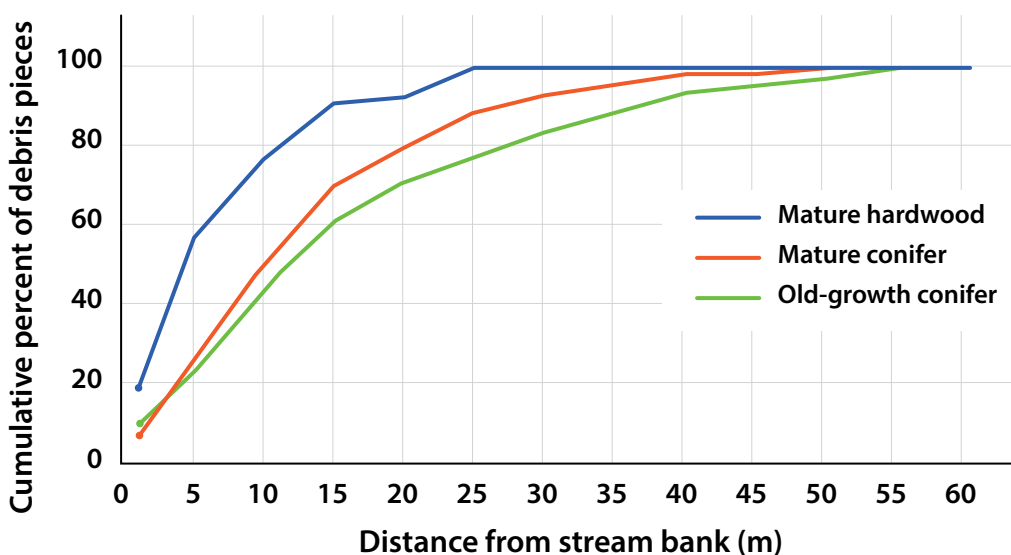


Figure 3.5. Distribution of source distances from tree origin to streambank. Empirically derived curves for old-growth conifer, mature conifer, and mature hardwood stands in western Oregon and Washington (from McDade et al. 1990). Empirically derived curves based on large wood with an identified source. One meter is equivalent to 3.3 feet.

and Washington; a practice that changed shortly after passage of the Clean Water Act of 1972. From 1987 to 2000, the Washington Forest Practices Rules required 23 to 65 trees per acre in riparian areas (WFPB 1987). In contrast, old-growth riparian areas may have 160 or more trees per acre (Acker et al. 2003). The current forest practices rule (WDNR 2005) require much wider stream-side buffers with much higher tree densities in riparian areas than previous rules. The current regulations should result in a stand basal area equal to that of a mature conifer forest when the riparian stand is 140 years old. In short, over the past 100 years, riparian areas in intensively managed forests of Washington have been subjected to many different types of management, and over the next 100 years these same riparian areas will change dramatically.

Past forest practices are known to have severely degraded instream wood (Bilby and Ward 1991; Ralph et al. 1994), but current forest practice regulations are expected to improve instream wood (WDNR 2005). Whether current regulations will result in enough instream wood to create fish habitats that meet policy goals is unknown, and resolving that issue will be difficult until riparian areas attain their desired future conditions a century or more from now. Nevertheless, theoretical and empirical evidence suggest two main differences in large wood recruitment between second-

growth, intensively managed forests and unmanaged mature and old-growth riparian forests.

First, the size of wood recruited from intensively managed forests is smaller than wood recruited from old-growth forests. Benda et al. (2002) found that the diameter of wood recruited from old-growth sites was, on average, up to twice the diameter of wood found in 50-year-old second-growth sites. Czarnomski et al. (2008) found significantly higher numbers of large wood pieces in stream segments adjacent to unmanaged mature and old-growth sites than in segments adjacent to 30- to 50-year-old intensively managed sites. From a theoretical perspective, these results are unsurprising—the dominant trees in a 200-year-old stand are much larger than the dominant trees in a 50-year-old stand. A similar relationship was also reported by McDade et al. (1990) who found that the size, both length and diameter, of instream large wood was related to forest age—wood was significantly smaller in younger forests (i.e., unmanaged mature forest versus old-growth forest).

Second, both theoretical models and empirical evidence show that maximum wood recruitment distances for intensively managed forest are less than the maximum recruitment distance for old-growth forests (McDade et al. 1990; Robison and Beschta 1990; Benda and Bigelow 2014). Again, these results are due to relative tree sizes—taller trees can contribute large wood from longer distances. The models show that the maximum recruitment distance for large wood is slightly less than the height of dominant trees; however, these models do not incorporate the recruitment processes of landslides and lateral channel migration which could substantially lengthen the maximum recruitment distance. For instance, in Benda et al. (2002) the theoretical maximum recruitment distance for their sixteen 50-year-old second-growth sites was about 98 ft (30 m), but due to landslides two sites had large wood recruited from beyond that distance—105 ft (32 m) and 210 ft (65 m). The results of Benda et al. (2002) and Benda and

Past forest practices are known to have severely degraded instream wood, but current forest practice regulations are expected to improve instream wood. Whether current regulations will result in enough instream wood to create fish habitats that meet policy goals is unknown.



Bank erosion recruits large wood into stream/Ned Pittman, WDFW

Bigelow (2014) also show that regardless of stand age or management, recruitment distances are primarily determined by recruitment processes. Riparian areas where bank erosion is the dominant process will, on average, have shorter recruitment distances, riparian areas where landslides dominate will have longer recruitment distances, and areas where other forms of tree mortality (e.g., windthrow, suppression, disease) dominate will have intermediate recruitment distances. In short, spatial variability in large wood recruitment is a function of many factors, including stream size and channel morphology, forest management, and natural disturbances such as landslides, floods, and windthrow.

3.4. Abundance of Instream Wood

3.4.1. Forested Regions of Washington

The abundance of instream large wood was much greater historically than it is today, especially in large rivers. One hundred fifty years ago, some woody debris jams on large rivers were nearly 1-mile-long (Sedell and Luchessa 1981), but

these impressive natural structures were cleared for purposes of river navigation. For instance, during the latter part of the 19th century, over 5,500 pieces of wood between 5 and 9 ft (1.5 and 2.7 m) in diameter were pulled from a 50-mile (80-km) section of the Willamette River (Sedell and Luchessa 1981). Collins et al. (2002) estimated that wood in some lowland Puget Sound rivers was 10 to 100 times greater prior to European settlement.

In contrast to large rivers, the abundance of large wood in small streams of unmanaged watersheds may still be representative of historical conditions. Fox and Bolton (2007) studied the quantities of instream large wood in natural, unmanaged forested watersheds in Washington. Ninety-six percent of their 150 sites had a stand age between 200 and 800 years (Fox 2001). In these watersheds, the processes of recruitment, decomposition, and transport were presumably undisturbed by human activities. Their findings, which are presented for forest zones and channel widths, could serve as reference or target conditions for instream large wood (Table 3.4).

3.4.2. Non-forested Regions of Washington

Fox and Bolton (2007) studied forested watersheds in forested regions (*sensu* Franklin and Dryness 1988), and, in fact, nearly all we know about instream wood is based on studies conducted in forested watersheds. This is unfortunate because our knowledge of instream wood for non-forested regions of Washington, such as semi-arid grasslands (*i.e.*, steppe or Palouse) and shrub-steppe, is limited. Nevertheless, instream wood was likely to have been more abundant than it is today for two reasons.

First, in basins with headwaters in forested regions, such as the Yakima, Wenatchee, and Walla Walla basins, wood was transported downstream to shrub-steppe

and grassland streams. This process is known to have occurred in other semi-arid and arid regions of the United States. Minckley and Rinne (1985) present historical evidence for the movement of large wood in rivers of the desert southwest: wood originated in forested headwaters, moved sporadically through desert riparian areas during flood events, and was ultimately deposited at the mouth of the Colorado River in Mexico. Minckley and Rinne (1985) identify interception of large wood by dams as a major cause of large wood reduction in semi-arid and arid river basins. At artificial reservoirs in eastern Washington, such as Keechelus, Kachess, Cle Elum, Bumping, Clear, and Rimrock lakes, large wood that could potentially interfere with dam operations is removed and burned (W. Meyer and B. Renfrow, Washington Department of Fish and Wildlife, personal communications). Some small water diversion dams do the same with large wood. This practice diminishes the quantity and quality of fish habitat in the Yakima and Tieton rivers, especially in their semi-arid shrub-steppe sections.

Second, riparian areas in grassland and shrub-steppe regions are inhabited by a wide variety of woody plants—Black Cottonwood *Populus balsamifera*, Quaking Aspen *Populus tremuloides*, White Alder *Alnus rhombifolia*, Thinleaf Alder *Alnus incana*, Water Birch *Betula occidentalis*, Black Hawthorne *Crataegus douglasii*, and Yellow Willow *Salix lutea* (Crawford 2003), and the historical abundance of woody plants in riparian areas is thought to have been much greater than it is today (Wissmar et al. 1994; Kauffman et al. 1997; Wissmar 2004). Reductions in woody plant abundance are mainly due to hydrological changes caused by water diversions for irrigation (Jamieson and Braatne 2001) and livestock grazing. Restoration projects can indicate the density of woody plants that historically existed in riparian areas prior to intensive livestock grazing. Only two years after the cessation of grazing within riparian areas in northeastern Oregon, the mean crown volume of willows and Thinleaf Alder tripled in size and that of Black Cottonwood increased 9-fold (Case and Kauffman

1997). Furthermore, shrub density increased by 50%. One possible reason for the severe impacts of grazing is that riparian vegetation in the semi-arid grassland and shrub-steppe regions of Washington evolved with little grazing by large herbivores (Mack and Thompson 1982).

With the exception of Black Cottonwood, woody plants in grassland and shrub-steppe regions do not contribute key pieces of large wood to stream channels (Table 3.1).

Historically, much wood in stream channels of semi-arid regions was likely to have been small wood, and much of that small wood may have been recruited to and stored in the channel through Beaver activity. Prior to 1864, Beaver are known to have been abundant in the shrub-steppe region of central Oregon, and the eradication of Beaver from central Oregon is thought to have caused a cascade of effects: gradual disintegration of Beaver dams led to incision of streambeds, lowering of water

Table 3.4. Distributions of large wood per 100 m of stream channel by forest regions in Washington State and by bankfull width (BFW) class (Fox and Bolton 2007). Large wood was defined as pieces exceeding 10 cm (4 in) in diameter and 2 m (≈6 ft) in length. Key piece sizes are defined in Table 3.1. One meter is approximately 3.3 feet.

Forest zones	BFW Class (m)	75th Percentile	Median	25th Percentile
		Number of pieces per 100 m		
Sitka Spruce <i>Picea sitchensis</i> , Western Hemlock <i>Tsuga heterophylla</i> , Silver Fir <i>Abies alba</i> , and Mountain Hemlock <i>T. mertensiana</i>	0-6	> 38	29	< 26
	> 6-30	> 63	52	< 29
	> 30-100	> 208	106	< 57
Subalpine Fir <i>Abies lasiocarpa</i> and Grand Fir <i>A. grandis</i>	0-3	> 28	22	< 15
	> 3-30	> 56	35	< 25
	> 30-50	> 63	34	< 22
Douglas-fir <i>Pseudotsuga menziesii</i> and Ponderosa Pine <i>Pinus ponderosa</i>	0-6	> 29	15	< 5
	> 6-30	> 35	17	< 5
		Number of key pieces per 100 m		
Sitka Spruce, Western Hemlock, Silver Fir, and Mountain Hemlock	0-30	> 11	6	< 4
	> 30-100	> 4	1.3	< 1
Subalpine Fir and Grand Fir	0-15	> 4	2	< 0.5
	>15-50	> 1	0.3	< 0.5
Douglas-fir and Ponderosa Pine	0-30	> 2	0.4	< 0.5
		Volume (m³) per 100 m		
Sitka Spruce, Western Hemlock, Silver Fir, and Mountain Hemlock	0-30	> 99	51	< 28
	> 30-100	> 317	93	< 44
Subalpine Fir and Grand Fir	0-3	> 10	8	< 3
	> 3-50	> 30	18	< 11
Douglas-fir and Ponderosa Pine	0-30	> 15	7	< 2



Wood jams are habitat features and are less common now than they were historically/Ned Pittman, WDFW

tables, loss of riparian vegetation, and subsequently deeper incision of channels (Buckley 1993). According to Pollock et al. (2007), the exact mechanism that caused widespread incision of streambeds remains uncertain, however, incision almost invariably coincided with widespread trapping of Beaver and the onset of intensive livestock grazing.

For the semi-arid grassland and shrub-steppe regions of Washington, we currently lack data with which to describe reference conditions for instream wood and for riparian plant communities. Historical reconstruction using General Land Office survey notes and historical photos is one way to develop qualitative descriptions of riparian plant communities (McAllister 2008); however, more quantitative descriptions would benefit development of management objectives. Much remains unknown about historical conditions of riparian areas in non-forested regions.

3.5. Fish, Wildlife, and Instream Wood

Authoritative reviews of the scientific literature regarding relationships between instream wood and fish or wildlife species have been written by Bisson et al. (1987), Benke and Wallace (2003), Dolloff and Warren (2003), Zalewski et al. (2003), Steel et al. (2003), and Wondzell and Bisson (2003). Certain small mammal and bird species are

known to be associated with wood in stream channels (Steel et al. 2003). However, we discuss only fish, amphibians, reptiles, and invertebrates; taxonomic groups known to have strong associations with instream wood.

3.5.1. Fish

For salmonids, especially juvenile Coho Salmon, there is no more important structural component than instream wood (Bisson et al. 1987). In Puget Sound lowland streams, measures of salmonid rearing habitat were strongly linked to instream large wood abundance (May et al. 1997). In headwater streams, step pools formed by large wood were important for Dolly Varden *Salvelinus malma*, juvenile Coho Salmon, steelhead, and Cutthroat Trout *Oncorhynchus clarkii* in reaches with gradients less than 4% to greater than 10% (Bryant et al. 2007). Adult spawning Sockeye Salmon *Oncorhynchus nerka* densities were positively correlated with cover provided by large wood and undercut banks, pool area, and large wood (Braun and Reynolds 2011). The instream abundance of juvenile salmonids often is directly related to the amount of large wood (Murphy et al. 1986; Bisson et al. 1987). Stream reaches where large wood was artificially added were used by higher densities of juvenile Coho Salmon in summer and winter, and Cutthroat Trout and steelhead in winter in 30 western Oregon and Washington streams when compared to reaches where large wood was not enhanced (Roni and Quinn 2001). Spawning Coho Salmon abundance increased after instream wood structures were restored (Crispin et al. 1993). A study in British Columbia found that the biomass of yearling and older salmonids was positively correlated with stream pool volume ($R^2 = 0.92$) and that over 70% of pool volume was formed by large wood (Fausch and Northcote 1992).

Large wood provides both direct and indirect benefits to fish (Bisson et al. 1987). Indirect benefits are related to wood's role as a roughness element, and this role is especially obvious in smaller streams where wood

can bridge much of a channel (Zalewski et al. 2003). Large wood within a small channel dissipates flow velocity, which reduces the energy fish expend as they move upstream (Zalewski et al. 2003). Bisson et al. (1987) state that sediment storage by large wood benefits fish primarily by buffering the stream network against rapid changes in sediment load that would degrade habitats, such as rapid sediment increases due to landslides. Wood also benefits fish by increasing habitat diversity. In seeking a path around large wood obstructions, water creates complex hydraulic patterns that carve pools and side channels, form falls, and enhance channel sinuosity, imposing numerous variations in a stream's hydrology and geomorphology. Another indirect benefit of instream large wood is its influences on the availability of prey for fish in the form of macroinvertebrates. Large wood provides habitat for invertebrates, which then supplies fish with a source of food (Bisson et al. 1987).

The direct benefits of instream large wood to fish are also important. Large pieces of instream wood provide fish with refuge from high velocity flows during floods and provide hiding cover from predators (Sedell et al. 1985; Bisson et al. 1987; Braun and Reynolds 2011). Uprturned tree roots and logs were the most common type of cover used by juvenile Coho Salmon and steelhead in an unlogged, west coast Vancouver Island stream (Bustard and Narver 1975). The deep pools often formed around these features made for good cover, particularly for older juveniles (Bustard and Narver 1975). After logging, almost all Coho Salmon that remained in channels over the winter sheltered in stream segments jammed with logs, with undercut banks, and in pools filled with upturned tree roots and other forest debris (Tschaplinski and Harman 1983). Hartman (1965) also found overwintering Coho Salmon fry preferring cover near logs, roots, and banks in streams in coastal British Columbia. Large wood increases fish density by visually isolating individual fish, which reduces inter- and intra-species competition (Dolloff and Reeves 1990; Crook and Robertson 1999).

3.5.2. Amphibians and Reptiles

Amphibians can be a dominant biotic component in Pacific Northwest streams (Olson et al. 2007), but in contrast to fishes and invertebrates, studies that characterize the importance of instream large wood for amphibians are sparse (Wondzell and Bisson 2003). However, diverse sources of data on stream-associated amphibian species life histories indicate that instream wood contributes to the creation and maintenance of breeding, rearing, and foraging habitats, and likely overwintering habitats as well. In particular, large wood can serve as the instream substrate for amphibian oviposition (Henry and Twitty 1940; Jones et al. 1990). Wood also forms steps in streams that promote sediment wedges (May and Gresswell 2003) that serve as variable but often extensive habitat matrices for oviposition and rearing (Nussbaum 1969; Wilkins and Peterson 2000). Moreover, wood-formed steps often create dam and plunge pools that are important for amphibian foraging or refuge (Wilkins and Peterson 2000; Welsh and Lind 2002). The basis of the former is that many aquatic invertebrates eaten by stream-associated amphibians occur in the habitat matrices created by wood-formed steps (Parker 1994; Steele and Brammer 2006; see next section). In coastal Washington headwater streams, the density of stream-associated amphibians



Van Dyke's Salamander *Plethodon vandykei* use large wood for cover/
Eric Lund, WDFW

was positively correlated with the amount of functional large wood ($R^2 = 0.50$), and torrent salamander (family Rhyacotritonidae) densities were positively correlated with the percentage of pools, indicating the importance of habitat complexity that large wood creates (Jackson et al. 2007). In Olympic National Park, large wood was a significant variable in explaining the densities of all three stream-associated amphibian species that were present, but its relative importance varied between species and was less important than one or more of aspect, gradient, and substrate in habitat use models for tailed frogs (family Ascaphidae) and torrent salamanders (Adams and Bury 2002).

Instream large wood is especially important for one Pacific Northwest reptile order: turtles. In the Northwest, water temperatures, even in the lowland stillwater habitats in which our two native turtle species occur, is often limiting (Holland 1994). Hence, the ability to bask securely (i.e., in a relatively predator-

free environment) at temperatures that exceed those of water is critical to the normal processes of digestion and for female turtles, successfully yolking up eggs. Large floating or anchored-downed logs with enough area extending above the water surface are the key structures on which basking can occur (Holland 1994). Such structures are especially important in stillwater side- and off-channel habitats of large streams.

3.5.3. Aquatic Invertebrates

The distribution and abundance of aquatic invertebrates are influenced by instream wood and certain taxa are dependent on instream wood. In streams of all sizes, areas of wood accumulation are often also invertebrate biodiversity hot spots (Benke and Wallace 2003; Wondzell and Bisson 2003). Many aquatic invertebrates use the numerous grooves, splits, and fissures in large wood as refuges from predators and harsh environments. Other invertebrate uses of wood include



Large wood in Deschutes River/Noll Steinweg, WDFW

oviposition, case making, and emergence, especially when submerged pieces are decayed rather than firm (Harmon et al. 1986). Several families of caddisfly use wood for case construction. Of ninety-two case-making caddisfly genera reviewed by Wiggins (1977), roughly a quarter exploit bark or wood to varying degrees for case construction. Instream wood also is used as sites for oviposition above and below the water line. Many caddisflies in the family Limnephilidae deposit their egg masses on moist wood. In the Coast Range of Oregon, Wisseman and Anderson (1984) found oviposition by a number of caddisfly taxa on overhanging logs. The surfaces of instream wood also are used as nursery areas for early instars, and for resting, molting, and pupation (Anderson et al. 1978).

Large wood is especially important as substrate for invertebrates to attach to in rivers with limited sources of stable substrate (Benke and Wallace 2003). Trees that have fallen into the main channels of low-gradient rivers frequently are the only stable habitat (Benke and Wallace 2003). In these streams, wood can be especially important for periphyton and macroinvertebrate taxa to attach themselves (Benke and Wallace 2003). In contrast to smaller rivers, instream large wood shifts to channel margins and floodplains of larger rivers (Bisson et al. 1987), and hence, in these main-stem locations invertebrate densities peak (Ward et al. 1982). In headwater streams, large wood and gravel habitats supported higher densities and biomass of benthic invertebrates than cobble habitats (Hernandez et al. 2005). Coe et al. (2009) saw significantly higher densities of invertebrates in Pacific Northwest streams where engineered logjams were added. They attributed this to increased overall habitat surface area, and thereby the potential for increased productivity relative to reaches with low levels of wood. Instream large wood also supported a richer and more diverse invertebrate fauna than either cobble or gravel substrates.

Wood provides invertebrates with access to a wide variety of food sources. Large wood traps and stores



Large wood on Cedar River/Hal Beecher, WDFW

organic matter, and wood can be directly consumed by some invertebrates (Benke and Wallace 2003). Trapped organic materials are food sources for bacteria, fungi, mollusks, insects, and crustaceans. Although only a small fraction of aquatic insect taxa exploit woody debris as a source of food (Harmon et al. 1986), direct wood consumption by aquatic invertebrates in the Pacific Northwest has been observed in some species of caddisfly, mayfly, beetles, and snails (Anderson et al. 1978; Dudley and Anderson 1982; Pereira and Anderson 1982; Pereira et al. 1982). Submerged large wood may also support surface films of micro-organisms (e.g., diatoms, bacteria, fungi) that efficiently take up instream nitrogen and form a food web base for aquatic invertebrates (Dudley and Anderson 1982; Johnson et al. 2003), that in turn support vertebrate species (Ashkenas et al. 2004). By moderating pulses of fine sediment (Entekin et al. 2009), instream large wood also acts to reduce the accumulation of sediment on algae (Richardson 2008), which is an important food to many macroinvertebrate taxa.

3.5.4. Fish and Wildlife Summary

The vital ecological role of instream wood has been known for at least 40 years (Swanson et al. 1976). Relationships between high quality salmonid habitats and instream large wood are well established (Bisson et al. 1987; Dollof and Warren 2003). Invertebrate taxa,

such as aquatic insects, are also known to rely on large wood as a habitat substrate and food source. Juvenile salmonids prey on aquatic insects. Amphibians and turtles also depend on the channel morphology and wood structure created by instream large wood.

3.6. Land Use Effects

The major human land uses in Washington—urban/suburban, agriculture, and forestry—have altered or removed extensive areas of riparian forest and have adversely impacted instream wood size, abundance, and distribution, and left many streams with a chronic deficiency of instream large wood compared to historical conditions (Maser et al. 1988; Bilby and Ward 1991; Stouder et al. 1997; May et al. 1997).

In general, the three major land uses impact instream large wood in similar ways—they diminish the amount of instream wood by reducing the number and size of trees in riparian areas. Furthermore, large wood is often purposefully removed from rivers and streams because it can block culverts or damage other human-made structures such as bridges, dams, or levees; cause streambank erosion that destroys private property; and present hazards to navigation or recreation. Culverts and dams also disrupt the transport of wood through a stream network and reduce the amount of wood in higher order streams and rivers.



Juvenile fish use large wood for shelter/WDFW

Most research on instream wood and riparian forests has occurred in unmanaged and managed forests, but much of the knowledge gained in forests—such as the functions of instream wood, natural amounts of instream wood, and recruitment mechanisms—is applicable to riparian areas in urban/suburban and agricultural settings as well, especially in forested ecoregions.

3.6.1. Forestry

Because mature conifer trees in the Pacific Northwest have large-diameter, decay-resistant boles, streams in this region have naturally high volumes of large wood compared to other parts of North America (Harmon et al. 1986). Nevertheless, harvest in and around riparian areas can result in immediate and long-term changes to the volume of instream wood. Czarnomski et al. (2008) found that instream wood volume and abundance varied significantly relative to timber harvest and adjacent tree stand age. They found instream wood volume and abundance were significantly higher in streams adjacent to unmanaged, mature and old-growth stands compared to streams along 30- to 50-year-old plantations, and significantly less in streams adjacent to 30- to 50-year-old plantations compared to those adjacent to 20- to 30-year-old plantations or mature and old-growth forest. Beechie et al. (2000) estimated that if a riparian buffer was established today in a 50-year-old stand of Douglas-fir, recovery of pool-forming large wood might take less than 100 years in small channels (e.g., ≤ 66 ft [20 m] wide), but could take as much as 200 years in larger channels.

The impacts of logging on instream large wood and aquatic habitats may not be realized for many decades after logging. In interior British Columbia, Chen et al. (2005) found that in the short term, instream large wood volume and biomass increased after logging. However, they concluded that in the long term, abundance of instream large wood may be greatly reduced as a

result of increased rates of decay, transport, and reduced recruitment from the adjacent riparian forest. With instream wood residence times averaging about 30 years, Hyatt and Naiman (2001) estimated that harvesting large riparian conifers would adversely impact aquatic habitats of large streams in about three to five decades. Murphy and Koski (1989) showed a 70% reduction of instream large wood 90 years after clearcutting without a riparian buffer. They also estimated a 250-year recovery time to pre-harvest levels.



Harvest near riparian areas can impact aquatic habitats/Marc Hayes, WDFW

The loss of riparian trees can come with long-term repercussions to functional aquatic habitat. Where riparian trees are absent, Beechie et al. (2000) predicted a lag of 7-49 and 15-91 years before pool-forming large wood could be recruited from Red Alder and Douglas-fir forests, respectively. The lag time for a given stream depends on multiple factors including channel width and the minimum size of pool-forming wood. In Alberta, instream large wood generated from stand-replacing fires was depleted within 100 years of the event but once the forests reestablished, new large wood recruitment was delayed by roughly 40 years (Powell et al. 2009).

A riparian management zone (RMZ) adjacent to logging differs in its ability to supply instream wood compared to riparian areas adjacent to unlogged uplands. On average, tree mortality was 50% greater in RMZs compared to riparian areas in unlogged landscapes, 3 to 15 years post-harvest (Martin and Grotefendt 2007). Differences in stand mortality between logged and unlogged tracts were primarily due to greater windthrow at a small proportion of RMZs in logged tracts. Additionally, downed tree recruitment from RMZ outer zones was more than double that of trees recruited

in unlogged tracts. Consequently, wood recruitment increased by an average of 2 trees per 330 ft (100 m) in the buffered versus unlogged forested tracts (Martin and Grotefendt 2007).

Trees in RMZs with adjacent clear-cuts may be more susceptible to windthrow. Windthrow in RMZs (85 ft [26 m] wide on both side of streams) increased instream large wood by 34% within one to three years after logging in small streams (Grizzel and Wolff 1998). The authors of that study suggested that the RMZs adjacent to clearcuts served as a long-term source of large wood. They added that over a 10-year period, windthrow could add an average of 1.9 trees per 984 ft (300 m) of stream. Along second to fifth order streams, windthrow in RMZs was 26 times greater up to three years post-harvest compared to estimated mortality rates of trees in riparian stands in unlogged tracts (Liquori 2006). Post-harvest windthrow may reduce tree density in RMZs enough to significantly reduce competition-induced tree mortality, which in turn may lead to substantially different wood recruitment dynamics in buffers compared to unlogged forests (Liquori 2006).

3.6.2. Urban/Suburban

Very few studies have examined the impacts of development on instream large wood dynamics. In their analysis of the effects of urbanization, May et al. (1997) noted that as a basin's urbanization increased the quantity of large wood declined, as did related measures of habitat quality, namely loss of riparian forest area, reduced pool area, and decreased habitat complexity. Urban streams greater than 2% gradient and lacking large wood were found to be more susceptible to scour than less developed counterparts. Other than restoration sites where instream large wood had been replaced, high quantities of instream large wood were only found in undeveloped watersheds.

An analysis of relationships of channel characteristics, land ownership, land use, and land cover to instream large wood abundance in western Oregon showed that the most important predictor for large wood volume was land ownership, followed by stream gradient (Wing and Skaugset 2002). They also observed fewer large wood pieces in streams near rural residential areas compared to managed forests. In a study outside the Pacific Northwest, researchers in the Piedmont region of Georgia found that the absence of forest cover in catchments in suburban Atlanta corresponded to a decrease of instream large wood biomass (Roy et al. 2005).



Agricultural area in western Washington/Marlin Greene, One Earth Images

3.6.3. Agriculture

Many types of agriculture remove riparian forest, and consequently, reduce the recruitment of large wood to fish-bearing rivers and streams. Within the Nooksack River basin of northwest Washington, riparian forest along reaches accessible to anadromous fish were evaluated based on their ability to contribute instream wood large enough to form pools (Hyatt et al. 2004). Seventy-four percent of this basin's riparian forests that failed to meet this criterion were found in lowland rural-agricultural areas. In contrast, only 20% of the stands that failed to meet this threshold were in federal and commercial forestlands. This contrast is notable given that agricultural and rural areas comprised only about 22% of Nooksack basin (Hyatt et al. 2004). Similar results were observed in an analysis relating land use and land cover to instream wood abundance in western Oregon (Wing and Skaugset 2002). In this study, they found fewer pieces of large wood in streams near agricultural land uses compared to that of managed forestlands.

In shrub-steppe and grassland ecoregions of eastern Washington, livestock grazing in riparian areas significantly reduces the amount of woody vegetation. Significant reductions in woody vegetation lead to numerous adverse impacts to aquatic habitats: increased streambank erosion, increased overland flow and erosion within riparian areas, increased turbidity, reduced shade, higher water temperatures, loss of cover for fish due to reductions in overhanging vegetation and undercut banks, reduction in the amount of instream small wood, changes to channel morphology such as fewer pools, fewer meanders, and channel incision, lowering the water table, and reduction in essential nutrients derived from detritus (Belsky et al. 1999).

3.6.4. Land Use Effects Summary

Land uses that affect riparian forest also affect instream large wood. Of the three major land uses, contemporary forestry has the least effect on instream large wood. However, for all three land uses, the severity of effects depends largely on how riparian areas are managed.

3.7. Conclusions

Many effects of wood on aquatic ecosystems are well understood and not subtle, and therefore, ecologists are very confident about the critical role of wood in fish habitats. Ecologists are also confident about the role of riparian forests in supplying large wood to aquatic systems. Successful conservation of fish habitats and fish species in the forested regions of Washington depends on riparian forest management that delivers adequate wood to aquatic ecosystems. From a management perspective, the main scientific uncertainties are: 1) the shape of the wood recruitment function (e.g., Figure 3.5), especially the shape under different watershed and site-level conditions; and 2) the potential contributions from recruitment mechanisms outside the riparian forest, such as landslides, debris flows, or extreme channel migration. Addressing these uncertainties through research could lead to more ecologically effective and economically efficient management of riparian areas.

To maintain or restore 100% of a site's large wood recruitment potential, the site's composition and structure should be similar to that of an unmanaged riparian forest. Given current uncertainties, re-establishing riparian forest similar to unmanaged, mature or old-growth forests should be the most reliable way to provide instream large wood sizes and abundance that are similar to historical levels.

An important management question is: what are source distances for large wood recruitment from riparian areas to aquatic ecosystems? We know that source distances for wood in riparian areas are a function of tree height—source distances are longer for riparian forests with taller trees. We also know that tree heights for old-growth conifer forests can exceed 200 ft (60 m). In Washington State, Fox (2003) found that mean heights of canopy trees in old-growth riparian areas (i.e., stand age > 200 years old) ranged from 100 to 240 ft (30 to 73 m). Height variation among riparian areas was largely explained by forest zone and site productivity class. If large wood has a minimum diameter of 4 in (10 cm), then only that portion of a tree's stem greater than 4 in (10 cm) in diameter is large wood. From tree taper equations for Douglas-fir (Biging 1984), we know that for trees between 100 to 240 ft (30 and 73 m) tall about 15 to 3 percent of the stem is not large wood, respectively.³ In other words, for the purpose of large wood recruitment, the "effective" tree height (*sensu* Robison and Beschta 1990; Van Sickle and Gregory 1990) ranges from 85 to 230 ft (26 to 70 m), depending on site productivity class. Therefore, in forested ecoregions, 100% of a site's large wood recruitment potential, is located about 85 to 230 ft (26 to 70 m) from the stream channel, depending on site productivity class. These source distances only account for trees recruited via bank erosion, windthrow, or tree mortality. It does not account for large wood recruited to the stream channel through landslides or debris flows, nor does it account for recruitment through extreme channel migration in large river floodplains. In addition, this does not account for source distances of small wood. Source distances for small wood equal a full tree height from the stream channel.

Ecologists are confident about the critical role of wood in creating fish habitat and the role of riparian forests in supplying large wood to aquatic systems.

³ Effective tree height calculations were done in Microsoft Excel with equations from Robison and Beschta (1990) and Biging (1984).

3.8. Literature Cited⁴

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Chapter 4. Stream Temperature

By: Kirk L. Krueger, Daniel J. Isaak, and Marc P. Hayes

4.1. Introduction

The great diversity of Washington's landscapes creates equally diverse stream thermal conditions (Figure 4.1). Broad ranges in elevation (0 - 14,000 ft, 0 - 4,300 m), precipitation, stream size, topography, and other factors contribute to some streams having average summer temperatures as low as 39°F (4°C); whereas others only a few miles away may exceed 68°F (20°C). Much of that thermal heterogeneity is dictated by effectively immutable geomorphic attributes of landscapes (e.g., elevation, aspect, topographic slope), which affect the potential amount of solar radiation available at a given location (Boyd and Kasper 2003). However, the types of riparian

vegetation and their condition also play important roles in determining the amount of solar radiation that reaches a stream's surface. Through management of riparian ecosystem conditions, especially vegetation, the spatiotemporal distribution of stream temperatures (i.e., thermal regime) (Boyd and Kasper 2003; Caissie 2006) can be affected, which in turn, directly and indirectly affect the survival and productivity of aquatic species (Beschta et al. 1987; McCullough 1999) including salmon.

Shade can substantially reduce the amount of direct (shortwave) solar radiation, usually the main cause of heating, that reaches a stream (Poole and Berman 2001). Indirect effects of riparian vegetation include, but are not limited to, maintenance of channel form and



Pink Salmon Oncorhynchus gorbuscha moving upstream to spawn/Ned Pittman, WDFW

hyporheic connectivity (Gregory et al. 1991; Stanford 1998; Poole and Berman 2001) that also affect stream temperatures (Boyd and Kasper 2003; Webb et al. 2008). Maintaining and restoring riparian ecosystem functions and the thermal regimes of aquatic systems is increasingly important in light of climate change and as land use intensifies. Land use can strongly influence the intensity, timing, duration, and geographic distributions (i.e., structure) of stream temperatures (NRC 2002).

In this chapter we briefly summarize the results of our literature review, and present a simple conceptual model that identifies components (environmental factors) and structures (relations of components) that affect stream temperatures, to facilitate understanding of potential effects of different management alternatives. We also briefly discuss considerations of the effects of riparian management on stream thermal regime within a watershed or stream network context, the sensitivity of some priority species to changes in stream thermal regime, and applications of current scientific information to riparian management for suitable thermal regimes for aquatic species. Much of the literature describing the effects of human activity on stream temperature has focused on summer maximum water temperatures. Increasingly, scientists are focusing on better understanding stream thermal regimes, which describe how the temperature of streams varies through time and throughout stream networks. This shift recognizes two important ideas: 1) fish and other aquatic organism use different stream habitats, defined in part by specific water temperature ranges, to complete their life cycle, and 2) heat energy inputs into streams are variable in space and time and heat energy is often carried downstream of the reach from which it was gained.

Our review of the scientific literature on the effects of riparian conditions on stream temperatures was extensive; including more than 6,000 articles relevant to riparian ecosystem research, of which more than 700 referenced stream temperatures and over 100 that referred to or reported measured effects of riparian

ecosystem conditions on stream temperatures. Our work also identifies research to inform management recommendations that are applicable across a wide range of environmental conditions (e.g., various latitudes, topographies, and land uses). Further, we wanted to address the broad range of thermal conditions that are important to aquatic species (e.g., frequency, duration, intensity, and predictability of summer high temperatures and temperatures during incubation (Lytle and Poff 2004); and the geographic distribution of stream temperatures (Torgersen et al. 1999; Poole et al. 2001; Ebersole et al. 2003a). Therefore, we reference additional scientific information to provide the context that allows for better understanding and application of riparian ecosystem-specific information. Several reviews were particularly valuable in directing our efforts (e.g., Elmore and Kauffman 1994; May 2003; Moore et al. 2005; Sather and May 2007; Bowler et al. 2012; Czarnomski and Hale 2013).

Scientists are focusing on better understanding stream thermal regimes, which describe how the temperature of streams varies through time and throughout stream networks.

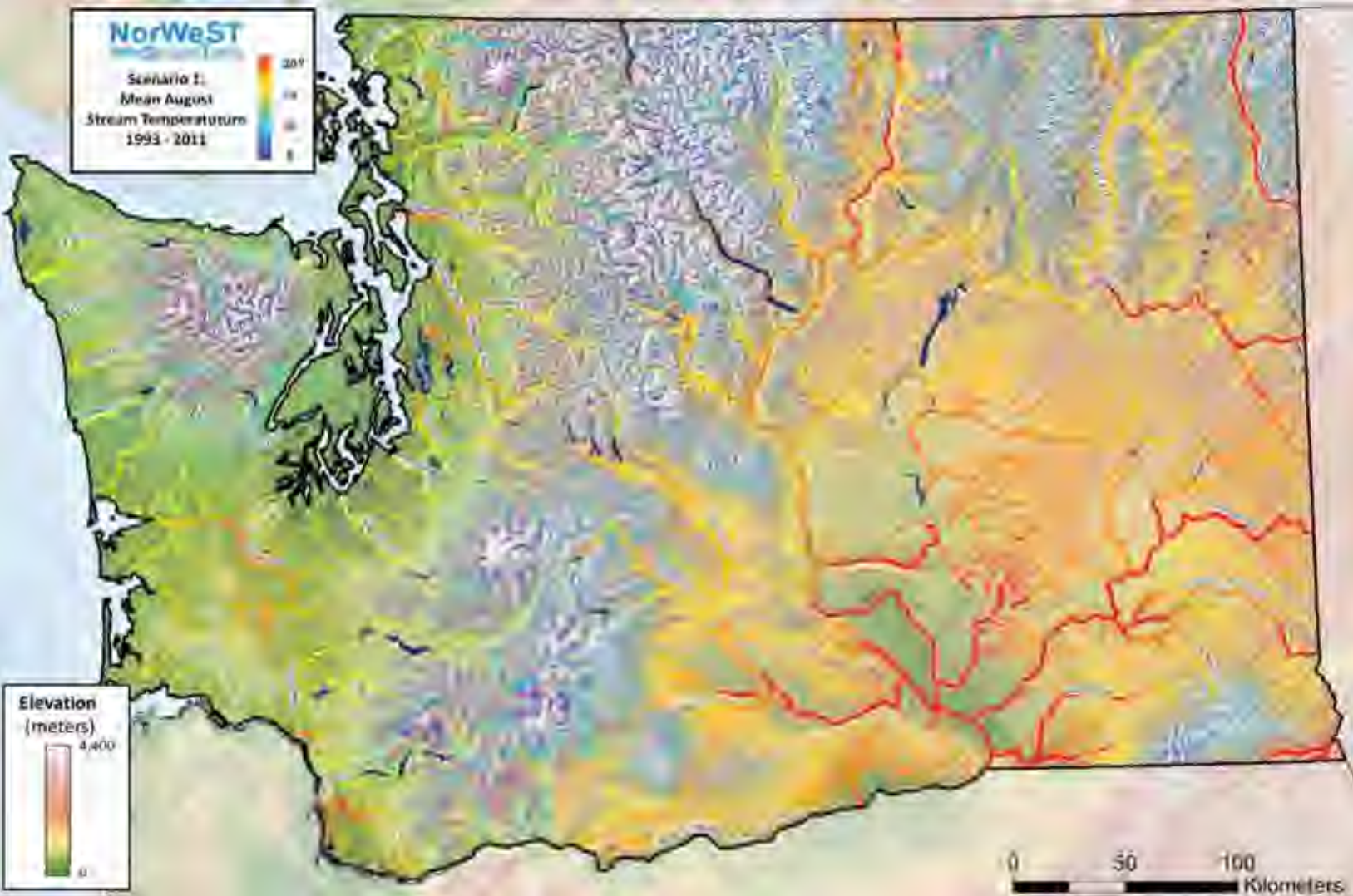


Figure 4.1. Stream thermalscape showing mean August temperatures for 66,236 kilometers (41,157 miles) of streams across Washington that was developed in the NorWeST project (poster available here: http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/downloads/14NorWeST_WashingtonStreamTemperatureMap.pdf). Topographic and geomorphic complexity across the state creates significant thermal heterogeneity that is moderated locally by riparian conditions.

4.1.1. State of the Science

The scientific literature establishes a clear expectation that reduction of stream shade, especially due to vegetation removal, will result in warmer summer stream temperatures (e.g., Sridhar et al. 2004; Allen et al. 2007). The literature, derived primarily from descriptive (e.g., case study) and occasionally statistically predictive (e.g., generalization across many case studies) studies, demonstrates that riparian management can affect shade and in turn stream temperatures (Johnson 2004; Moore et al. 2005). The vast majority of those studies document an increase in a temperature statistic, often mean daily maximum temperature during summer, associated with a loss

of shade (Johnson 2004; Moore et al. 2005; Bowler et al. 2012), but a few studies have shown mixed results (Johnson 2004; Moore et al. 2005; Janisch et al. 2012; Kibler et al. 2013).

Variability in stream temperatures among locations (Figure 4.1) and among some study results is due to both temporally constant attributes of landscapes (e.g., elevation, topographic slope, drainage area) and temporally variable attributes (e.g., stream wetted width, stream flow) that affect the potential amount of solar radiation available at a given location (Boyd and Kasper 2003) and the thermal sensitivity of the stream, respectively. The amount of solar radiation available is often referred to as thermal loading potential or

potential solar load. At a given thermal input or load, the temperature change responsiveness of a stream is often referred to as “thermal sensitivity” (Beschta et al. 1987; Moore et al. 2005). Thermal sensitivity is influenced by many physical factors. Streams with higher flows of surface and groundwater, and hyporheic exchange rates (Cristea and Burges 2010; Arismendi et al. 2012) tend to be relatively thermally insensitive. Wood loading, channel complexity and depth can also affect thermal load and sensitivity. The potential solar load in combination with thermal sensitivity (discussed in detail below) of locations across a stream network and through time largely determine a stream thermal regime.

In addition to solar radiation, other microclimate variables - such as air temperature, wind speed, and humidity - may affect instream water temperatures. Microclimate conditions interact with energy exchanges at the air-water interface (Figure 4.2) and can thereby affect stream thermal regimes (Moore et al. 2005; Benyahya et al. 2010), especially in small streams (Caissie 2016). However, we believe the effects of microclimate on the thermal regime of streams with fully functioning riparian ecosystems are minor for two reasons: 1) microclimate effects (e.g., changes in air temperature and humidity) at forest edges rarely extend farther than one tree height into mature riparian forest (Moore et al. 2005; Rykken et al. 2007; Reeves et al. 2018), and 2) sensible heat exchanges comprise only a small portion of total heat flux in streams (Johnson 2004; Moore et al. 2005). In fact, net solar radiation effects on stream temperatures are generally about an order of magnitude greater than sensible and latent heat exchanges at the air-water interface (Moore et al. 2005; D. Caissie, Fisheries and Oceans Canada, personal communication). However, we also agree with Reeves et al. (2018), who note that the range of effects measured in different studies suggests substantial uncertainties regarding riparian ecosystem management with respect to microclimate.

Riparian ecosystem-stream temperature research appears to be transitioning from largely local, descriptive (e.g., case study and generalizations of case studies) to predictive, mechanistic, and deterministic modeling across larger areas (e.g., Boyd and Kasper 2003; Allen et al. 2007). Mechanistic models attempt to include most of the factors that affect stream temperatures (Figure 4.2) in a given area and thus do not rely on statistical extrapolation from other locations. These types of models can provide relatively accurate and precise temperature predictions at various spatial and temporal scales (Leinenbach et al. 2013). Further, they can provide useful information on systems and processes that are not readily estimated through statistical approaches used in case studies. However, collecting the environmental data necessary for accurate prediction of the effects of riparian management actions on stream thermal regimes via mechanistic models is difficult and often prohibitively expensive (Allen et al. 2007). For example, studies on the effects of riparian ecosystem or land cover management on stream temperatures at large spatial extents (e.g., watersheds of large streams or rivers) and cumulative effects are very rare. Watershed-scale studies (e.g., Janisch et al. 2012; Kibler et al. 2013) are often limited to relatively small watersheds (e.g., 2 to 1,000 ha) and second order streams.

New types of statistical models for stream network data (Ver Hoef et al. 2006; Isaak et al. 2014) have been applied to large stream temperature databases (Isaak et al. 2017a) and these have enabled relatively accurate predictions ($R^2 = 0.90$; RMSE = 1.8°F or 1.0°C) and mapping of summer thermal conditions across all Washington streams (Figure 4.1). Those statistical approaches use predictor variables derived from broad geospatial and remotely sensed datasets (e.g., elevation, stream slope, riparian density from the National Land Cover Database) so they do not provide insights to local temperature anomalies that could be associated with alterations of riparian or channel conditions. However,

these statistical models do provide accurate thermal status maps that could be used with mechanistic models or field measurements to better ascertain the influence of riparian conditions on stream temperatures.

Scientific knowledge of the importance of stream temperatures on aquatic species has also advanced since the publication of Knutson and Naef in 1997; especially by better describing the importance of thermal regimes (rather than only extreme high temperatures) on fish survival, growth, and productivity (Ward and Stanford 1982; McCullough 1999; Caissie 2006; McCullough et al. 2009; Hinch et al. 2012). For example, the collapse of the Fraser River Sockeye Salmon *Oncorhynchus nerka* spawning run in 2009 was largely attributed to thermal exposure due to early migration, which resulted in indirect, but often fatal, effects (Hinch et al. 2012). Following Olden and Naiman (2010), we suggest that thermal regimes can be described by their rates of change, magnitude, frequency, timing, and duration, and also their spatial distribution in a stream. The timing and duration of thermal exposure, in addition to exposure to extreme temperatures, affects the survival and productivity of many aquatic species (Caissie 2006).

Importantly, studies such as those of Murphy and Hall (1981), Murphy et al. (1981), Hawkins et al. (1983), and Bilby and Bisson (1987) that demonstrated apparent beneficial effects of reduced riparian shade on an aquatic species, such as increased salmonid growth or abundance, can now be considered in a broader ecological context. It should be noted that in these studies observed temperature increases were small and apparent beneficial effects were attributed to increased solar radiation, primary production, and consequent bottom-up stimulation of the food web. These findings are consistent with the idea that oftentimes the biological effects of altered temperatures differ among locations (Li et al. 1994; Farrell et al. 2008), and that such differences in effects may be attributed to the difference between local temperature and the

thermal niche of a species. For example, in reaches where temperatures are near a species' thermal maxima, additional warming will cause the habitat to become unsuitable. However, in streams that are too cold for a species, warmer temperatures may increase habitat suitability (Isaak and Hubert 2004; Isaak et al. 2017b). In addition to direct stream temperature changes on a single species, changes may affect ecological trade-offs between species. Rezende et al. (2014) showed that faster growth might also be associated with increased competition with non-native species (Lawrence et al. 2014).

Widespread alterations of upland and riparian conditions and subsequent changes in stream composition and structure have likely already impacted thermal conditions in many streams (Poole and Berman 2001) and such impacts will be further exacerbated by the ongoing effects of climate change (Isaak et al. 2012; Holsinger et al. 2014). Streams with degraded riparian conditions, however, also offer opportunities where restoration actions could mitigate future warming and improve ecological resilience by enhancing the survival and productivity of the populations and assemblages that use those systems.

4.2. Conceptual Model

We provide a conceptual model to help describe the important components, structures, and processes that affect stream temperatures and that can result in different effects of riparian management actions on stream temperatures among locations (Figure 4.2). Our conceptual model is largely a simplification of the model "Heat Source" in Boyd (1996) and Boyd and Kasper (2003) and developed based on the preponderance of scientific evidence. Heat Source is a deterministic, mechanistic model developed to predict dynamic open channel heat and mass transfer. As such, it includes parameters for all variables that are known

to significantly affect stream temperatures. Our simplified conceptual model describes components and parameters that can have a large effect on stream temperatures or that are affected by riparian ecosystem management. We provide this model in an attempt to improve basic understanding of stream thermal processes and to identify important composition, structure, and functions that are subject to management and that affect stream temperatures. Additional information based on the models of Poole and Berman (2001), Moore et al. (2005), and Leinenbach et al. (2013) are included to more clearly identify factors that affect thermal loading potential and stream thermal sensitivity via riparian management.

Scientific understanding of the environmental factors and their relations that affect stream thermal regimes is well developed, as demonstrated by the development of deterministic, mechanistic models (e.g., Boyd and Kasper 2003) that can provide accurate temperature predictions when sufficient data are available to run the model and when the stream system remains relatively stable. Such models have been applied successfully at the spatial extent of individual stream reaches (Cristea and Janisch 2007; Cole and Newton 2013) and watersheds (Coffin et al. 2011; Bisson et al. 2013; Booth et al. 2014), suggesting that our understanding of the composition, structure, and functions that affect stream temperatures are well understood and can be

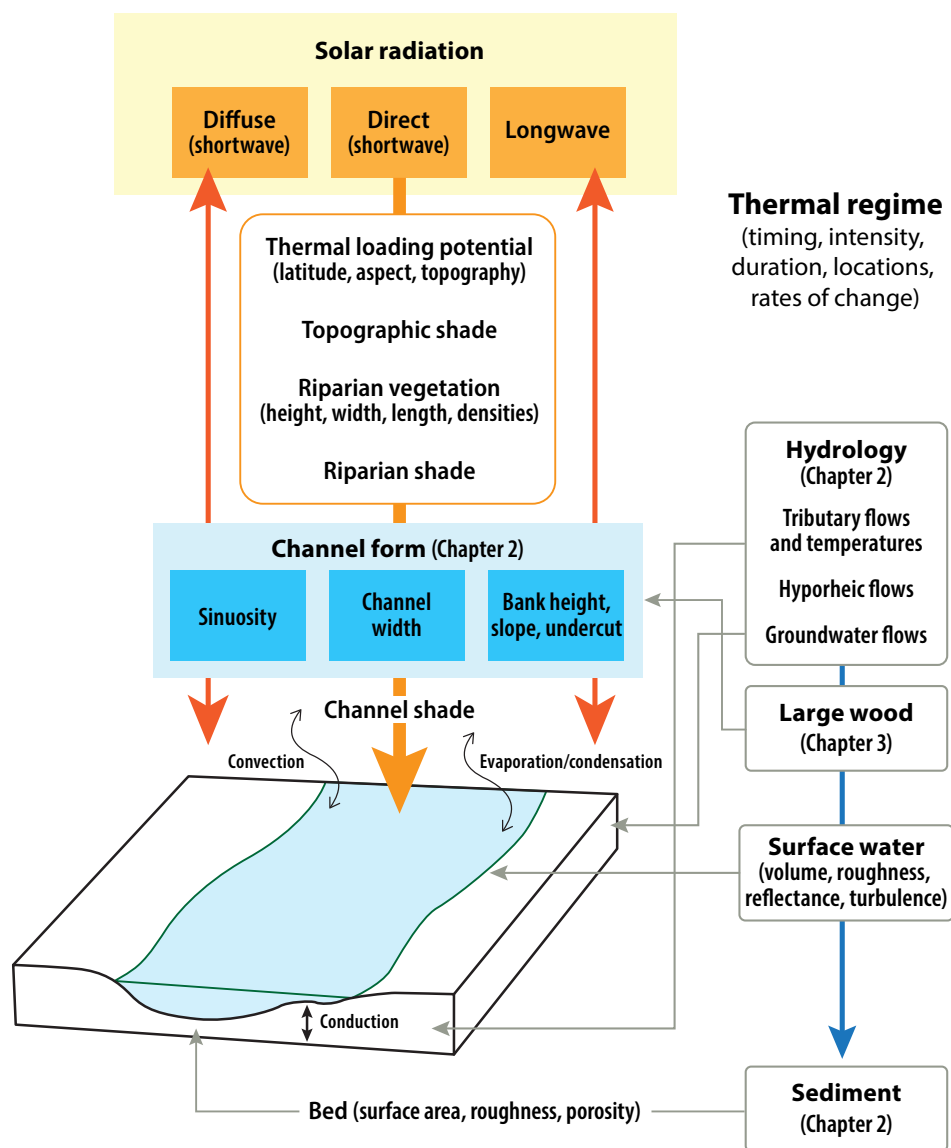


Figure 4.2. Conceptual model that identifies some factors that affect the thermal regime of stream networks. Relative importance is noted by line weight and arrows indicate directions of flows. Note that most of the elements in the model are influenced by human activities and that many components and structures are not presented here. See Boyd and Kasper (2003) for a more thorough review.



Dense tree canopies rarely provide 100% shade/Ned Pittman, WDFW

reliably applied to management problems. Rates of direct (shortwave) solar radiation reaching the stream surface and the volumes and temperatures of water are consistently identified as the dominant processes affecting the thermal regime of streams (Sinokrot and Stefan 1993; Johnson 2004). At many locations these two dominant processes are subject to management: direct solar radiation reaching a stream via vegetation management and water flows via water diversion, storage, and return (Olden and Naiman 2010).

The thermal loading potential of a stream reach is controlled in part by temporally constant and largely independent factors such as latitude, aspect, elevation, and topographic shading (Figure 4.2, Boyd and Kasper 2003; Janisch et al. 2012). Streams at high latitudes are less exposed to solar radiation, the ultimate source of heat energy to streams, than streams at low latitudes. Stream aspect affects stream temperatures because a stream's orientation relative to the path of the sun (which differs seasonally) determines the amount of direct solar radiation that a stream receives (Johnson 1971). Elevation affects the ambient air temperatures that streams are exposed to, as well as the dominant form and amount of precipitation (i.e., snow or rain). For these reasons, higher elevation streams are usually colder and commonly, although not always, less thermally sensitive than lower elevation streams (Luce et al. 2014). Topography can shade a stream from direct solar radiation and the effects of topography and aspect

can interact. The effects of these four geographic factors can be difficult to detect (Isaak and Hubert 2001) and are likely responsible for some of the variability of the results of case studies that measured the effects of riparian management on stream temperatures. Note that some of these attributes (e.g., elevation) also affect the composition and structure of riparian vegetation. Stream thermal loading is not only controlled by independent factors such as latitude, aspect, elevation, and topographic shading. The scientific literature clearly identifies shade from riparian vegetation as important to stream temperatures, especially for small (narrow) streams (e.g., Beschta 1987; Poole and Berman 2001; Johnson 2004; Sridhar et al. 2004; Moore et al. 2005; Caissie 2006; Allen et al. 2007; Bowler et al. 2012; Garner et al. 2014). The effects of altered stream shading on temperatures is complex because thermal loading potential and thermal sensitivity of streams differ among locations. Some attributes, such as water volume, wetted width, and width-depth ratio can affect both thermal loading potential and thermal sensitivity (Cristea and Janisch 2007; DeWalle 2010). For a given volume of water, wider channels of the same length have a greater surface area that can intercept more direct solar radiation (Boyd and Kasper 2003) and also exchange more heat through atmospheric conduction. The width of a stream also affects the amount of shade that can be provided by topography and riparian vegetation (Cristea and Janisch 2007; DeWalle 2010). That is, riparian vegetation of given height, density, and width might shade a larger proportion of a narrow channel for a longer period than for a wide channel. Stream widths, especially wetted channel widths, are often much less temporally stable than the other factors that control thermal loading potential. Management actions that result in changes in stream width (e.g., over-grazing [Belsky et al. 1999; Chapter 2] and maintenance of wide forested riparian areas that can result in wide channels [Sweeney and Newbold 2014]) can increase thermal loading potential and thermal sensitivity.

While shortwave radiation input and water volume and temperature largely control temperature regime, longitudinal channel form (stream reach and cross section) can also affect stream temperature, for example, via high sinuosity and the presence of undercut banks (Frissell et al. 1986; Bisson et al. 2006). Channel form and features that increase stream roughness can store gravel (Buffington et al. 2004) and increase hyporheic exchange (Wondzell and Gooseff 2013) that, in turn, can affect stream temperatures by storing and releasing heat (Burkholder et al. 2008). Large wood can also store large amounts of gravel in some streams (Buffington et al. 2004) and affect channel form (Chapter 3; Keller and Swanson 1979; Abbe and Montgomery 1996; Konrad et al. 2005) which might subsequently affect stream temperatures. For example, sediment deposition due to instream large wood might increase hyporheic flow and stream width, which can subsequently effect stream temperatures. Steep or undercut banks can also provide shade (Boyd and Kasper 2003) which, in some locations (Ebersole et al. 2003b), can lower water temperatures at small spatial extents (e.g., individual pools; Ebersole et al. 2003a), even in large streams and rivers. Unfortunately, relatively few studies quantify the effects of channel form on thermal sensitivity and stream temperatures, which likely adds variability among stream temperature case studies and limits our ability to predict their relative importance at specific locations. Groundwater and tributary flows also affect stream temperatures (Malard et al. 2002) in two ways, 1) by adding volume and increasing flow velocity that can make streams less sensitive to thermal change (i.e., increasing thermal capacity), and 2) by adding water that is at a different temperature than receiving waters (Boyd and Kasper 2003; Story et al. 2003). However, the effects of groundwater flows can be difficult to detect due to spatiotemporal lags (Alvarez et al. 2004; Arrigoni et al. 2008) and difficult to apply to management due to the paucity of information describing groundwater flows. Additionally, side channels and wetlands can provide large volumes of water at different temperatures to

receiving stream water (Bobba et al. 2010). Streambed attributes, such as porosity and surface area, are largely controlled by the flows of water and available sediment (see Chapter 2). Streambed attributes can affect the thermal regime of a reach by affecting heat conduction (Sinokrot and Stefan 1993), by regulating the amount and velocity of water flow through the streambed, and by controlling the rates and locations of groundwater flows (Malcolm et al. 2002). The effects of these processes on stream temperatures can be spatially and temporally discontinuous and dynamic, especially in systems where stream form is heterogeneous and dynamic (Wright et al. 2005; Wondzell 2012). Hyporheic flows often have little effect on average stream surface water temperatures except for small streams at low flows but can create discrete locations of cool water (Wondzell 2012) that may serve as important refugia for salmon. Hyporheic flows can be influenced by flow regulation (e.g., dams), which can reduce variation in both flows and temperatures that reduces the potential for hyporheic exchange to act as a thermal buffer (Ward and Stanford 1995; Poole and Berman 2001; Nyberg et al. 2008).



Juvenile salmon/Portia Leigh, WDFW

The interaction of complex in- and near-stream riparian ecosystem processes can lead to a cascade of events (i.e., a series of related events triggered by single event) and new system states (Pringle and Triska 2000; Allan 2004). These cascading events are almost impossible to predict. For example, the removal of riparian trees typically reduces shading and increases solar radiation to the stream. Even when reductions in shade have a small direct effect on stream temperatures, the loss of trees can increase bank susceptibility to erosion (Chapters 2 and 3; Micheli and Kirchner 2002; Gomi et al. 2004) resulting in a wider stream that increases thermal loading and thermally sensitivity of the stream. Similarly, channel incision resulting from riparian management, may increase local topographic shading to the stream, but lower streambed and water elevations that can shift the riparian vegetation composition and structure. This shift in riparian vegetation can result in less stable streambanks and less riparian shade that ultimately offsets any benefits of topographical shading on water temperature (Toledo and Kauffman 2001). The results of such interactions are difficult to predict because they rely on accurate predictions of changes to stream morphology, vegetation composition and structure (which interact and have non-linear responses), and water and sediment flows (which can be stochastic).

The processes that affect the timing, duration, and geographic distribution of stream temperatures are complex due to the variability of the environment in which these processes occur (Figure 4.2). The relative importance of these ecological processes differs among locations and through time (Poole and Berman 2001; Webb et al. 2008). Scientific literature is clear about the expected effect of reducing stream shading, especially during summer; water gets warmer, particularly peak temperatures. Science is less able to provide accurate and precise predictions of the effects of specific riparian management measures. For example, the studies presented in Figure 4.3 represent statistical models

relating changes in riparian buffer width to changes in stream temperature. Data in Figure 4.3 are collected by measuring stream temperature before and after a reduction in the width of a forested riparian buffer which in turn decreases shade to the stream. Model output (prediction) is change in temperature related to specific buffer widths. The models tell us that reducing shade usually increases stream temperatures (following the shape of the dotted line connecting points), but they cannot predict exactly how much shade reduction will result in a specific temperature increase. A manager attempting to use the statistical model in Figure 4.3 to predict how a reduction from a fully forested site to a 30-foot wide buffer might affect summer stream temperatures is confronted with a range of possible answers. Those answers fall within the 90% credible intervals for one study representing a change between 1.25 and 2.25°C (2.25 and 4.05°F), and for another study between -0.5 to nearly 5.0°C (-0.9 to nearly 9.0°F). Uncertainty in this case describes our inability to accurately predict exact outcomes. While rarely applied due to their expense, mechanistic models and attendant data (e.g., hyporheic flows and temperatures) provide the best approach for predicting accurate site-specific outcomes from management.

Fortunately, the literature is very clear that solar radiation is often the dominant factor affecting stream heat budgets during all seasons except winter (Webb et al. 2008). Results of case studies can prove very useful by clearly describing the expected direction and shape of the relations between attributes of riparian ecosystems (e.g., width of vegetation) and stream shade and temperature. Importantly, riparian shade is often directly amenable to management and in many locations riparian vegetation height and density may be more closely associated with shade than width of riparian vegetation per se (DeWalle 2010). In any case, the literature is very clear about the importance of riparian vegetation for providing shade to streams (Figure 4.3a).

4.3. Species Sensitivity

4.3.1. Fish

The scientific literature describing the importance of temperature, especially high temperatures, to fish is extensive (e.g., Brett 1952, 1971; Brett et al. 1969; Richter and Kolmes 2005). As aquatic ectotherms, the physiology of fish are strongly affected by water temperatures (McCullough et al. 2001; Welsh et al. 2001). Studies have frequently found associations between temperature and the geographic distribution (Welsh et al. 2001), spawn timing (Hodgson and Quinn 2002), growth rates, egg development and survival, competitive interactions, life stage survival, and behavior of fish (McCullough 1999; McCullough et al. 2009). Salmonids have frequently been studied because of their cultural and economic importance and their relative sensitivity to

high temperatures, narrow thermal tolerance, and narrow aerobic scope (Farrell et al. 2008; Eliason et al. 2011; Ayllon et al. 2013). Summer temperature information is useful for identifying acute problems, but may be insufficient for ensuring population resilience because indirect effects and exposure to altered thermal regimes, not just extreme summer temperatures, can affect fish survival and productivity (McCullough 1999).

Recent research has increasingly focused on the effects of water temperatures and thermal regimes for fishes that have narrow thermal tolerance (i.e., range of suitable temperatures) or aerobic scope (Farrell et al. 2008; Eliason et al. 2011; Ayllon et al. 2013). This work is particularly relevant to salmonids in the Pacific Northwest that have life histories adapted to historical, location-specific thermal regimes (Brannon et al. 2004; Farrell et al. 2008; Eliason et al. 2011). Much of this research is related to the increasing threats posed by climate change, and some studies have already found evidence of existing, detrimental effects of increased stream temperatures on fish. For example, Isaak et al.



Juvenile anadromous salmon can spend up to 3 years in streams depending on the species/Ned Pittman, WDFW

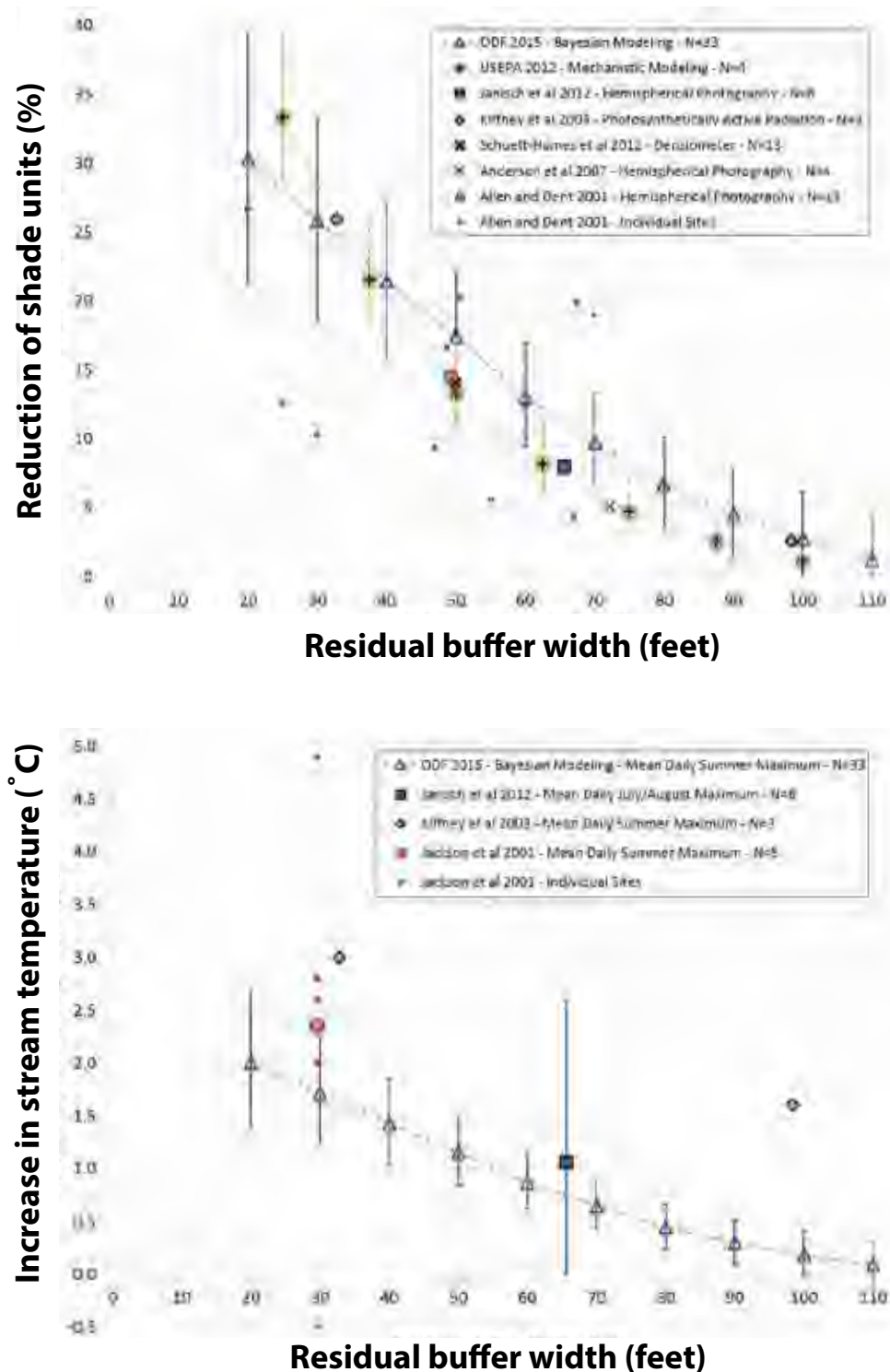


Figure 4.3. Observed shade (a: top panel) and temperature response (b: bottom panel) associated with “no-cut” riparian buffers with adjacent clearcut harvest. Only studies that employed a Before-After-Control-Impact design and conducted in Pacific Northwest forests are included. Shade unit is percent from completely shaded. Bayesian modeling results (and 90% credible intervals) were derived from data collected as part of Groom et al. (2011). Analyses provided by P. Leinenbach, USEPA Region 10.

(2010, 2015) found increases in stream temperatures would result in losses of Bull Trout *Salvelinus confluentus* and Cutthroat Trout *Oncorhynchus clarkii* habitats, but also that especially cold streams could serve as climate refugia during the 21st century. Additionally, a number of recent studies have described some complex effects of altered thermal regimes to the productivity and survival of fish at different life stages and dramatic differences in thermal tolerance and aerobic scope among populations and species. For example, Hinch et al. (2012) describe complex links between the physiology, behavior, environment, disease exposure, and the effect of thermal exposure, on the population-specific survival of migrating Sockeye Salmon. Hodgson and Quinn (2002), Keefer et al. (2007), Strange (2010) and others have documented that high temperatures and previous thermal exposure can inhibit fish migration, and Marsh (1985) and Kappenman et al. (2013) have documented that high and low temperatures can impede spawning and embryo development and that optimal temperatures for embryo survival and development differ among species. Steel et al. (2012) found that thermal variability (without changing mean temperature) can affect the emergence timing and development of Chinook Salmon *Oncorhynchus tshawytscha*.

The literature is conclusive about the importance of stream thermal regimes to fish survival and productivity and also demonstrates wide variability in sensitivity to altered thermal regimes among species and among populations within species (Steel et al. 2012). More research would help us fill the sizeable gap in our understanding of the risk posed by altered thermal regimes on the survival and productivity of populations of salmonids or non-salmonid fishes, and on the ecological interactions that affect survival, productivity and population viability. For example,



Chum Salmon Oncorhynchus keta in spawning colors/Ned Pittman, WDFW

the time of hatching (i.e., duration of incubation) of salmonid eggs is largely determined by their thermal exposure during incubation. Relatively small changes in temperature can advance or delay maturation and subsequently hatching date (Groot and Margolis 2010) and effects of temperature can differ among closely related populations of the same species that spawn in different habitats (Hendry et al. 1998). Regardless of the ultimate cause, changes in thermal regimes can, for example, uncouple trophic interactions due to temporal mismatches, such as fry emerging when their preferred food is not available to them (Winder and Schindler 2004; Post et al. 2008). Altered thermal regimes can also affect other life stages by altering the timing of parr-smolt transformation (Zaugg and Wagner 1973), the duration of freshwater rearing (Sauter et al. 2001) which can affect ocean survival (Weitkamp et al. 2015), and the timing and success of spawning migration (Crossin et al. 2008). Altered thermal regimes can also affect ecological interactions. For example,

Wise management of riparian and aquatic systems would ideally consider the distribution and dynamics of stream temperatures in space and time and at scales that are relevant to the species in the region.

Lawrence et al. (2014) demonstrated that higher stream temperatures can expand the geographic distribution of non-native Smallmouth Bass *Micropterus dolomieu* and increase their predation on salmon. These results are complicated by the fact that effects of altered thermal regimes often differ among populations and life stages of a species, and among species (Brett 1971; Zaugg and Wagner 1973) which makes prediction of the exact effects of any riparian shade reduction and subsequent effects on stream thermal regime on fish survival and productivity uncertain. This uncertainty is compounded by fish behavioral responses, such as daily and seasonal movement among locations where thermal conditions differ (Torgersen et al. 2001).

Our understanding of the importance of altered thermal regimes on fish has improved substantially since the publication of Knutson and Naef (1997). Discussion of stream temperature by Knutson and Naef (1997) focused mostly on summer high temperatures and their effects on fish, but did not identify many components and structures of ecosystems that can affect stream temperatures or the importance of thermal regimes to fish. In particular, more recent studies are able to measure thermal exposure of fish through time, occasionally in field conditions, and estimate physiological attributes such as growth rate (Sauter and Connolly 2010).

Most studies calculate a single statistic that describes an important attribute of a stream's thermal regime (e.g., mean maximum daily summer temperature) and identify species, population, or life stage attributes that are correlated with that statistic, such as a critical thermal limit. These studies have been useful for demonstrating the importance of temperature and for setting some management objectives. However, they are insufficient for effective, long-term management of perturbed systems because changes in temperature means (i.e., chronic exposure) or extremes (i.e., acute exposure) can result in different selective pressures and evolutionary responses (Rezende et al. 2014) and

because life stages, populations, and species differ widely in their sensitivity to altered thermal regimes (Farrell et al. 2008; Hinch et al. 2012). Further, we now better understand that many individual fish and especially populations use (and perhaps are dependent on) a dynamic mosaic of habitats (Fausch et al. 2002; Ward et al. 2002; Wiens 2002); that is, they move between discrete locations with different temperatures (Torgersen et al. 1999). Such movement among "patches" can be important to individual survival and population persistence because thermal conditions at discrete locations can be highly temporally variable (Dugdale et al. 2013) and spatially complex (Fullerton et al. 2015). Management of stream thermal regimes should carefully consider the spatiotemporal distribution and dynamics of thermal conditions at scales that are relevant to the species in the region (Fausch et al. 2002) at durations that are relevant to the rates of system change and recovery from disturbance.

4.3.2. Amphibians and Reptiles

Few studies address the effects of altered thermal regimes on stream-associated amphibians and reptiles, which currently limits the level of specificity to which reliable management recommendations can be made. However, some important insights are possible and these are best discussed in the context of breeding habitat: 1) amphibians that breed in the flowing portions of stream networks, and 2) amphibians and reptiles that breed in or use off-channel stillwater habitats associated with stream networks.

Instream-breeding amphibians (giant salamanders, *Dicamptodon* spp.; tailed frogs, *Ascaphus* spp.; and torrent salamanders, *Rhyacotriton* spp.) are generally described as having low thermal requirements (Bury 2008). However, those requirements are often characterized solely in terms of critical thermal maxima (Brattstrom 1963; Claussen 1973; Brown 1975; Bury



Giant salamanders (*Dicamptodon* spp.) can be found in small western Washington streams/Eric Lund, WDFW

2008), while stream temperatures in which these species are found are considerably lower than those maxima (invariably $\leq 61^{\circ}\text{F}$ [16°C]; e.g., Brattstrom 1963; Welsh 1990; Welsh and Lind 1996; Pollett et al. 2010). Moreover, water temperatures at which these species first become stressed are entirely unknown. Several studies demonstrate higher density or relative abundances (Stoddard and Hayes 2005; Pollett et al. 2010) of amphibians at the margin of their temperature maxima although the mechanism responsible for this effect is unclear. Similar to fish, identifying critical effects of temperatures on amphibians is complicated by a host of potential variables, e.g., younger life stages frequently have cooler temperature requirements (de Vlaming and Bury 1970; Brown 1975) than older life stages. Importantly, very little research has been conducted on the effects of altered thermal regimes on the timing of life history events, such as the time of hatching, and indirect effects, such as possible ecological temporal mismatches, altered predator-prey relations, and disease frequency and effect (e.g., Hari et al. 2006), that would be useful for identifying important conservation and management actions.

Amphibians and reptiles that breed or utilize riverine off-channel stillwater habitats (e.g., oxbow lakes and permanent and seasonally flooded riverine wetlands) associated with stream networks generally have warmer thermal requirements than instream breeding amphibians. For stillwater-breeding amphibians, thermal requirements vary as a function of the thermal tolerance limits of a specific life stage (often eggs and embryos), which determine the seasonal interval in which they lay eggs. For example, Northern Red-legged Frog *Rana aurora* embryos have the lowest critical thermal maximum of any North American frog (about 68°F or 20°C) (Licht 1971), and they oviposit in late winter, at which time surface water temperatures of stillwater habitats rarely if ever put its embryos at risk. Except for our two turtle species (Western Pond Turtle *Actinemys marmorata* and Western Painted Turtle *Chrysemys picta*) and selected garter snake species *Thamnophis*, especially the Common Garter Snake *T. sirtalis* and the Western Terrestrial Garter Snake *T. elegans*, few reptiles utilize aquatic habitats in the Pacific Northwest. These reptiles have



Riparian corridor/Ned Pittman, WDFW

thermal requirements that are more elevated than the temperatures generally found in stillwater habitats except during the warmest part of summer. For this reason, aerial basking (basking out of water) at daytime temperatures that are warmer than water temperature can be critical for these species for effective digestion of food or production of eggs. This pattern is especially important for turtles that need aquatic aerial basking sites isolated from predators, which in most stillwater habitats are provided by large downed wood with relatively level accessible surfaces above the water line (Holland 1994).

4.3.3. Invertebrates

Few studies have examined the effects of altered thermal regimes on stream-associated invertebrates in the Pacific Northwest. However, broad relationships between the geographic distributions of invertebrates and their thermal tolerance have been reported (Beschta et al. 1987; Moulton et al. 1993) as have changes in emergence timing and asynchronous emergence among sexes due to small increases in summer temperatures (Li et al. 2011), demonstrating the importance of temperature to invertebrates. Stream temperature can affect invertebrate density, growth, size at maturation, and sex ratios and the effects often

differ among species (Hogg and Williams 1996). Altered stream thermal regimes appear to have important effects on many invertebrates and, subsequently, on stream food webs. Indirect effects such as altered predator-prey relations and disease frequency may also be important but have not been well studied. Riparian ecosystem management for aquatic invertebrates is also constrained by a general lack of information on their geographic distribution.

4.3.4. Species Sensitivity Summary

Management of vegetation in riparian ecosystems can affect stream temperatures and, subsequently, fish, amphibian, and invertebrate abundance and survival. Stream temperature influences important food web and energetic interactions between fish, amphibians, and invertebrates in multiple direct ways and likely in more subtle but relatively unstudied indirect ways (Baxter et al. 2005). The effects of thermal regime has received little study for amphibians and invertebrates. Fortunately, our understanding of the mechanisms that affect stream thermal regime can provide useful guidance in the absence of better information.

4.4. Land Use Effects

4.4.1. Urbanization

There have been very few studies specifically relating urbanization to riparian ecosystem function and subsequent effects on stream thermal regimes (Paul and Meyer 2001). Clearly, urbanization related changes to riparian areas can be similar to riparian changes associated with agriculture and forestry as far as stream temperature is concerned, e.g., removal of shade, reduction in large wood inputs. Urban areas have additional issues that can affect stream temperatures including heat island

effects, and inputs of wastewater and runoff from impervious surfaces (Kinouchi et al. 2006; Hester and Doyle 2011). Some of these complicating factors may contribute to the absence of detectable effects on stream temperatures studies in some comparative studies (Wahl et al. 2013). Nonetheless, urbanization is considered to have adverse effects on stream temperatures (LeBlanc et al. 1997; Finkenbine 1998), especially when riparian functions are affected (Booth et al. 2001). To protect stream thermal regimes in urban settings, conservation efforts should focus on maintaining riparian functions, mitigating anthropogenic changes to hydrology, and preserving watershed connectivity (e.g., movement of water, sediment, wood, nutrients, and species).

4.4.2. Agriculture

In comparison to urbanization studies, studies of the effects of agricultural practices on riparian ecosystems or subsequent effects on stream thermal regimes are fairly abundant, especially for grazing lands (e.g., Li et al. 1994; Tait et al. 1994; Maloney et al. 1999; Zoellick 2004) and crop lands (e.g., Waite and Carpenter 2000). Studies examining the effects of agriculture, particularly livestock grazing, generally find stream temperature increases associated with disturbance of the riparian ecosystem (Zoellick 2004; Webb et al. 2008). Livestock use of streamside areas can increase a stream's exposure to direct sunlight by reducing shade from streamside vegetation (Li et al. 1994). Livestock can also reduce the amount of undercut banks and increase stream channel width through trampling and vegetation removal (Belsky et al. 1999; Chapter 2). Channel widening can also result in reduced depth, which can exacerbate warming (Poole and Berman 2001). However, results of observational studies are mixed, with occasional absences of predicted detectable increases in stream temperature due to changes in riparian ecosystems as a result of agriculture (e.g., Tait et al. 1994) and wide variation in effect on riparian

Studies of the effects of land management on riparian functions and stream temperatures confirm the importance of riparian ecosystems to stream thermal regimes.

vegetation among locations and types of agriculture (see Maloney et al. 1999). Importantly, Zoellick (2004) found that riparian vegetation can recover after removal of the disturbance agent (e.g., livestock). For crop lands, the importance of riparian ecosystem attributes, e.g., vegetation width, height and density, on stream temperatures have been documented (Waite and Carpenter 2000) and, similar to grazed lands, effects differ widely among locations (Benedict and Shaw 2012).

4.4.3. Forestry

Relative to urbanization and agriculture, many studies in the Pacific Northwest have examined the effects of forest management on stream temperatures. Decades of research have frequently documented increased stream temperature due to forestry practices (Olson and Rugger 2007), and our understanding of the mechanisms by which forest practices affect stream temperatures is well developed (Beschta et al. 1987; Groom et al. 2011). Most studies find that forestry, especially when riparian vegetation is disturbed, results in higher stream temperatures than in less disturbed locations (Li et al. 1994), however, exceptions to this pattern are not uncommon. For example, Liquori and Jackson (2001) found stream temperatures 3 to 7°F (1.5 to 4°C) greater in stream reaches surrounded by dense riparian forests compared to downstream reaches

adjacent to scrub-shrub riparian communities. Many of the studies of the effects of forestry on stream temperatures include consideration of some of the components and structures that affect stream thermal regimes identified by Boyd and Kasper (2003) and Poole and Berman (2001). For example, Liquori and Jackson (2001) suggest that their results are due to lower width-to-depth ratio, higher rates of hyporheic or groundwater exchange, and greater amounts of shade in shrub-scrub associated reaches. Maloney et al. (1999) found that much of the variation in their results (in mostly agricultural settings) was explained by reach length, shade, elevation, aspect, and especially by stream gradient and air temperature. Similarly, Kiffney et al. (2003) and Janisch et al. (2012) described the influence of groundwater and hyporheic exchange on their results.

4.4.4. Land Use Summary

Studies of the effects of land management, especially the many studies of forestry, on riparian functions and stream temperatures confirm the importance of riparian ecosystems to stream thermal regimes. Additionally, they emphasize the high degree of variability among locations of the functions that affect stream thermal

regimes, even among adjacent stream reaches, that so often produce variable results. Unfortunately, studies that examined the effects of land management on the complete thermal regime of a stream are lacking. Such studies could be especially valuable because the cumulative effects of riparian ecosystem or upland management on stream temperatures can dominate local effects (Chapter 8). Further, most studies use only a few statistics that describe peak or average temperatures, usually during summer. Such statistics are useful, but have limited ability to address dynamic, water quality parameters including temperature (Poole et al. 2004) related to species needs. Thus, predicting the effects of land management on other thermal attributes (e.g., duration or frequency of stressful temperatures) or during other seasons when thermal exposure can significantly affect some species (e.g., overwinter incubation) is difficult. Similarly, even cumulatively, the relatively small number of studies and their skewed geographic distribution (i.e., most are on low-order streams in maritime regions) constrain our ability to provide broad and precise generalizations or make accurate predictions to other locations. Conservation efforts for maintaining stream thermal regimes must be based on our understanding of direct and indirect mechanisms of stream heating affected by human activities, wise use of statistical models relating shade and stream temperature across the watershed until mechanistic models become available, and preserving watershed connectivity (e.g., movement of water, sediment, wood, nutrients, and species).

4.5. Conclusions

Scientific understanding of the structure and function of streams and the importance of thermal regimes has improved substantially since the publication of Knutson and Naef (1997). This understanding underscores the need to consider temperature statistics other than the daily maximum temperature during summer. We now have mechanistic,



Light through alder tree canopy/Ned Pittman, WDFW

deterministic models that can accurately predict changes in stream temperatures for specific locations due to specific management actions in the riparian ecosystem. We are also better able to set directional or qualitative expectations for cumulative effects on temperatures at the spatial extent of watersheds. However, quantitative information needed to run mechanistic, deterministic models to make site-scale predictions (e.g., surface water and groundwater flows and temperatures) is expensive to collect and thus are rarely used in management settings. Further, even the most capable stream temperature predictive models are limited by the assumption that the channel structure remains relatively stable (e.g., cross-section shape will not change) even though there is strong evidence that riparian and some types of upslope management affects channel stability (Chapters 2 and 3) at least in some reach types.

Scientific models and most observational studies find that shade from riparian vegetation can affect stream thermal regimes, particularly by lowering peak temperatures during summer. Recent monitoring studies have found substantial variation in the thermal sensitivity of apparently similar stream reaches. The use of improved monitoring tools (e.g., digital temperature loggers), more robust study designs e.g., Before-After-Control-Impact designs (Eberhardt 1976; Stewart-Oaten et al. 1986), more powerful statistical analyses (Gomi et al. 2006; Isaak et al. 2014), and longer study durations have improved our ability to detect effects of riparian management actions on stream temperatures. Importantly, better understanding of the structure and function of streams, especially the importance of surface, ground, and hyporheic water flows on stream temperatures, has allowed scientists to identify likely causes for failures to detect effects of riparian shade reductions on stream temperatures.



Giant salamander (Dicamptodon spp.) egg cluster/Jack Armstrong, WDFW

Scientific understanding of the importance of stream temperatures on aquatic species has improved substantially over the past two decades, especially for salmonids. Most studies provide useful descriptions of some direct effects of exposure to high temperatures on specific life stages. Laboratory and field studies demonstrated the importance of temperature on fish survival and allowed for comparisons among species, populations, and life stages, and thus the identification of those that are likely most sensitive to heat stress. They have also demonstrated substantial differences in sensitivity among species, populations, and life stages which make developing simple thermal standards challenging and likely inadequate for management. Several recent studies have described effects of prolonged exposure to elevated, but non-lethal, temperatures and altered thermal regimes. These studies demonstrate some of the complexity of this management challenge. Even when altered thermal regimes do not have immediate lethal effects on species, there are costs or trade-offs, such as changes in growth, survival, productivity, and energetic requirements. Detecting such effects is beyond the scope of most studies and will often require long-term, comprehensive monitoring of populations through several life cycles. Such studies will likely need to be conducted at spatial



Salmon eggs in Morse Creek/Steve Boessow, WDFW

extents and durations that account for fish behavior, such as daily and seasonal movement among locations where temperature regimes differ.

Relatively few studies that describe the effects of temperatures or thermal regimes on reptiles, amphibians or invertebrates have been completed. Most studies of these taxonomic groups have simply identified seasonal thermal preferences in the field or the effects of acute temperature in laboratory settings. Such studies are valuable for identifying thermally sensitive species, but are insufficient for management. Further, we found no study that addressed ecological interactions that might be mediated by riparian condition on a stream's thermal regime.

Studies generally show that the effects of urbanization, agriculture, and forestry on watershed and riparian ecosystems result in warmer summer stream temperatures, an expectation consistent with the conceptual model. Importantly, these land uses often include surface water routing to streams (e.g., roads and ditches) that can change the timing, intensity, duration, and temperatures of stream flows. The changes in

temperature detected differed among regions, land uses, and studies. The relatively low number of studies and high variability among study results limits our ability to accurately predict outcomes in unstudied locations and precludes us from reliably calculating a mean (i.e., expected) resulting temperature change, even for a specific temperature statistic. Of the studies we reviewed, most were designed to detect an effect using a specific stream temperature statistic (e.g., mean daily maximum summer temperature) rather than changes in the stream's thermal regime. This limits the inferences that can be made, especially from studies in which anticipated temperature changes were not detected, and to make reliable, precise generalizations from study results.

Although we have sound understanding of the composition, structure, and functions that affect stream thermal regimes, substantial uncertainty remains regarding the effects of any specific riparian management action on stream thermal regimes in most locations. That uncertainty is amplified by our relative lack of understanding at large spatial and long temporal extents for which few studies have been

completed. Recovery of stream temperatures due to shade from vegetation regrowth can occur in less than a decade following disturbance (D'Souza et al. 2011), but recovery rates differ widely among locations due to differences in stream size and components that control rates of vegetation re-establishment and growth (Gecy and Wilson 1990; D'Souza et al. 2011). Although scientists are very certain that temperatures and thermal regimes are important to many aquatic species, relatively little is known about ecological interactions (e.g., predator-prey relations), behaviors (e.g., movement among locations of different temperature), and indirect effects (e.g., effects on the rates and severity of disease). These interactions may be very important. For example, Lawrence et al. (2014) suggest that riparian restoration in some locations might prevent extirpation of Chinook Salmon and restrict the expansion of non-native fish in some locations by maintaining relatively cool stream temperatures. Such uncertainties often compound and should be addressed explicitly when making management decisions, especially when the decisions can have important, lasting effects (Harwood and Stokes 2003). Management of riparian ecosystem composition (e.g., vegetation species, side channels) and structure (e.g., longitudinal and lateral connectivity) can importantly benefit aquatic species. Management for such beneficial effects might prove especially important as our climate continues to change.

The state of the science regarding stream thermal regimes is uneven. On the one hand, we have a very good understanding of the physics of stream heating and cooling. We understand the relative magnitudes of direct and indirect effects of ecosystem changes on stream thermal regimes and have the ability to quantify these effects given enough time and resources. Shade provided by riparian vegetation is generally considered the single most important, albeit not the only, process of the system that humans can directly effect. These findings are undisputed. On the other hand, because thermal regimes are affected by a variety of factors and their interactions, stream temperatures are difficult to

precisely predict on the basis on any single factor alone (e.g., shade). Thus, predicting stream temperature based solely on shade removal or buffer width will likely always suffer from imprecision. In addition to this prediction challenge, and despite the fact that we know suitable water temperatures are critical to the persistence of aquatic species, we are only now beginning to understand how aquatic organisms interact with and are impacted by changes in the stream thermal regime. The combination of what we know and do not know about how changes to stream thermal regimes affect aquatic species and how human activities can affect those regimes makes conservation in the face of a changing climate particularly challenging.

4.6. Literature Cited¹

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Long-toed salamander *Ambystoma macrodactylum*/Scott Fitkin, WDFW

Chapter 5. Pollutant Removal

By: Jeffrey L. Ullman and George F. Wilhere

5.1. Introduction

The capability of riparian areas to remove certain pollutants from runoff has been known to scientists for over 60 years (e.g., Trimble and Sartz 1957). Understanding the complex processes and associated factors that affect the pollutant removal function of riparian areas is essential for developing management strategies that will protect aquatic ecosystems. Management of riparian areas for pollutant removal differs from the other ecological functions discussed in this document in that the primary focus is on mitigating activities occurring outside the riparian area. The pollutant removal function is unique in that it only exists in the presence of human activities that generate polluted water, and it is only necessary when runoff from upland activities threaten to degrade water quality.

This chapter summarizes key information relevant to riparian pollutant removal function. First, a general background is presented on the main processes and related site-level factors affecting the transport and fate of nonpoint source pollutants in riparian areas. Next, the biological impacts, common sources, *in situ* chemistry, transport pathways, and mitigation are reviewed for five types of pollutants—sediments, excess nutrients, metals, pesticides and other organic compounds, and pathogens. Last, a summary of what is currently known about the relationships between riparian buffer width and pollutant removal is provided. Riparian buffer is not synonymous with riparian area. Riparian area is an ecological designation that is synonymous with riparian ecosystem (see Chapter 1). Riparian buffer is a management designation, and a buffer may be narrower or wider than the riparian ecosystem.



Yellowjacket Creek/George Fornes, WDFW

This chapter only addresses nonpoint-source chemical pollutants that interact with riparian areas. Hence, it does not deal with “thermal pollution” effects on water temperature (see Chapter 4), which is another important water quality parameter. Similarly, it does not deal with pollutants routed via roads, ditches, and drains into urban and suburban stormwater runoff systems, or with polluted water routed to rivers and streams via agricultural tile drainage.

While the scientific literature reviewed here includes information collected during the 1970s and 1980s, when scientists first started to rigorously investigate the removal of pollutants by riparian areas (Correll 1997), more recent findings are highlighted. Decades of research have revealed that the ecosystem structures and processes responsible for pollutant removal functions of riparian areas are complex, spatially and temporally variable, and dependent on site-level environmental conditions. This complexity and variability are the main reasons for inconsistent results found in the published research and the lack of definitive recommendations regarding the structure and size of riparian buffers required for pollutant removal. Nevertheless, general trends in research findings can guide policy makers and resource managers to management strategies that address these uncertainties and lead to adequate protection of water quality.

5.2. The Pollutant Removal Function of Riparian Areas



Water quality refers to the physical, chemical, and biological characteristics of water that indicate a waterbody's

suitability to meet human needs or habitat requirements for fish and wildlife. Riparian areas exert a significant influence on water quality due to their position between terrestrial and aquatic ecosystems. Pollutants in dissolved, chemical, or suspended solid forms are transported by water from uplands to surface waterbodies, and while passing through riparian areas contaminated water undergoes a variety of physical, chemical, and biological processes that reduce pollutant concentrations. The processes in riparian areas affecting pollutant transport and fate are complex and often interrelated. Riparian areas slow surface runoff and increase infiltration of water into the soil, thereby enhancing both deposition of solids and filtration of water-borne pollutants. Riparian areas also intercept and act on contaminants in subsurface flow through dilution, sorption¹, physical transformation, chemical degradation, or volatilization by various biogeochemical processes and through uptake and assimilation by plants, fungi, and microbes.

There is overwhelming evidence in the scientific literature that riparian buffers reduce nonpoint source water pollution for a variety of pollutants—including sediments, excess nutrients, metals, organic compounds such as pesticides, and pathogens. Management activities can enhance the physical, chemical, and biological mechanisms that reduce the flow of polluted waters to river and streams.

¹ Sorption or “to sorb” is a physical and chemical process by which one substance becomes attached to another. It encompasses two processes adsorption and absorption. Adsorption is the binding of molecules or particles to a substance's surface. The reverse of adsorption is desorption. Absorption is the filling of minute pores in a substance by molecules or particles.



Riparian buffer widths for pollution removal need not be one-size-fits-all/U.S. Dept. of Agriculture, National Agriculture Imagery Program

However, the science is very clear that results vary considerably depending on local conditions, and that the configuration of a riparian buffer may effectively remove one type of pollutant while having minimal effect on another. Although riparian management can reduce significantly the quantity of pollutants entering surface waters, riparian areas are not sufficient by themselves to fully mitigate pollution from nonpoint sources. Thus, it is critical to view pollution control from a holistic, watershed perspective that also manages contaminated runoff at its source, i.e., upland areas subjected to various intensive land uses: forestry, agriculture, commercial, and urban, suburban, and rural residential. Nevertheless, maintaining functional riparian areas is essential for reducing nonpoint source pollution and must be a key component in any suite of management actions focused on water quality.

5.3. Processes Influencing the Pollutant Removal Function

Riparian areas are consistently shown to remove a variety of nonpoint source pollutants, such as those originating from agricultural lands, urban areas, construction sites, and forestry operations. However, the effectiveness of riparian buffers is highly variable (Hickey and Doran 2004; Lee et al. 2004, Anbumozhi et al. 2005; Zhang et al. 2010). Inconsistencies among research results can be explained by the multi-dimensional heterogeneity of riparian ecosystems; the complex, interconnected processes that act on contaminant transport and fate; and the variety of research methods employed. Many site-specific factors contribute to this variability,

including riparian buffer width, slope, topography, surface and subsurface hydrology, soil properties, riparian vegetation, and adjacent upland characteristics. Of all these factors hydrology, soil, and vegetation play dominant roles governing pollutant transport and fate (NRC 2002). The following sections discuss the effects of these three site-level characteristics on the pollutant removal function of riparian areas.

5.3.1. Hydrology

Hydrologic regimes at the terrestrial-aquatic interface impart a particularly significant influence on the attenuation of pollutants by riparian areas. Three principal pathways govern water movement through these systems: 1) overland flow and shallow subsurface flow from adjacent uplands, 2) groundwater flow, and 3) instream water movement that includes hyporheic exchange as well as flood conditions (NRC 2002). Each of these flow paths can act as conduits for pollutant transport to aquatic ecosystems depending on site-specific conditions and pollutant type. Furthermore, seasonal stream flows, fluctuating water tables, and intermittent flooding create a dynamic environment that subjects pollutants to a range of biogeochemical processes.

Upland sources of water often originate as precipitation. During and immediately after a precipitation event, water from upland areas follows different flow paths to the stream channel, each contributing differently to pollutant transport and fate. Overland flow can be either infiltration-excess² (Hortonian overland flow) or saturation-excess³ overland flow. Water that enters the soil profile can also travel downslope in shallow subsurface flow (interflow) through the unsaturated zone⁴. Depending on site-specific conditions, water in one of these flow paths may switch to another.

Collectively these flow paths are commonly termed hillslope runoff. Under certain circumstances, such as in the presence of deep, well-drained soils that facilitate percolation, portions of the shallow subsurface flow can reach the groundwater table and resume transport in the groundwater system. These pathways extend into riparian areas before reaching a surface waterbody.

As overland flow travels through the landscape it can pick up pollutants that can be in either particulate or soluble form. When water infiltrates the soil surface, suspended particulate matter and associated contaminants are entrapped at the soil surface, almost exclusively limiting the form of pollutants that are transported through the subsurface to soluble forms that remain in solution. However, recent research highlights the significance of colloid-facilitated transport as an additional means by which contaminants can move through the subsurface (Sen and Khilar 2006; Bradford and Torkzaban 2008). Colloidal forms (particles ranging from 1 to 1,000 nm) can remain dispersed in solution and exhibit characteristics resembling solutions. This behavior can consequently mobilize substances that tend to sorb to soil particles or organic matter that would otherwise not be able to move through the subsurface. While the fundamental physics and chemistry of this mechanism is understood, the contribution of colloids to pollutant migration through the soil profile is unresolved. Essentially no literature exists on the role of colloids in riparian areas, contributing to uncertainty in predicting the ultimate fate of associated pollutants.

The fundamental variables of interest regarding groundwater are flow rate and travel time, which influence natural chemical and biological processes that remove soluble pollutants, such as sorption to soils, microbial degradation, and plant uptake (Vogt et al.

² Infiltration-excess overland flow occurs when water enters a soil system faster than the soil can absorb or transport it, such as when precipitation exceeds the infiltration capacity of the soil.

³ Saturation-excess overland flow occurs when the soil becomes saturated, and any additional precipitation results in runoff.

⁴ The unsaturated zone is also known as the vadose zone. It extends from the ground surface to the water table. Beneath the water table is the zone of saturation.

2012). As groundwater approaches the stream margin biogeochemical activity increases, and this gradient contributes to temporal and spatial variability in solute fluxes (Hayashi and Rosenberry 2002). It should be noted that groundwater exhibits a different geochemical composition than shallow subsurface flow that originates from precipitation events. Groundwater samples typically have a greater specific conductance (related to salinity), higher mineral content and elevated pH (Landmeyer 2011). Differences in chemical composition and biogeochemical activity are likely to manifest differences in pollutant removal from groundwater.

The hyporheic zone is the region beneath and alongside the streambed that represents the groundwater-surface water interface. While hydrologists have a solid understanding of most other hydrologic processes occurring in riparian areas, understanding of the exchanges between groundwater and in-channel surface waters is considerably less (UKEA 2009; Gu et al. 2012). Hyporheic flow patterns are multifaceted and influenced by the pressure gradient at the stream margin, (micro)morphology of the channel,

the spatial distribution of hydraulic conductivity along the streambank, and the water exchange rate between the river and the riparian area (Kalbus et al. 2009; Lewandowski 2011). The complexity of the hydrologic regime is further compounded by seasonal variations, and at times intra-seasonal oscillations, in the direction of water flow (Wroblicky et al. 1998), as well as instances where ambient movement of deeper groundwater flows near the interface. Despite the confounding nature of the hyporheic zone, it is vital to consider hyporheic exchange when discussing subsurface fluxes of pollutants, as this zone is a direct link to streams through which contaminants can be transported to lotic systems (Gordon et al. 2004).

Not only does the hyporheic zone play a critical role in regulating pollutant fluxes from riparian areas to the adjacent lotic environment, the heterogeneous structure at the interface, an oscillating water table, and shifting flow regimes exert a significant influence on biogeochemical cycling. The fluctuating water table alters oxygen concentrations and oxidation-reduction (redox) potential, and the flow regime provides a continuous source of reactants. This dynamic environment allows for anaerobic and aerobic processes to occur simultaneously and in close proximity (Wang et al. 2014). The strong hydraulic and biogeochemical gradients that result from mixing of the subsurface water coming from riparian areas and the surface water of the stream channel create biogeochemical hot spots that exhibit disproportionately high reaction rates compared to the surrounding matrix (McClain et al. 2003). For instance, the convergence of shallow subsurface flow and groundwater at the stream interface can generate hot spots of denitrification. Similarly, hot moments represent brief periods of elevated reaction rates relative to longer periods (e.g., during a rainfall event). Later sections of this chapter discuss this concept in more detail.

As groundwater approaches a streambank, biogeochemical activity increases. Groundwater flow rate and travel time through the riparian area influence natural chemical and biological processes that remove soluble pollutants.

5.3.2. Soils

Soils play a critical role in influencing the transport and fate of pollutants in riparian areas. Soil texture and structure act as primary hydrologic regulators, significantly influencing the movement and distribution of contaminants. Comprised of a complex mixture of solid, liquid, and gaseous phases, riparian soils provide a heterogeneous matrix that supports plant and microbial communities. The solid phase encompasses mineral and organic particles of differing sizes and chemical composition that can sorb metals, organic chemicals, and other pollutants, thereby preventing them from migrating to the stream channel. The multiplicity and interaction of various biogeochemical processes in riparian soils contribute greatly to pollutant removal.

Unlike upland soils that are derived from terrestrial parent material, riparian soils primarily develop through the deposition of sediments that originate from various upstream sources. These alluvial deposits establish a heterogeneous patchwork of stratified sediments of

different textures, which influences the movement of waterborne contaminants. Huggenberger et al. (1998) provide a good review of the geomorphology and characterization of alluvial soils, but a brief description is warranted here to provide a background related to the movement of contaminants through riparian soils. Deposits of clay, silt, sand, and gravel, and continual disturbance by seasonal high flows and occasional extreme flood events, create a complex mosaic of soil microenvironments that can vary considerably both vertically within the soil profile and along the length of the stream channel (Malanson 1993). A general trend can be observed where coarser sediments are deposited along steep-gradient streams while finer particles are washed downstream and deposited along low-gradient reaches as stream energy dissipates and wider floodplains develop (BLM 2003). Soil particle size also tends to decrease moving away from the stream edge (Huggenberger et al. 1998). This vertical, longitudinal, and lateral spatial structure results in disparate hydrologic conditions, and corresponding differences in pollutant fate, at locations in close proximity.



Rough-skinned Newt Taricha granulosa/Renee Kinnick, WDFW

The soil microenvironments described above influence hydrologic conditions, which consequently affect pollutant transport. Soil texture and structure dictate water storage capacity and retention, flow paths and hydraulic conductivity. Coarse textured soils enable a greater hydraulic conductivity that shortens hydraulic residence time in the riparian area, thereby reducing the period in which attenuation mechanisms can act on soluble contaminants before they reach the stream channel. Water may percolate below the root zone and limit potential interactions between vegetation and pollutants in deep, well-drained soils, such as those commonly found in forested riparian areas in humid climatic regions (NRC 2002). However, the root zone intercepts subsurface flow to a greater degree in forested riparian areas that exhibit shallow soils overlying a confining layer (e.g., shallow aquiclude). Overland flow that predominates in arid environments often undergoes limited infiltration due to a tendency for riparian soils to exhibit low permeability in these regions, which allows much of the runoff and associated waterborne contaminants to enter the stream with minimal attenuation (NRC 2002; Buffler et al. 2005).

Altered soil structure can influence pollutant attenuation (Vervoort et al. 1999). Compaction, for instance caused by over-grazing or vehicular traffic, and accompanying structural changes and surface soil instability can lead to diminished infiltration and amplified overland flow (Bohn and Buckhouse 1985; McInnis and McIver 2001). Soils with low infiltration rates typically exhibit a diminished capacity to retain pollutants in riparian areas (Johnson and Buffler 2008). Subsurface soil structure influences water movement and distribution in the unsaturated zone, affecting pollutant transport. Subsurface soil structure also impacts soil aeration and plant root growth, which have ramifications on pollutant fate. Preferential flow in soil macropores represents another facet of soil structure that affects pollutant removal (Allaire et al. 2015). Preferential flow of water through large connected void spaces in soils, which result from fractures, animal burrows and other

processes, can enhance subsurface pollutant transport to river systems (Angier et al. 2002; Fuchs et al. 2009; Menichino et al. 2014). Alluvial deposits in riparian areas can further increase the connectivity of subsurface flows with stream channels, increasing lateral contaminant transport toward the stream channel. Preferential flow paths diminish the potential for contaminant sorption by both reducing interactions with soil particles and associated sorption sites and contributing to a higher flow velocity that reduces sorption kinetics. Although preferential flow paths have been a familiar concept in the field of soil science for some time, the recognized importance of these conduits has increased in recent years. This enhanced understanding is particularly important for controlling pollutants such as phosphorus that historically were not considered to undergo much, if any, subsurface transport (Angier et al. 2002; Fox et al. 2011a).

Artificial preferential flow also can be created by tile drains that are used by agricultural operations to remove excess water from the soil profile. Tile drains have been shown to enhance the movement of nutrients and herbicides from agricultural fields to streams, bypassing the natural attenuation processes that would have otherwise reduced the movement of these agrochemicals to aquatic ecosystems (Guan et al. 2011; Vidon and Cuadra 2011; Jaynes and Isenhardt 2014).

In addition to playing an integral role in influencing the hydrologic linkage between upland areas and the stream channel, riparian soils provide a dynamic framework that regulates biogeochemical processes that act on contaminants. Soluble pollutants that have entered the soil profile, either from subsurface flow from upland areas or through infiltration in the riparian area, are subject to a variety of processes. Contaminants prone to sorption can be retained within the soil profile of the riparian area, reducing their potential of migrating to the stream channel. Chemicals typically have a greater affinity for clay minerals or organic matter, and thus the attenuation due to sorption will vary depending on



Riparian area along White River/Alan Bauer

the soil composition. Microbial assemblages in riparian soils can contribute to the assimilation, transformation, and degradation of a range of chemicals. Anaerobic conditions in saturated soils found in riparian areas differ considerably from the aerobic environments of adjacent uplands, altering the redox potential. The fate of numerous contaminants is influenced strongly by the redox potential of the soil and associated microbial communities. Fluctuating water tables can alter the redox state, resulting in seasonal variations in chemical species distributed within the riparian area. Although broad generalizations can be made, the literature highlights that temporal changes in soil complexities are not well understood (NRC 2002).

Vegetative communities are also impacted by soil conditions in riparian areas. Plant species exhibit habitat preferences that follow soil moisture gradients across riparian areas. The influence of vegetation on contaminant fate and transport will be discussed in the next section. However, it is salient to note here that soil compaction and other disturbances can lead to invasive plant species that can degrade riparian ecosystem

function in relation to pollutant attenuation. Disturbed soils can lose their native species diversity and develop more homogenous stands of an exotic species (e.g., Himalayan Blackberry *Rubus armeniacus*) that often do not have the same vegetative density or root structure as the native population, thereby altering riparian area efficacy in pollutant removal.

5.3.3. Vegetation

Riparian vegetation also plays a critical role in attenuating pollutant transport to surface waters. Plants physically alter the movement of water and associated contaminants, provide habitat for microbial communities that assimilate and transform contaminants, and influence soil redox conditions that govern many biogeochemical cycles. Plant root systems provide bank stabilization, which reduces the direct introduction of sediments into aquatic ecosystems via streambank erosion. Soil stabilization also limits erosion and gully formation that can result from overland flow moving through a riparian area. In addition, forested riparian



Vegetated buffers reduce nonpoint source pollution to rivers and streams/U.S. Dept. of Agriculture, National Agriculture Imagery Program

areas have been shown to enhance instream processing of contaminants, including nutrients and pesticides (Sweeney et al. 2004). This section provides a brief overview of the influence vegetation has on pollutant attenuation in riparian areas and identifies critical points to consider when developing management plans. A number of focused review articles present further details on riparian vegetation-hydrology interactions and mechanisms by which plants can attenuate contaminants in riparian areas (e.g., Tabacchi et al. 2000; Williams and Scott 2009; Dosskey et al. 2010).

The high vegetation density inherent in streamside ecosystems serves a critical function in modulating overland flow and amplifying infiltration. The stems of grass and herbaceous groundcover, trunks of woody vegetation, and downed wood create resistance to overland flow, slowing it, and causing deposition

onto and infiltration into the soil profile (Fisher and Binkley 2000; Schuster and Grismer 2004). Vegetation also helps maintain soil structure by increasing soil macropore formation through root growth and decay, which further enhances soil permeability. Soluble contaminants present in overland flow enter the soil column, augmenting attenuation through the various mechanisms discussed throughout this chapter. The reduced velocity of the overland flow caused by the riparian plant community causes suspended particles to settle out of the water column, reducing the transport of sediment and sediment-borne pollutants to the stream. Similarly, lower velocity flows will limit erosion within the riparian area, reducing potential contributions to stream sediment loads and avoiding gully formation, which concentrates overland flows and short circuits pollutant attenuation. A dense overstory canopy will further reduce erosion by intercepting precipitation



that would fall directly onto bare soil, and a dense plant community also reduces erosion of riparian soils by diminishing the velocity of runoff and floodwaters (Schultz et al. 2000).

Vegetation also increases soil surface roughness by producing herbaceous litter and woody debris, and by altering micro-topography, which slows surface flow and enhances infiltration of water. In contrast, sites with exposed mineral soil tend to exhibit low surface roughness that limits infiltration, and these sites are susceptible to increased transport to streams via overland flow.

Vegetation also influences the hydrologic behavior of subsurface and groundwater flow through streamside areas. Root uptake and transpiration by both herbaceous and woody plants can modify subsurface flow and

soil moisture regimes in the unsaturated zone under unsaturated conditions. These alterations not only influence pollutant transport through riparian soils, but also affect redox conditions that govern biogeochemical transformations. Deeper-rooted plants can impact groundwater levels by reducing the pressure head at the water table through direct uptake or by extracting water along a water potential gradient. Hence, trees can cause daily or seasonal changes to water table levels, a phenomenon more prevalent in drier climates (Landmeyer 2011). Correspondingly, contaminant fluxes from riparian areas to surface waterbodies may exhibit similar diurnal and seasonal patterns. Water uptake by roots can similarly form a hydraulic barrier that creates an upward water flow through the soil profile that can reduce pollutant leaching and inhibit contaminant plumes from spreading horizontally (Pilon-Smits 2005).



Chinook salmon Oncorhynchus tshawytscha/Morgan Bond

Riparian management strategies often emphasize the effectiveness of forested riparian areas for protecting water quality. However, research over the last two decades reveals that forests are not always the most effective vegetation for removing pollutants. Results can vary between sites, but research has shown that grass buffers (also called vegetative filter strips or grass filter strips) can yield similar reductions in sediments and sediment-borne pollutants (Correll 1997; Hawes and Smith 2004; Dosskey et al. 2010). Grasses and

While vegetation modulates water flow, it is vital to recognize the interconnected nature between riparian plant communities and hydrologic regimes. Riparian plant communities are determined largely by their adaptation to high moisture environments. Groundwater often represents a primary water source for riparian plants, principally trees and deeper-rooted flora. Consequently, alterations in groundwater regimes can have a detrimental impact on species diversity, density, and distribution, especially in drier regions where vegetation is typically concentrated along a narrow band of suitable soil moisture conditions (NRC 2002). Dramatic changes to plant communities can significantly limit the pollutant removal function of a riparian area. Thus, managers should consider the interrelationships between vegetation and subsurface hydrology. Kuglerová et al. (2014) expounded on this theme in a recent review examining the effects of forest management on groundwater processes and resultant water quality. The authors concluded that logging operations in riparian areas and hydrologically connected upland forests can alter groundwater regimes and affect water quality. They recommended site-specific riparian management where wider buffers would be implemented at critical groundwater discharge locations but narrower buffers would be allowed at sites lacking groundwater flow paths.

similar plants create a dense vegetative obstacle that slows overland flow, promotes deposition of sediments and attached pollutants, and provides an opportunity for the plants and associated microbes to capture soluble contaminants that enter the soil profile (Dillaha et al. 1989). Filter strips often serve as an effective alternative for protecting water quality from pollutants generated by upland activities where it is impractical to implement forested riparian areas, such as adjacent to agricultural fields, in urban settings, or along highways.

According to Lacas et al. (2005), much of the sediment removal effected by grass filter strips occurs mainly as a result of sedimentation immediately upslope of the strip in an area of still water that builds up against the strip's outer boundary. Furthermore, they note, the deposit formed upslope can expand into the filter strip, and that sediment deposition can increase to the point of forming channels that concentrate overland flow and induce the formation of water pathways with high velocities.

The primary drawback of a vegetative filter strip is that it addresses only pollutant removal and does not provide the other functions of forested riparian areas such as shading, large wood, and bank stability. Furthermore, grasses have a relatively shallow root

structure and thus vegetative filter strips are not as effective in removing pollutants from groundwater. In contrast, trees inherently have a deeper root zone that can effectively intercept subsurface flow and often reach shallow groundwater. Therefore, forested riparian areas can be more effective at removing soluble pollutants in subsurface and groundwater flow through plant uptake and by associated microbial communities that act on the pollutants in the rhizosphere. Considering both situations, structurally diverse riparian areas that contain a combination of grasses, shrubs and trees provide a more robust system for mitigating a range of pollutants (Fischer and Fischenich 2000). A similar concept was proposed by Welsch (1991), who presented a three-zone model that considered an herbaceous filter strip between uplands and the start of the riparian area, followed by a managed forest, and culminating with an undisturbed forest immediately adjacent to the streambank.

Vegetation in riparian buffers also provides a range of phytoremediation processes, wherein plants and associated microbial populations remove, contain, degrade or eliminate pollutants. Investigations on the phytoremediation potential of riparian vegetation to attenuate nutrients have been conducted for some time and results are well documented. The management of vegetation specifically as a pollutant treatment technology for organic compounds and metals has gained acceptance in general over the last couple of decades (Pilon-Smits 2005), but studies on phytoremediation specific to riparian areas remains fairly limited. However, recent research suggests that the promotion of specific plant species to attenuate organic chemicals and metals in riparian areas can be used to treat localized areas of concern (e.g., chemical spills, industrial sites, mine tailings). Design of a phytoremediation treatment system depends largely on the three primary factors identified by Susarla et al. (2002) that govern contaminant uptake and distribution in plants and the surrounding soil system:

physicochemical characteristics of the pollutant (e.g., polarity, lipophilicity), environmental conditions (e.g., soil moisture, pH), and plant characteristics (e.g., available enzymes, root structure). Specifics on the phytoremediation potential of different pollutant classes in riparian areas will be discussed later in the respective sections of this chapter, while more detailed descriptions of phytoremediation are readily found in a large number of scientific reviews (e.g., Salt et al. 1998; Pulford and Watson 2003; Pilon-Smits 2005; Sarma 2011).

5.4. Specific Pollutants

For the purposes of riparian area management, we are most interested in five types of water pollutants: sediments, excess nutrients (in particular, nitrogen and phosphorus containing compounds), metals (in particular copper), toxic organic compounds (especially pesticides), and pathogens (especially those related to agricultural animal waste). The physical, chemical, and biological processes through which riparian areas remove these pollutants from water vary tremendously. Consequently, the degree to which riparian areas can remove each of these pollutants, and thereby protect aquatic ecosystems, varies significantly. The following sections describe the complicated processes and mechanisms involved in determining removal efficacy of specific pollutants by riparian areas.

Vegetation in riparian buffers provides a range of phytoremediation processes, wherein plants and associated microbial populations remove, contain, degrade or eliminate pollutants.

5.4.1. Sediments

Sediment transport in streams is a natural process, but excessive sediment loads can significantly degrade water quality. The impact of sediments on aquatic organisms has been researched extensively for many decades, and can consist of lethal, sub-lethal and behavioral effects (Newcombe and MacDonald 1991). Sediments that settle out of the water column can smother gravel and cobble streambeds that are essential for salmonid spawning and habitat for benthic macroinvertebrates and other organisms that form critical links in stream food webs. For example, the filling of interstitial spaces in coarse sediment matrices with fine sediments are thought to reduce or eliminate refuge and foraging habitat for selected life stages of stream-dwelling amphibians (Welsh and Ollivier 1998). Increased turbidity levels, indicative of suspended particles, can elicit physiological stress in fish through

gill abrasion, impaired immune function and lowered growth rates (Redding et al. 1987; Au et al. 2004). High suspended sediment loads reduce visibility, which limits fish foraging ability and influences predator avoidance reactions (Redding et al. 1987). Aquatic vegetation and periphyton can be reduced due to diminished light penetration. Sediments also impart indirect effects on aquatic organisms. Elevated turbidity decreases the water albedo (reflectiveness), which increases the fraction of radiant energy absorbed by the water and increases stream temperature, leading to corresponding reductions in dissolved oxygen concentrations. Furthermore, sediments serve as a transport mechanism for other pollutants, carrying attached contaminants from upland sources to the stream channel. Soil particles that harbor legacy contaminants perpetuate water quality problems, such as those caused by DDT in some Washington streams despite this pesticide being banned in 1972 (Ecology 2007).



Restored vegetation in riparian area to capture pollutants in runoff/U.S. Dept. of Agriculture, National Agriculture Imagery Program

While the extent of these detrimental effects is largely a function of concentration and duration, and there is little agreement on the degree of ecological risk in the literature, sediments are a ubiquitous pollutant that many scientists regard as the worst form of pollution in aquatic ecosystems (Newcombe and MacDonald 1991; Waters 1995).

Erosion rates in uplands can be significantly increased by agricultural activities, construction sites, deforestation, and other land uses. Riparian areas effectively remove soil particles carried from upland areas via overland flow by slowing overland flow velocities, promoting sediment settling, and acting as sediment sinks⁵. Mass wasting (also referred to as mass movement, mass failure, or slope movement), wherein large masses of soil and geologic material move downslope into a stream, acts as another potential sediment source in hilly or steep mountainous environments. Although limited in spatial distribution, this geomorphic process can overwhelm the sediment removal capacity of riparian areas.

Our understanding of the riparian area's sediment removal function will be enhanced with a basic understanding of sediment erosion and transport processes. Briefly, the impact of falling raindrops can loosen soil particles via splash erosion. Overland flow picks up soil particles and transports them downslope through sheet erosion. Generation of concentrated flow paths results in rill erosion, which enhances sediment delivery and increases erosion rates through flow that is on the order of a few centimeters deep. Gully erosion develops when deep, narrow channels form, leading to increased erosion and more rapid sediment delivery. It is important to prevent the formation of rill and gully erosion entering riparian areas because channel formation extending into riparian areas short-circuits

sediment removal and represents a direct conduit from terrestrial to aquatic systems. Merritt et al. (2003) provide an extensive review of various erosion and sediment transport models that can be employed to determine the potential sediment loads that could enter a riparian area.

While the upland hydrologic regime acts as a principal driver governing the movement of eroded soil particles, the aforementioned erosion mechanisms can be significantly tempered by intact soil cover. This can be accomplished by vegetation overlying a dense cover of herbaceous litter and woody debris. Vegetation increases surface roughness which slows surface flow and enhances water infiltration, both of which promote the settling out of sediments (Figure 5.1). Muñoz-Carpena et al. (1999) showed that spacing between vegetation is the most important parameter in sediment attenuation in riparian buffers, although soil characteristics, sediment load, and slope also play prominent roles.

Agriculturally generated nitrogen continues to present an issue, and it is becoming increasingly apparent that smaller hobby farms and lawn fertilizers used in suburban and urban areas can lead to severely degraded water quality.

⁵ Streambank erosion, channel incision, and surface erosion in riparian areas present other potential sediment sources. As this chapter focuses on the removal of pollutants generated by upland activities, these geomorphological processes are outside the scope of this chapter. However, it should be noted that riparian vegetation can increase bank stability, thereby decreasing erosion along the stream channel (see Chapter 2).

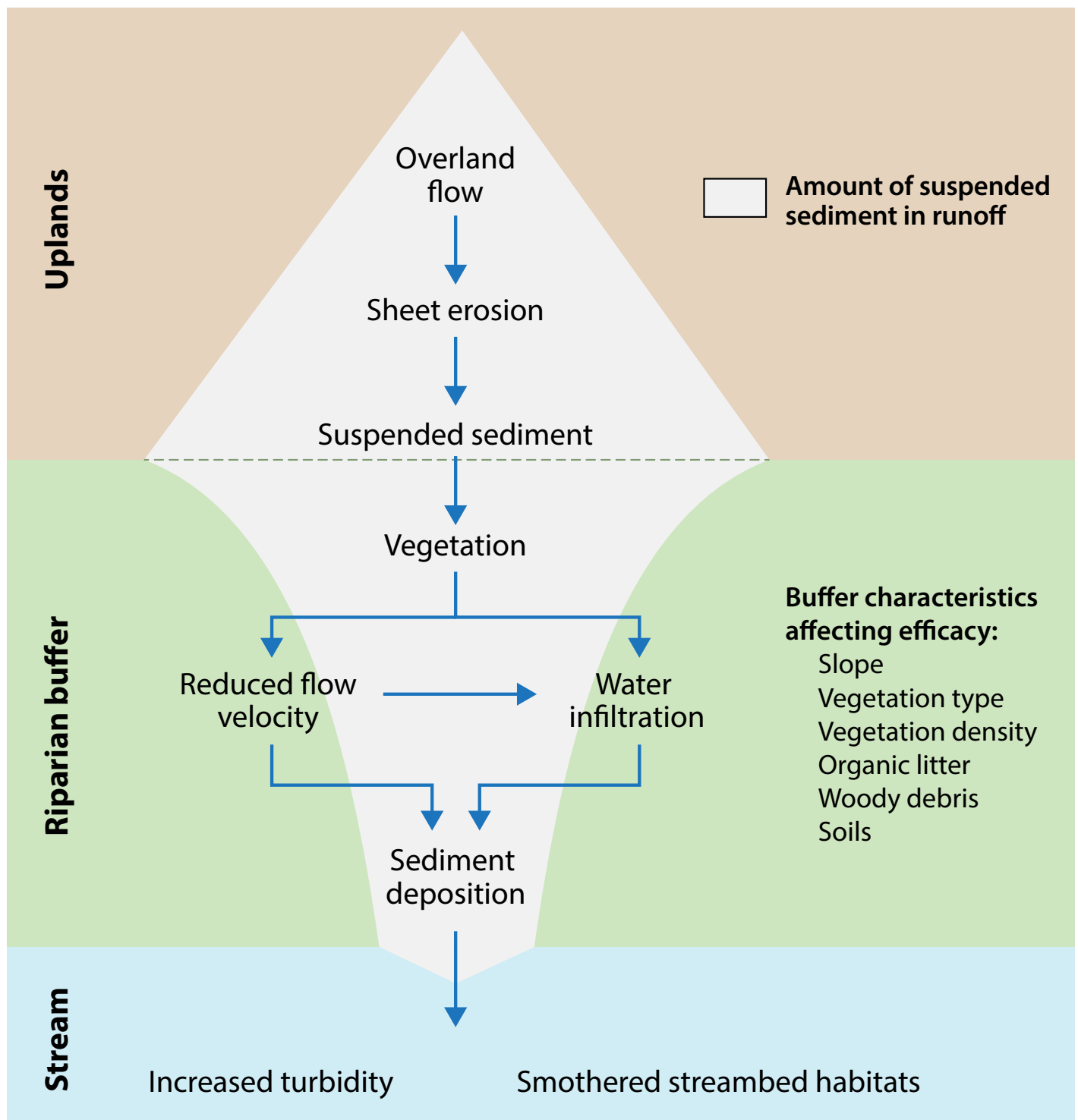


Figure 5.1 Efficacy of riparian buffer in removal of sediment from runoff. The amount of suspended sediment in runoff increases through sheet erosion of upland soils. Vegetation, woody debris, and organic litter in riparian buffer reduce flow velocity. Reduced flow velocity and increased water infiltration into soils causes deposition of suspended sediments. Sediments not removed from runoff increase turbidity and can smother gravel or cobble streambed habitats.

Riparian buffer widths required for sediment attenuation vary considerably depending on the site-specific conditions (e.g., slope, area of adjacent uplands, drainage paths, vegetation density). Sediment particle sizes are also a consideration in buffer width design – larger particles are deposited within the first 10 to 33 ft (3 to 10 m) of a buffer but smaller particles settle out at greater distances (Sheridan et al. 1999; Syversen et al. 2001; Dosskey et al. 2002; Yuan et al. 2009). The potential quantity of overland flow should also be a consideration when determining buffer widths, and hence, upland area should also factor into the determination of buffer width. Leeds et al. (1994) suggested that on agricultural lands the ratio of field drainage area to buffer area should be no greater than 50:1, and for consistently higher water quality the ratio should be on the order of 3:1 to 8:1. From research conducted on forested lands undergoing timber harvest, Clinton (2011) concluded that leaving a forested riparian buffer of 33 ft (10 m) would sufficiently reduce sediment transport to the adjacent stream, assuming responsible timber harvest practices, although greater widths have been recommended depending on the circumstance (Castelle et al. 1994). Furthermore, the relationship between buffer width and sediment attenuation is non-linear, necessitating a disproportionate increase in width to achieve an incremental increase in sediment removal. This relationship was described in a literature review of research on riparian buffers conducted by Sweeney and Newbold (2014). They concluded that a sediment removal efficiency of about 65% is typical for 30 ft (10 m) buffers but an 85% removal efficiency required more than twice that width, about 100 ft (30 m).

5.4.2. Excess Nutrients

Excess nutrients, in this context referring specifically to nitrogen and phosphorus, have long been recognized as

significant water quality impairments. Eutrophication, the nutrient enrichment of aquatic systems, promotes algal blooms that shift community structure. Subsequent bloom die off leads to oxygen deficiency in the water column as oxygen is consumed by microorganisms during the decay of the excess organic matter. Hypoxia can have devastating consequences on aquatic animal communities, killing immobile organisms (e.g., clams) and mobile species (e.g., fish) that are not able to escape the deoxygenated zone. Excessive accumulation of cyanobacteria (formerly known as blue-green algae), resulting from shifts in nutrient ratios in the water, can release cyanotoxins which can cause dermal reactions, gastroenteritis, liver and kidney poisoning, and neurological impacts in humans or animals following water contact. Canine deaths due to cyanotoxin exposure have been confirmed throughout the country, with Washington reporting the highest number of cases among 27 states (Backer et al. 2013). In some cases, selected nutrients are toxic at concentrations within typical fertilizer application ranges. For example, embryos of the highly aquatic Oregon Spotted Frog *Rana pretiosa*, a federally threatened species in the Pacific Northwest, all died after 15-day exposure to nitrite (NO_2^-) concentrations lower than 2 mg/L (Marco et al. 1999).

Fertilizers and manures are major sources of excess nutrients entering riparian areas. Wastewater discharges and leaking septic tanks introduce nutrients to riverine systems, but those sources fall outside the scope of this review. Agricultural activities have long been blamed as the biggest nonpoint source for nutrients. The enormous contribution of phosphorus to the eutrophication of surface waters led to extensive promotion of various best management practices (BMPs)⁶ for reducing off-field transport of phosphorus. Nevertheless, there has been a general lack of improvement in water quality of many receiving

⁶ In general usage "best management practice" (BMP) means one or more practices that are determined to be an effective and practicable means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals. Under Washington State regulations, BMP means physical, structural, and/or managerial practices approved by the Washington Department of Ecology that, when used singularly or in combination, prevent or reduce pollutant discharges (WAC 173-201A-020).

streams. In addition to existing agricultural sources of phosphorus, it is increasingly evident that “legacy phosphorus” from past activities that accumulated in watersheds contributes to current water quality problems (Jarvie et al. 2013). Agriculturally generated nitrogen continues to present an issue, as it can leach through the soil and move with shallow groundwater flows through riparian soils and enter receiving waters. It is also becoming increasingly apparent that smaller hobby farms and lawn fertilizers used in suburban/urban areas can lead to severely degraded water quality (Cheng et al. 2014).

For a thorough discussion of nitrogen and phosphorus dynamics in natural, undisturbed riparian areas see Chapter 6. For this chapter it is salient to note the differing biogeochemical cycles exhibited by nitrogen and phosphorus: nitrogen displays complex transformations between various species including atmospheric forms whereas phosphorus undergoes relatively simple shifts between soluble, sorbed, precipitate and organic forms. Nitrogen and phosphorus are often casually grouped together as nutrients, but this discrepancy in chemical behavior leads to significantly different considerations when assessing their removal by riparian areas.

Nitrogen

Due to its soluble nature in its aqueous forms, a significant portion of the excess nitrogen entering streamside areas will enter riparian soils either through infiltration or via groundwater transport. Nitrogen then can undergo attenuation through a variety of mechanisms. It is widely accepted that denitrification acts as the primary pathway for removing nitrate (NO_3^-) from water in riparian areas (Fennessy and Cronk 1997; Cey et al. 1999; Wang et al. 2014). This process is governed by specific denitrifying bacteria that use nitrate during anaerobic respiration, reducing it to the gaseous forms of nitric oxide (NO) and nitrous oxide (N_2O) and ultimately molecular nitrogen (N_2). These

gaseous species can then volatilize in harmless forms to the atmosphere and be completely eliminated as a potential pollutant. This process requires the presence of a shallow water table, anoxic conditions, denitrifying bacteria and an available carbon source—conditions commonly associated with riparian areas. Hydric soils, despite occupying a limited area within riparian areas, are important sites of anaerobic activity that promote denitrification. If groundwater bypasses riparian soils then nutrient pollution of surface waters may occur despite the presence of a riparian buffer (Burt et al. 1999). In a highly cited critical review of research on nitrate removal in riparian areas, Hill (1996) asserted that understanding denitrification requires a better understanding of groundwater interactions with riparian vegetation and soils.

Plant uptake of dissolved nitrogen in subsurface flows moving through riparian areas provides an additional mechanism that can remove considerable amounts of nitrate. A significant difference from denitrification though is that vegetative uptake is often viewed as transient storage for nitrogen because nitrogen assimilated by plants will be reintroduced to the ecosystem following leaf senescence or plant death. Both grasses and trees have been widely shown to remove nitrogen in riparian areas, but studies have yielded contradictory observations and conclusions regarding which vegetation type is more effective (Groffman et al. 1991; Osborne and Kovacic 1993; Schnabel et al. 1997). A meta-analysis performed to assess the key riparian variables responsible for nitrogen removal concluded that forested buffers exhibited the greatest propensity for nitrogen uptake, and surpassed the efficacy of both grasses and communities composed of both trees and grass (Zhang et al. 2010). Although this study did not end the debate, many researchers believe that deeper and more expansive root structure allows trees to take up greater proportions of nitrogen. A riparian area’s age may also be a variable affecting nitrogen removal. Cors and Tchon (2007) evaluated denitrification enzyme activity in two

riparian areas of different ages: 6 and 20 years old. They found the older system was significantly more effective at denitrification, which was attributed to a greater accumulation of carbon.

Research focusing on hot spots and hot moments has provided a more nuanced understanding of nitrogen dynamics in riparian areas. Hot spots and hot moments that develop in the hyporheic zone are increasingly being recognized as a contributing mechanism to nitrogen attenuation (McClain et al. 2003; Vidon et al. 2010; Gu et al. 2012). A landmark paper by Hedin et al. (1998) exemplified the concept of enhanced nitrogen removal at hot spots along the soil-stream interface in a mixed forested-agricultural watershed. A first-order stream exhibited two converging primary flow paths, one consisting of shallow subsurface flow containing high concentrations of chemical reducers (i.e., dissolved organic carbon, CH_4 , and NH_4^+) and the other a near-stream upwelling of deep groundwater containing high concentrations of oxidizers (i.e., NO_3^- , N_2O , and SO_4^{2-}). A zone of high denitrification resulted that was less than 3 ft (1 m) wide and remained active for the two-year study period. Hedin et al. (1998) suggested that nitrate removal via denitrification could be sustained depending on the spatial location of high flow pathways, the propensity of the chemical environment to support rapid denitrification, and the availability of oxidizable carbon. Furthermore, they recommended that management actions enhancing natural carbon inputs could be adopted to optimize nitrate removal by denitrification.

Phosphorus

Unlike nitrogen, phosphorus possesses a binding affinity for soil particles and typically enters riparian areas adsorbed to soil particles carried by overland flow. Hence, phosphorus removal is closely connected to sediment removal by riparian areas. A comprehensive review of phosphorus dynamics in grass buffer strips surmised that that optimum phosphorus retention occurs in filter strips that are at least 16 to 33 ft (5 to 10



Unknown species of crayfish in the Deschutes River/Steve Boessow, WDFW

m) wide (Dorioz et al. 2006), but this recommendation is debatable. It is generally recognized that a positive correlation exists between buffer width and phosphorus retention in riparian areas, and hence, buffers greater than 33 ft (10 m) offer greater removal efficacy. Independent studies have consistently found 60% to 80% phosphorus removal by buffers roughly 15 to 53 ft (4.6 to 16.3 m) wide (Dillaha et al. 1989; Vought et al. 1994; Lee et al. 2003). Forested riparian ecosystems assessments have yielded less consistent results, with studies showing phosphorus removal ranging from 30% to 80% in deciduous riparian areas (Lowrance et al. 1984; Cooper and Gilliam 1987). This discrepancy corresponds with the premise that a robust stand of grass provides better attenuation of sediments and associated pollutants than forested riparian areas.

Even though these results appear convincing at first glance, a significant proportion of the body of research consists of short-term studies that fail to account for changes in riparian function over time. While it can confidently be stated that riparian areas offer effective short-term control of sediment-bound phosphorus, uncertainty exists regarding their long-term efficacy. Filter strips receiving sediment loads are well known to become less effective over time due to internal erosion and sediment accumulation. The continual incorporation of phosphorus into surface soils presumably would lead to a saturation of the system that could not only decrease removal of new phosphorus entering the

riparian area, but also lead to release and export of dissolved phosphorus to the stream that had previously been stored in riparian soils (Muscutt et al. 1993). Some studies have reported significant removal of soluble phosphorus in surface runoff (Peterjohn and Correll 1984). However, contradictory reports indicate little retention of soluble forms, with the majority moving through the area in surface runoff (Daniels and Gilliam 1996). Plants take up some of the phosphorus in the riparian soils, but this mechanism is not nearly as significant in removal as it is for nitrogen. Increased removal of soluble forms could potentially be achieved with various amendments, such as biochar (charcoal used as a soil amendment), that could enhance phosphorus sorption (Zhang et al. 2014).

A relatively new research topic related to phosphorus attenuation focuses on subsurface transport of soluble phosphorus forms. It was long accepted as dogma that phosphorus did not leach or move through the soil profile. Although scattered findings contradicted this view during the preceding decades (e.g., Peverill et al. 1977), this conviction remained recalcitrant and was still taught in university soil courses up until the last decade. This belief has now been dispelled by increasing evidence that phosphorus can move through

the soil profile, particularly in coarse textured soils. A preponderance of the recent research on this topic has been conducted in upland soils, but the findings are relevant for riparian areas and are particularly true in coarse alluvial soils. This has been demonstrated by the rapid transport of soluble phosphorus forms through preferential flow paths (Fuchs et al. 2009). This movement can serve as an important transport mechanism that should be considered when determining potential phosphorus fluxes reaching the stream channel. Although extensive literature exists on phosphorus cycling in a variety of settings, relatively little information is available on phosphorus dynamics in the hyporheic zone and further research is needed to understand phosphorus flux through this interface between the stream and groundwater flowing through riparian areas (Zhang 2014).

5.4.3. Metals

Metals (as well as metalloids that share similar properties, such as arsenic) are elements naturally found in geologic material. They enter the environment either through natural weathering processes or through anthropogenic activities. Localized metal deposits can result in elevated concentrations in streams that can be hazardous to biota. Metal pollution in aquatic ecosystems appeared as a serious environmental issue on a wide scale in the late 19th and early 20th century due to increasing industrial and mining activities. Contamination sources have grown over time to include a range of other activities, the most pertinent to this discussion on riparian areas being runoff from urban and agricultural lands. While mining activities present significant metal inputs into certain streams in Washington, protecting water quality from these sources requires the implementation of specific remediation techniques that are outside the scope of this chapter.

While it can confidently be stated that riparian areas offer effective short-term control of sediment-bound phosphorus, uncertainty exists regarding their long-term efficacy. Riparian filter strips are well known to become less effective over time.

Metals present a significant environmental hazard that can lead to a variety of health issues in plants and animals. While some metals are essential elements required for normal growth and development of biota, these can also impart toxicological issues when concentrations exceed a given threshold. Among other health effects, metals can be carcinogenic, cause reproductive problems, and interfere with the normal function of the heart, bones, intestines, and kidneys. While debate continues over the specific mechanisms associated with metal toxicity in plants, it is generally recognized that oxidative stress represents a primary driver that results in cellular damage (Pinto et al. 2003). Some heavy metals bioaccumulate and biomagnify, which leads to elevated concentrations exhibited at higher trophic levels (Boening 2000). The propensity for metals to bioaccumulate can be magnified by biologically mediated transformation into organometallic complexes, such as methylmercury. Metal toxicity is often related to the chemical species formed, which often relates to their bioavailability. For instance, chromium(III) compounds are not considered a significant health risk while chromium(V)

is a well-known carcinogen. Similarly, metal complexation with dissolved organic carbon often inhibits their bioavailability.

While copper's detrimental environmental impacts have been recognized for many decades (Sprague and Ramsay 1965), it has received increased attention in recent years as toxicity symptoms have become more pronounced. Copper is an essential mineral for organisms, contributing to enzymatic and metabolic function, but toxic effects have been observed at all levels of the aquatic food chain when it exceeds particular concentrations. Copper has been shown to have detrimental effects on plants, retarding growth at concentrations as low as 1.0 part per billion (ppb) and impeding photosynthesis at 5.0 ppb levels (USEPA 1980). While reductions in algal production can theoretically exert an indirect effect on zooplankton by limiting their food source, copper can impart a lethal effect on these organisms at low parts per billion levels (Ingersoll and Winner 1982). Similarly, significant mortality has been shown to occur in benthic macroinvertebrates at similar copper



Juvenile salmon need clean water/Ned Pittman, WDFW

concentrations (Clements et al. 1992). Copper presents a litany of issues to fish. Lethal concentrations vary considerably between fish species and fluctuate depending on environmental conditions. Sub-lethal effects are conveyed at lower concentrations, which include hindering osmoregulation, weakening immune response, altering enzymatic and metabolic activity, impairing olfaction (sense of smell), altering migration patterns and predator avoidance behavior, and modifying hatch rates (Lortz and McPherson 1977; Sorensen 1991; Rougier et al. 1994; Baldwin et al. 2003; Monteiro et al 2005; Sandahl et al. 2007; McIntyre et al. 2012). Synergistic impacts that occur when copper is present in combination with other pollutants highlights the current concern over this element (Hecht 2007). Effects similar to those observed in fish have been recorded in amphibians following exposure to rather low concentrations of copper ions (Cu^{2+}). For example, the concentration of copper at which half of larval Northern Leopard Frogs *Rana pipiens* would die following a seven-day exposure was estimated at 0.067 mg/L (Redick and La Point 2004). The same study revealed lethargy, loss of equilibrium, and loss of appetite at copper concentrations of 36 ppb. A widespread pattern in copper exposure studies with amphibians is a general impairment of predator evasion behaviors (Garcia-Muñoz et al. 2011).

Anthropogenic copper inputs to the environment include those of other metals, but what sets copper apart are two significant sources. The first is the agricultural use of copper-based pesticides. Copper sulfate and other copper-based pesticides are frequently used as a fungicide to protect a variety of crops, including fruits and potatoes. The second is the release of copper from vehicle brake pads. This unique source has received considerable attention as an environmental hazard worldwide, and has led to the 2010 adoption of Washington State's Brake Material Friction Act (RCW 70.285) that is phasing out copper in automobile brakes (Straffelini et al. 2015). Copper can also enter the environment through atmospheric deposition,

which is a potential pathway in industrial and mining regions (USEPA 1980). These sources introduce copper into the environment as a nonpoint source pollutant, which makes copper very different from other metals. While the following discussion will continue to refer to metals in general, the reader should recognize that the nonpoint source nature of copper makes it the primary metal of concern in Washington in regards to attenuation in riparian areas.

Metals form various inorganic and organic species, the nature of which directly relates to its bioavailability and mobility through a riparian area. Metal speciation is driven through complex biogeochemical processes. Environmental conditions and the chemical nature of the surrounding constituents play a significant role in dictating the form that a metal might take. This is particularly relevant to riparian areas where fluctuating water tables alter redox conditions, and correspondingly metal dynamics in riparian soils. Daily oscillations related to the photocycle, for instance, have been shown to occur in aquatic ecosystems as a result of biogeochemical interactions involving temperature, acidity, and biofilms (Nimick et al. 2011). Consequently, zinc, manganese, and cadmium can increase several-fold between late afternoon and early morning. In contrast, arsenic undergoes the opposite diel pattern; meanwhile copper and lead do not undergo regular diel cycling.

The metal species resulting from soil acidity and redox conditions can form precipitates, exhibit an affinity to clay minerals and oxide/hydroxide compounds, and thus be more readily retained in riparian areas. Conversely, metals stay in solution as more mobile forms that leach and move toward the stream. Typically, metals more readily enter solution under acidic conditions. Meanwhile the ionic strength of the water (a measure of the concentration of all the ions in solution) presents a confounding variable in these processes. The impact of other ions manifests through enhanced metal desorption from soil particles with increasing

salinity. Carbonates in riparian soils promote metal retention by buffering acidity (i.e., preventing increased acidity), limiting metal solubility, and forming insoluble precipitates with metals.

Organic constituents in soil-water systems also play a major role in metal fate and transport processes. It has been clearly understood for some time that humic substances, a classification of complex and heterogeneous macromolecules that represent a substantial component of natural organic matter, have the capacity to bind significant amounts of metals (Reuter and Perdue 1977). While association of metal ions with soil organic matter can retain metals, humic substances can act as colloids and contribute to colloid-enhanced movement. The environmental factors and mechanisms involved in metal-humic interactions are multifaceted, but it is salient to recognize the impacts that organic matter in riparian soils can have on the movement of metals to the stream channel. A more detailed explanation of the inorganic and organic factors that influence metal behavior is presented in a review by Du Laing et al. (2009), which includes a specific focus on riparian areas.

Unlike organic contaminants that can degrade, metals are recalcitrant and removal in riparian areas depends largely on retention. Although the brief description of metal chemistry provided here elucidates the primary factors that affect their movement in the environment, management practices to enhance their attenuation are limited, and metal mobility will be driven overwhelmingly by environmental conditions. An exception to this statement is phytoremediation.

Phytoremediation of metals offers promise as a means to enhance metals removal in riparian areas. Although significant research on this process did not start in earnest until the late 1990s, since then hundreds of scientific papers have been published on the topic. Correspondingly, there is a plethora of review articles (e.g., Ghosh and Singh 2005; Sarma 2011; Koptsik 2014;

Laghlimi et al. 2015). Four classes of phytoremediation can influence metal attenuation in soil, including phytoextraction (removal of metals from the soil-water system by plants), phytostabilization (minimizing metal transport and sequestering them in the soil near the roots), phytovolatilization (uptake and transpiration by plants; this process is primarily limited to mercury and arsenic), and rhizofiltration (sorption, concentration and precipitation of metals in the root mass). Of these, the first two mechanisms are the most effective in attenuating metals (Laghlimi et al. 2015). In general, trees are a more effective form of vegetation due to their size, perennial nature, and the depth of root growth. Different metals will accumulate in different parts of a tree. For instance, copper tends to be immobilized and retained principally in the roots while zinc moves into the branches and leaf mass (Pulford and Watson 2003). Some plant and tree species act as hyper-accumulators that are tolerant of high metal concentrations in soils and can amass metals in their tissues through detoxification mechanisms (Sarma 2011). These species could be preferentially planted in areas where metals are a particular concern to help attenuate metal movement to the stream channel. As leaves will fall to the ground, riparian management could include the periodic removal of vegetative debris to off-site locations to avoid subsequent movement to the stream. Often there is no need to plant nonindigenous plants as a variety of common native riparian vegetative species can provide phytoremediation capabilities. For instance, willows (*Salix* spp.) have been shown to attenuate various metals in riparian areas to great effect (Bourret et al. 2009; Zhongmin et al. 2012).

Soil amendments offer another form of “green remediation” that has been increasingly used in soil systems since the turn of the century. A wide variety of amendments can be used either to mobilize metals by promoting uptake via phytoextraction or to immobilize (stabilize) metals in a solid phase. For instance, chelating agents have been applied at sites around the globe to enhance desorption, while phosphate



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fertilizers are common amendments intended to intensify metal sorption and form precipitates. Several topical reviews describing assorted soil additives have been published that provide more detail on this *in-situ* remediation technique (e.g., Bolan et al. 2014; Mahar et al. 2015). Similarly, over the last decade biochar has seen increased application in the context of attenuating metals (Ahmad et al. 2014). Although studies on the use of soil amendments to attenuate metals in riparian soils are limited, recent findings showed that additions of 11 different materials, such as biochar, bentonite, cement bypass kiln dust, and limestone to a floodplain soil could provide a potential remediation technique (Rinklebe and Shaheen 2015). An evaluation of the amendments in riparian soils heavily contaminated with copper (over 3,000 mg/kg) showed that most of the additives shifted the geochemical forms of copper through either increased sorption or by transformation to more plant available forms. Although the authors concluded that the low amendment rates that could practically be applied would inadequately immobilize copper, the increased copper concentration found in grass tissues at the same site indicates a means of enhanced phytoremediation.

Clearly, the use of soil amendments requires further field verification in riparian areas, but this approach to enhancing natural attenuation mechanisms shows promise.

5.4.4. Pesticides and Other Organic Compounds

An extensive array of organic contaminants exists in the environment that can threaten water quality in aquatic ecosystems. This category of compounds describes molecules that contain carbon covalently bonded to other elements, and includes both naturally derived and synthetic chemicals. This chapter focuses on anthropogenic compounds that exert a toxic effect on aquatic organisms.

The multitude of organic chemicals makes it impractical to touch on each class here, but common examples that present environmental health risks in aquatic habitats include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides. While the detrimental effects of many of these pollutants have been recognized for some time, studies continually identify emerging contaminants of concern ("emerging" does not only connote new compounds, but also chemicals that have been in use without realizing the extent of their toxicity). For instance, hazards associated with flame retardants, such as polybrominated diphenyl ethers (PBDEs), have been highlighted over the last decade (Covaci et al. 2011; Ye et al. 2015). Recent research emphasis also has been placed on a variety of trace organic compounds, including pharmaceuticals and personal-care products (PPCPs), as it is now recognized that these chemicals can exert negative impacts on fish and other aquatic organisms at both the individual and population levels even at extremely low (e.g. parts per trillions) concentrations (Mueller 2004; Kümmerer 2009a; Kümmerer 2009b; Luo et al. 2014). In addition, there is growing awareness that while individual pesticides may have little or no effect

when examined alone, that same pesticide as part of a pesticide mixture may be lethal to amphibians (Hua and Relyea 2014).

While only a brief discussion was provided above on the various organic pollutants that act as environmental contaminants, a little more information on pesticides is warranted, as they are more likely to be used in uplands and transported into riparian areas. Pesticides consist of any substance that is used to control fungal, plant, or animal pests. These chemicals represent a broad range of different chemicals that are derived from various sources such as plant extracts (nicotine, pyrethrum, neem oil), inorganics (e.g., copper sulphate; inorganic pesticides will not be discussed here), and synthetics. Synthetic pesticides are themselves a broad class that includes legacy organochlorines (chlorinated hydrocarbons such as DDT), organophosphates (e.g., Malathion), phenoxyacetic acids (e.g., MCP), carbamates (e.g., carbaryl), and neonicotinoids (e.g., imidacloprid). Pesticide pollution of streams can impact non-target organisms resulting in a wide variety of physiological and ecological problems (Mann et al. 2009), including altered growth (Alvarez and Fuiman 2005) and reproduction (Moore et al. 2007), altered community dynamics (Fleeger et al. 2003), and the loss of species (Relyea and Diecks 2008).

The ecological impacts of organic pollutants on aquatic organisms vary considerably, depending on not only the contaminant type but also the environmental conditions. Various compounds can be carcinogenic (causing cancer), mutagenic (altering genetic material and fomenting mutations), and teratogenic (stimulating abnormalities). Organic pollutants can also act as endocrine disrupting chemicals (EDCs), adversely impacting development, reproduction, neurologic, and immune system function in humans and wildlife (Colborn et al. 1993). Endocrine disruption has emerged as a key issue as studies have identified more cases of detrimental impacts, such as the discovery of atrazine-induced feminization of male Northern Leopard Frogs at

very low concentrations (Hayes et al. 2003). This finding is controversial, but it has increased awareness that many organic compounds have potentially unrecognized endocrine-disrupting effects. Some organic contaminants, such as halogenated hydrocarbons, are capable of bioaccumulating in individuals and biomagnify up the food chain (Rahman et al. 2001).

To further complicate potential risk, pesticides rarely occur singly in aquatic environments. For example, a comprehensive decadal assessment of 178 streams in agricultural, urban, and mixed-land use watersheds found two or more pesticides more than 90% of the time and ten or more pesticides 20% of the time (USGS 2006). Ecological and toxicological research is increasingly recognizing the complexity of contaminant mixtures, which may have antagonistic, additive, or synergistic interactions in biota (Cedergreen 2014). For example, combining the pesticides diazinon and Malathion inhibits brain activity, and therefore swimming performance in fish at concentrations more than 50 times lower than the concentrations that cause an impact when these pesticides are used singly (Laetz et al. 2013). Although the examples given focused on pesticides, mixtures of hydrocarbons originating from roadways, parking lots and other locations can also be found in urban watersheds, including pollutants such as PAHs that originate from coal-tar-sealed parking lots (Scoggins et al. 2007). Amalgamations of these urban generated organic contaminants have been shown to impart both sub-lethal and lethal effects on aquatic organisms and disrupt stream communities (PSAT 2007; Scoggins et al. 2007; Spromberg et al. 2016).

The sheer number of different sub-classes of pesticides makes it impractical to provide information on the chemical behavior of all the potential contaminants that might be encountered in riparian areas. Pesticide pollution is extremely complex due to the multitude of types, the wide range of molecular sizes, the diversity of chemical structures, and the ability of these compounds to react and transform into new products. However,

some basic information on organic compounds will enable a better understanding of the effects riparian buffer size and structure have on pesticide pollutants. It is essential to identify the physicochemical properties of organic contaminants to adequately assess fate and transport pathways through riparian areas. Specific gravity, water solubility, vapor pressure, and partitioning coefficients such as the octanol/water partition ($\log K_{ow}$) and organic carbon partition coefficients (K_{oc}) all serve as predictors of a substance's potential mobility and attenuation in riparian areas.

Natural organic matter has a significant impact on the degree of attenuation riparian soils impart on pesticides. The aforementioned K_{oc} represents the ratio of the amount of chemical adsorbed to the soil to the amount of chemical that remains in solution, related to the mass fraction of organic matter in the soil (Delle Site 2001). This value essentially indicates the affinity of a pollutant to soil organic matter and is a predictor of its potential mobility through the soil, where higher K_{oc} values correlate to less mobile organic contaminants and low K_{oc} values correlate to more mobile organic contaminants. Hydrophobic, nonpolar compounds, such as PAHs, are typically associated with particles in soil-water systems, whereas polar contaminants often exist in dissolved forms that exhibit a greater propensity for movement through the ecosystem.

The relationship between pesticides and their respective K_{oc} values can be confounded by humic substances, which are a heterogeneous mixture of chemically complex macromolecules that comprise a substantial component of natural organic matter. Humic substances have long been known to exert a significant impact on the movement of organic contaminants (Hayes 1970; Khan 1972). These amorphous compounds, which are classified into humic acid, fulvic acid, and humin fractions based on their molecular size and chemical behavior, can effectively bind organic pollutants and present either water-insoluble entities that are retained in the soil column or water-soluble colloids that can

facilitate transport through riparian soils to the stream channel. Even when present in small quantities, these chemically reactive compounds can dramatically influence the binding, persistence, and translocation of organic pollutants. The interactions between humic substances and organic contaminants are beyond the scope of this chapter, but their potential to affect K_{oc} values by up to an order of magnitude is salient to predicting their attenuation by riparian buffers (Grathwohl 1990; Kopinke et al. 2001). Nevertheless, in general the attenuation of organic pollutants in riparian areas is positively correlated with soil organic matter.

Pesticides and other organic pollutants can also be retained in riparian areas through sorption to mineral components in the soil, although often to a lesser extent than to organic matter (Delle Site 2001). The surface area of soil particles enhances the binding of organic pollutants, which increases with finer soil textures such as those found in clays. The mineral composition of the soil particles also influences binding affinity by offering different forms of attachment sites. Those compounds that do not attach to soil material are susceptible to leaching, which can result in them entering the groundwater and being transported to the stream. Contaminants associated with inorganic particulates are usually much less bioavailable, although they can become bioavailable if particles are ingested by biota (Moermond et al. 2004).

Pesticides and other organic pollutants can undergo abiotic and biotic transformations that further compound the complexity of their chemistry. Abiotic processes include degradation due to chemical reactions such as hydrolysis (Mitchell et al. 2014; Mitchell et al. 2015). Biotic transformations include biologically mediated reactions, such as bacterial metabolism. Although the potential for biodegradation is dependent on the chemical structure of the contaminant, indigenous soil bacteria can use many organic compounds as a metabolic substrate. Repeated exposure to the same type of pesticides can foster microbial communities that

become contaminant specialists (Vidon et al. 2010). For example, soils receiving repeated applications of the pesticide 2,4-D harbor more 2,4-D-degrading microbes than similar plots receiving fewer applications (Gonod et al. 2006). Similarly, PAH-degrading bacteria were more abundant in rain gardens receiving stormwater runoff than upland control plots (LeFevre et al. 2012). The robust microbial communities found in riparian areas, resulting from conditions discussed previously, helps attenuate many organic compounds in riparian soils. Being biologically mediated, however, the degradation rates will fluctuate seasonally depending on temperature and soil moisture.

Phytoremediation by riparian vegetation provides an additional attenuation mechanism for organic contaminants. Although phytoremediation has received significant interest over the last two decades, the literature contains few papers on this method specific to pesticides in riparian areas. However, the principles are the same as those described in the vegetation section found earlier in this chapter, and presumably the results would be similarly positive. This premise was highlighted in a review article on the potential effectiveness of phytoremediation in riparian areas, where Karthikeyan et al. (2004) drew on similarities between streamside areas and other locations where phytoremediation has been effectively employed to treat pesticide-contaminated soil and water. Similarly, another review paper summarized a range of studies that investigated phytoremediation in aquatic settings, addressing plant species such as cattail (*Typha* spp.) and Cutgrass *Leersia oryzoides* which can be found along the riparian-aquatic ecosystem transition (Moore et al. 2011). A study directly examining the use of phytoremediation in riparian areas found that Tussock Sedge *Carex stricta*, Switchgrass *Panicum virgatum* and Gamagrass *Tripsacum dactyloides* led to approximately 70% reduction in total petroleum hydrocarbons under controlled riparian conditions, while there was only about 20% reduction associated with a Narrowleaf Willow *Salix exigua* and poplar

(*Populus* spp.) (Euliss 2008). Following the same procedure in an uncontrolled riparian field site did not reproduce these promising results, but the authors presumed there was a continuous pollutant source re-contaminating the site during the study. A field study examining the phytoremediation potential of willows (*Salix* spp.) in riparian areas yielded a 49% decrease in PCB concentrations before contaminated groundwater reached the stream margin (Skłodowski et al. 2014). Although there is not enough information available in the literature to provide design guidelines for implementing a phytoremediation-based system, there is promise in this approach to attenuating organic contaminants in riparian areas and further research should be encouraged.

Mycoremediation, the degradation of contaminants by fungi, is a type of bioremediation that occurs in soils. This process likely takes place in riparian soils with high organic matter content where lignin-degrading fungi (more commonly known as wood-decay fungi, a class that includes brown rot, soft rot, and white rot) exist. These microorganisms possess the ability to breakdown organic contaminants, particularly PAHs, through the release of a variety of oxidizing enzymes (Haritash and Kaushik 2001). Research on promoting lignin-degrading fungi as a remediation agent started to appear in

The central problem faced by resource managers is determining the adequate riparian buffer width, composition, and structure to protect water quality with high degrees of efficacy, efficiency, and certainty.



Spawning Chum Salmon Oncorhynchus keta/Ned Pitman, WDFW

the literature in the 1990s, but did not receive much attention until after the turn of the century (Lamar et al. 1993; Boonchan et al. 2000; Canet et al. 2001). Results vary considerably, but it is not uncommon to observe 50% to 90% reductions in organic pollutants resulting from mycoremediation-mediated degradation (Lamar et al. 1993; Boonchan et al. 2000; Haritash and Kaushik 2001). Although this degradation process is mentioned here to highlight the mechanisms affecting organic pollutants in riparian soils, it has been suggested that mycoremediation could potentially be capitalized on as an engineered mitigation technique in riparian areas, but more research is needed (Jones 2009).

Despite the large body of knowledge that has been developed, the mechanistic understanding of pesticide transport through riparian areas is incomplete. The following summarizes our understanding of the typical transport pathways of a pesticide; this is essential information to consider when determining appropriate riparian widths for attenuation. Pesticide migration from terrestrial sources to stream channels can follow a number of different pathways. The specific transport mechanism governing pesticide movement from uplands through riparian areas and into surface waters is highly

correlated to the type of pesticide in question. Surface runoff can carry pesticides off fields as either dissolved forms or attached to eroded soil particles. Leaching of compounds entails their vertical movement through the soil, after which they can either move toward the stream through the unsaturated zone or via groundwater flow. The chemicals that move in the dissolved form tend to be those that exhibit low to moderate sorption properties, as compounds that possess lower partition coefficients are prone to leach into the soil profile. Leaching is further promoted in regions with high precipitation and in soils that are coarse-textured, contain a low percentage of organic matter, or demonstrate a high degree of macropore flow. Pesticides that predominantly follow sediment-facilitated transport are generally those that display a strong affinity to soil particles (i.e., $K_{OC} > 1,000 \text{ L/kg}$).

While the literature lacks information on the potential attenuation in riparian areas for most organic pollutants, there are a substantial number of papers on the movement of pesticides through buffer strips. A number of review papers evaluate pesticide attenuation in riparian areas, with a particular emphasis on managed vegetative filter strips (Krutz et al. 2005; Lacas et al.

2005; Reichenberger et al. 2007). Due to the complexity of the attenuation mechanisms involved, the removal rates within buffers vary considerably between disparate compounds, as well as when comparing the removal rates of the same pesticide at different locations. Depending on the conditions, mass removal rates for some pesticides can be negligible while others can reach 100%. Research has shown that herbicide type and filter strip width are primary factors affecting herbicide retention in riparian areas, while antecedent moisture conditions exert an additional effect wherein pesticide attenuation is generally negatively correlated with soil moisture. The type of vegetation appears to have negligible impact on pesticide retention, with studies showing that a grass-shrub-tree mixture exhibited comparable mitigation as grass only. Interestingly, one study found that pesticide mitigation was greater at higher incoming concentrations, which was attributed to better sorption to soil and plant material (Misra et al. 1996).

Due to confounding and often conflicting results, after 35 years of research, there remains a lack of consensus on the minimum filter strip widths needed for effective pesticide removal from surface and surface overland flow. The NRCS recommends a standard width of 49 ft (15 m) with the aim of achieving 50% effectiveness, but there is not much evidence to support this guidance (NRCS 2000). Another general recommendation for diffuse runoff suggests riparian widths of 33 and 66 ft (10 and 20 m) for hillslopes of under and over 328 ft (100 m) in length, respectively (Lacas et al. 2005). However, because this recommendation is based on only one experimental study, it may not be applicable to other locations with different hydrological, soil, and vegetative conditions.

Pesticide Spray Drift

Pesticide spray drift, the aerial transport of pesticide droplets off target areas during spray application, presents another pathway by which these chemicals

can enter aquatic ecosystems. Unlike hydrological transport, pesticide physicochemical properties play a negligible role in aerial transport (although formulation does act as an influencing factor). Weather conditions (e.g., wind speed, temperature, and humidity), equipment type, application practices, and target crop all affect aerial transport. There is a better understanding of pesticide aerial drift to streams than that of hydrological pathways, either as a result of occurring in a less complex matrix, or as Reichenberger et al. (2007) asserts, due to aerial drift receiving more regulatory scrutiny.

Management of riparian areas can significantly reduce pesticide spray drift in many cases, particularly when conducted in conjunction with proper application practices. However, in their review of mitigation via windbreaks, Ucar and Hall (2001) found no general consensus on optimum riparian buffer widths to protect water quality. Their review reports that research has yielded buffer width recommendations that range from 20 to 150 ft (6 to 45 m) for ground application and 80 to over 4,000 ft (25 to over 1,200 m) for aerial application. Despite this lack of harmony in recommendations, individual cases have yielded positive results. Analysis of a forested riparian area in British Columbia found that a 25 ft (7.6 m) buffer limited the amount of herbicide reaching the stream to less than 0.1% of the aerial application (Feng et al. 1990). In an agricultural setting, a simple 10 ft (3 m) no-spray buffer reduced herbicide drift deposition to adjacent surface waters by 95%, and no measurable drift reached the stream at a width of 20 ft (6 m) as long as the wind-speed was below 15 mph (25 kph) in the direction towards the buffer (De Snoo and De Wit 1998). Many factors contribute to the effectiveness in reducing pesticide drift to acceptable levels. While wind-speed and application method exert significant impacts, vegetation height, density, orientation, and species composition all play pivotal roles. For instance, Ucar and Hall (2001) suggest that, in general, evergreen species display capture efficiencies 2 to 4 times greater than deciduous trees.

5.4.5. Pathogens

Pathogens impair more waterbodies in Washington than any other contaminant (USEPA 2015). Fecal contamination of surface waters can lead to the introduction of various pathogenic bacteria, fungi, viruses, protozoans, and worms that infect the gastrointestinal tract and present a health risk to both humans and wildlife. Common infections related to fecal pollution result from the presence of pathogenic bacteria such as *Escherichia coli* (*E. coli*), *Salmonella* spp. and *Vibrio* spp. or viruses such as Rotavirus. Primary pathogenic protozoans of concern include *Cryptosporidium parvum* and *Giardia lamblia*, which are able to form oocysts (protective spores) that allow them to survive outside of a host for long periods. Helminths represent a general class of parasitic worms, including flatworms and roundworms, which can act as intestinal parasites. The myriad pathogens that can be found in riverine systems following fecal contamination makes it impractical to list them here, but it is important to understand the four different pathogenic categories that can be conveyed to people through surface water contact or ingestion.

Pathogens comprise a diverse range of microorganisms that are typically found in low concentrations, making it impractical to test for specific pathogens when conducting water quality assessments. As an alternative, “pathogen indicator organisms” are used as a proxy to assess the potential presence of pathogens in a water sample. Commonly employed pathogen indicators include total coliforms, fecal coliforms, and *E. coli*. Total coliforms comprise a group of five genera of bacteria that easily can be analytically differentiated from other microorganisms, and while some occur naturally in soils, many are found in the gastrointestinal tract of warm-blooded animals and can serve as a general marker for fecal contamination. Fecal coliforms represent a sub-group of total coliforms that more specifically reside in the intestines of warm-blooded

animals, making them a more accurate indication of the presence of fecal material in water. Washington water quality standards use fecal coliforms as indicator organisms to determine water quality impairment. *E. coli*, a species in the fecal coliform group, is a dominant inhabitant in the digestive tract and is generally considered the best indicator of fecal pollution of the three. As *E. coli* are indigenous enteric bacteria, they are not in themselves pathogenic although some strains are (e.g., *E. coli* O157:57). Although most of these indicator organisms are not pathogenic, it is common to refer to them as pathogens when discussing water quality (shortening the phrase “pathogens and pathogenic indicator organisms”), and while technically inaccurate, we will use that term in this section. We use the term in a way that should allow the reader to differentiate between whether we are referencing pathogens specifically or the broader group that includes pathogen indicator organisms.

As the pathogens in question are enteric, they are introduced into the environment through the feces of warm-blooded animals. Principal pathways for pathogens entering aquatic ecosystems are through direct defecation by livestock, wildlife, and pets in the riparian area and via overland flow carrying fecal material from upland pastures, animal feeding operations, fields that have received land-applied manures, or seepage from septic or sewage systems. Feces from domesticated dogs can be a predominant pathogen source in urban areas, as a study in Seattle attributed 30% of the fecal contamination to canines (Tobiason et al. 2002). Hobby farms also present an often-overlooked source adversely affecting water quality, and this has been shown to be an issue in Washington (Morace and McKenzie 2002).

The fate of pathogenic microorganisms in the environment is still not well understood in general and much uncertainty remains in the context of riparian areas. While many of the pathogens that can contaminate surface waters are obligate parasites,

some can persist outside of an animal's gastrointestinal tract in the environment. The length of time these microorganisms can survive under different conditions is a current topic of debate in the research community. The general assumption in the past was that these enteric organisms were not able to persist in the environment for more than a few days following excretion in feces. However, more recent research indicates that bacterial pathogens can survive for much longer periods, and it is generally recognized that persistence in the environment for two to three months is not uncommon. Longer survival rates are possible given the correct conditions, as demonstrated in a laboratory study where *E. coli* O157:H7 persisted for over 190 days in manure-amended soils (Jiang et al. 2002). General factors that influence the survival of pathogenic bacteria that enter riparian areas include soil moisture, temperature, pH, sunlight, nutrient availability, soil texture, and biological interactions. Moist, nutrient-laden, shady conditions such as those often found in riparian areas theoretically would provide an environment in which pathogens could survive longer, potentially being picked up by overland flow and introduced to adjacent stream channels.

Although considerable research has been conducted through the years on bacterial movement through environmental systems, research is in the nascent stages of examining the transport and fate of pathogens across the landscape and in riparian areas. Unc and Goss (2004) offer a concise review on the transport of bacteria from manure in relation to protecting water resources, and although the material presented does not focus on streamside areas it does provide fundamental information on the mechanisms involved in pathogen transport. The body of research that has examined pathogen attenuation in riparian areas is small although expanding, and almost all findings are related to vegetative filter strips and do not consider natural riparian ecosystems.

The capacity of vegetative filter strips to remove pathogens is not well established and research results

have demonstrated that these systems exhibit great variability in their effectiveness in removing pathogens. A number of studies have shown that filter strips impart no significant influence on pathogen and pathogenic indicator organism concentrations moving toward a stream channel (Walker et al. 1990; Schellinger and Clausen 1992; Chaubey et al. 1995; Coyne et al. 1995; Entry et al. 2000). Contradictory findings have been generated by other studies that promote the idea that well maintained filter strips can serve as an effective BMP to prevent pathogens from reaching surface waterbodies (Coyne et al. 1998; Fajardo et al. 2001; Tate et al. 2006).

Inconsistent findings result from a number of factors. Soil infiltration, antecedent soil moisture conditions prior to a rain event, vegetation status, topography, and rainfall intensity and duration all have been identified as key controlling variables (Muñoz-Carpena et al. 1999; Guber et al. 2009). Each of these parameters relates to the concept that pathogens being carried in overland flow are removed by their infiltration into the soil where they typically are filtered or adsorbed to soil particles. High intensity rain events and concentrated flow can significantly reduce pathogen removal efficacy below that which would occur under low-flow conditions (Fox et al. 2011b). Vegetative filter strip width plays a significant role in pollutant removal, where a linear

Although considerable research has been conducted on bacterial movement through environmental systems, research is in the nascent stages of examining the transport and fate of pathogens across the landscape and in riparian areas.

decrease in pathogenic bacteria has been consistently observed with increasing buffer width (Young et al. 1980). However, a potential exists for trapped pathogens to later be remobilized in subsequent runoff events. Higher concentrations of pathogens have been recorded in runoff during a second runoff event, which suggests that filter strips could become indirect sources of pathogens under some conditions (Collins et al. 2004).

5.5. Effect of Riparian Buffer Width on Pollutant Removal

The pollutant removal function of riparian areas has been studied for at least 40 years (e.g., Doyle et al. 1975), and the enormous quantity of scientific research over the past four decades has motivated numerous reviews of the scientific literature (Norris 1993; Osborne and Kovacic 1993; Barling and Moore 1994; Vought et al. 1995; Fennessy and Cronk 1997; Lyons et al. 2000; Dosskey 2001; Hickey and Doran 2004; Lacas et al. 2005; Krutz et al. 2005; Polyakov et al. 2005; Hoffman et al. 2009; Dosskey et al. 2010). Despite the large quantity of research and number of literature reviews, no widely accepted recommendations have emerged on minimum buffer widths needed to protect water quality. The lack of agreement amongst scientists is due, in part, to the surprising complexity of the mechanisms that remove pollutants from surface and subsurface flows in riparian areas, to the variety of research methods used to study pollutant removal by riparian buffers, and to the many different environmental conditions at research sites.

The quantitative metric of pollutant removal by riparian areas is referred to as removal efficacy, removal efficiency, or percent removal. These measures are usually defined as:

$$E_R = \frac{m_{in} - m_{out}}{m_{in}} \times 100 \quad (1)$$

where m_{in} and m_{out} are the mass or concentration of the pollutant entering and exiting a riparian buffer, respectively. The primary question addressed by nearly all research on the pollutant removal function of riparian areas, and by nearly all literature reviews, is how does riparian buffer width affect removal efficacy? The main answers are: 1) removal efficacy increases as buffer width increases, 2) topographic slope and vegetation type strongly affect removal efficacy, and 3) the relationship between removal efficacy and buffer width is highly variable.

In addition to the many literature reviews cited above, several statistical meta-analyses of research results (Mayer et al. 2007; Liu et al. 2008; Yuan et al. 2009; Zhang et al. 2010; Sweeney and Newbold 2014) provide synoptic perspectives on what is currently known about the relationship between buffer width and removal efficacy (Table 5.1). Research results from throughout the world were collected by all five meta-analyses, but the majority were from North America. The remainder of this section discusses the findings of those meta-analyses.

Four meta-analyses looked at the results of research on sediment removal. The meta-analyses found that buffer width alone explained 28% to 37% of the variance in sediment removal results. Models for removal efficacy versus buffer width predicted a wide range of buffer widths necessary for 90% efficacy: 33, 39, 75, and 170 ft (10, 12, 23, and 52 m) (Figure 5.2). Three of the meta-analyses found that adding slope as an independent variable significantly improved the fit of their models to the data. Two meta-analyses (Liu et al. 2008; Zhang et al. 2010) using the same studies but different modeling assumptions, found that optimum slope for sediment removal was about 10%. In other words, removal efficacy increased as slope increased from 1 to 10%, but then removal efficacy decreased as slope increased above 10%. However, extrapolating these findings to other locations should be done cautiously as this relationship may not hold under many conditions. Zhang et al. (2010) found that buffer width, slope,

and vegetation type together could explain 65% of the variance in sediment removal results. Curiously, they also found that buffers composed of grasses only or trees only were more efficacious at removing sediment than buffers composed of both grasses and trees (Figure 5.4).

Three separate meta-analyses looked at the results of research on nitrogen removal. The meta-analyses of Zhang et al. (2010) and Mayer et al. (2007) produced very different relationships for removal efficacy versus buffer width. Zhang et al. (2010) found that buffer width alone explained 44% of the variance in nitrogen removal results, but Mayer et al. (2007) found buffer width alone explained only 9%. Furthermore, Zhang et al. (2010) predicted that buffer widths of 80 ft (24 m) are necessary for 90% removal efficacy, while Mayer et al. (2007) predicted buffer widths of 436 ft (133 m) for the same efficacy (Figure 5.3). Separate models by Mayer et al. (2007) for surface and subsurface flows found a significant relationship (assuming $\alpha = 0.05$) between buffer width and removal efficacy for surface flows ($R^2 = 0.21$, $P = 0.03$) but not for subsurface flows ($R^2 = 0.02$, $P = 0.3$). Despite this result, Mayer et al. (2007) found that riparian buffers were more efficacious in removing nitrogen from subsurface waters than from surface waters. Mayer et al. (2007) found no significant relationship between nitrogen removal and buffer vegetation type but their collection of studies did show that buffers lacking trees (herbaceous cover only) were the least efficacious at removing nitrogen.

Zhang et al. (2010) found a relationship between vegetation type and nitrogen removal and that buffers composed of trees remove more nitrogen than buffers completely or partially composed of grasses. Zhang et al.'s model that included buffer width and vegetation type explained 49% of the variance in nitrogen removal results.

Comparing regression models for sediment and nitrogen removal (Figures 5.2 and 5.3) illustrates three important points regarding the pollutant removal function of riparian areas. First, the magnitude of removal efficacy for different pollutants can be very different. According to the models, 80% of sediment was removed at roughly 50 to 65 ft (15 to 20 m), but 80% removal of nitrogen may require buffer widths two to four times wider. Second, the variability of removal efficacy for various pollutants can be significantly different. The regression models for nitrogen removal show much more variation than the models for sediment removal. The wider variation is due, in part, to the greater complexity of the chemical and biological processes affecting nitrogen removal compared to the simpler physical processes affecting sediment removal. Hence, our ability to predict removal efficacy and our certainty about water quality protection can be very different for different pollutants. Third, for all pollutants the relationship between buffer width and removal efficacy follows a law of diminishing marginal returns. That is, the marginal (or incremental) amount of pollutant removal decreases as buffer width increases.

Zhang et al. (2010) also conducted meta-analysis for phosphorus and pesticides. Buffer width alone explained 35% of the variance in phosphorus removal results (Figure 5.5), and with the addition of vegetation as an independent variable, the model explained 47% of the variance. The buffer-width-only model predicts 89% phosphorus removal with a buffer 98 ft (30 m) wide.⁷ Buffers with trees were found to remove more phosphorus than buffers completely or partially composed of grasses. The pesticide meta-analysis included 11 chemicals (norflurazon, fluometuron, lindane, deisopropylatrazine, deethylatrazine, atrazine, permethrin, bromide, terbuthylazine, metolachlor, isoproturon). Buffer width alone explained 60% of the variance in pesticide removal results, and vegetation was found to be an insignificant predictor variable. The model predicts 92% pesticide removal with a buffer 65 ft (20 m) wide.

⁷ Because Zhang et al. (2010) assumed an asymptotic equation for their regression, the phosphorus model was invalid for efficacies greater than 89.5%.

Using data provided by Zhang et al. (2010), we calculated prediction intervals for their phosphorus model.⁸ A prediction interval describes the precision of a model's predictions and the interval's width is a metric of uncertainty. For a buffer 33 ft (10 m) wide, the width of the 90% prediction interval is 64%. Therefore, while the model predicts that a 33 ft (10 m) buffer will provide an average removal efficacy of 70%, the actual removal

efficacy obtained by another study on phosphorus removal (i.e., one which was not included in the meta-analysis) is likely to be somewhere between 38 and 100% (70% ± 32%). The low precision of the model's prediction interval is related to the unexplained variance that could be attributed to other variables not included in the regression, such as site slope and various soil properties.

Table 5.1. Descriptive information for functional relationships on sediment removal shown in Figure 5.2 and nitrogen removal shown in Figure 5.3. Reference numbers 1 through 4 correspond to numbers in Figures 5.2 and 5.3. In the equations, E_R is the removal efficacy, $width$ is riparian buffer width, and a , b , c , d , and k_{50} are parameters determined through linear or nonlinear regression.

Pollutant	Meta-analysis	Form of equation	Model	N^{***}	R^2	P value
Sediment	(1) Liu et al. (2008)**	$E_R = a + b \ln(width)$	width	79	0.34	< 0.001
		$E_R = a + b \times width + c \times slope + d \times slope^2$	width & slope = 5% width & slope = 10% width & slope = 15%	79	0.43	< 0.0001
	(2) Yuan et al. (2009)	$E_R = a + b \ln(width)$	width	75	0.30	na*
			width & slope ≤ 5%	53	0.32	na
			width & slope > 5%	14	0.17	na
	(3) Zhang et al. (2010)**	$E_R = a (1 - e^{b \times width})$	width	81	0.37	< 0.0001
		$E_R = a (1 - e^{b \times width}) + c + d \times slope$	width & slope = 5% & grass or trees width & slope = 10% & grass or trees width & slope = 15% & grass or trees	81	0.65	< 0.001
	(4) Sweeney and Newbold (2014)	$E_R = \frac{width}{k_{50} + width}$	width	22	0.28	na
Nitrogen	(1) Mayer et al. (2007)	$E_R = a \times width^b$	width, surface water only	23	0.21	0.03
			width & herbaceous vegetation	32	0.21	0.009
			width & herbaceous/forest vegetation	11	0.39	0.04
	(2) Zhang et al. (2010)	$E_R = a (1 - e^{b \times width})$	width	61	0.44	< 0.0001
		$E_R = a (1 - e^{b \times width}) + c$	width & trees vegetation width & grass or mixed grass/trees veg.	61	0.49	< 0.001
	(3) Sweeney and Newbold (2014)†	$E_R = 100 (1 - e^{b \times width/q})$	width & q set to 58‡ width & q set to 115	30	0.37	na*

* Signifies that P value was not reported in cited study.

** Nearly all the studies included by Liu et al. (2008) and Zhang et al. (2010) in their meta-analyses were the same studies.

*** N signifies number of studies in meta-analysis.

† Studies for subsurface nitrate removal only.

‡ q represents subsurface water flux. 58 and 115 L/m/day are median and mean subsurface water fluxes for studies collected by Sweeney and Newbold (2014).

⁸ A prediction interval is a range that is likely to contain the dependent response value (Y_i) for a new observation (X_i). A prediction interval assumes that the new observation is taken from the same population used to create the regression equation.

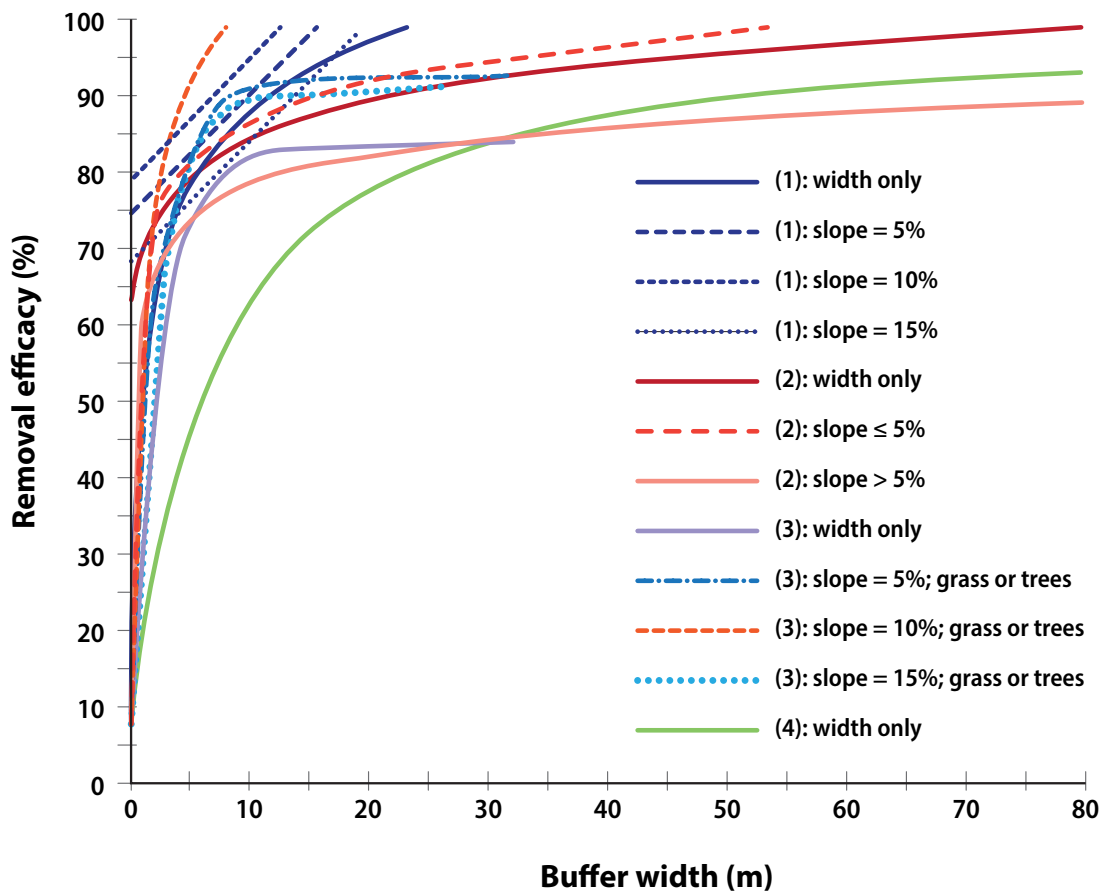


Figure 5.2. Relationships between sediment removal efficacy and riparian buffer width developed by four separate meta-analyses. Numbers in parentheses refer to different meta-analyses. See descriptive information in Table 5.1.

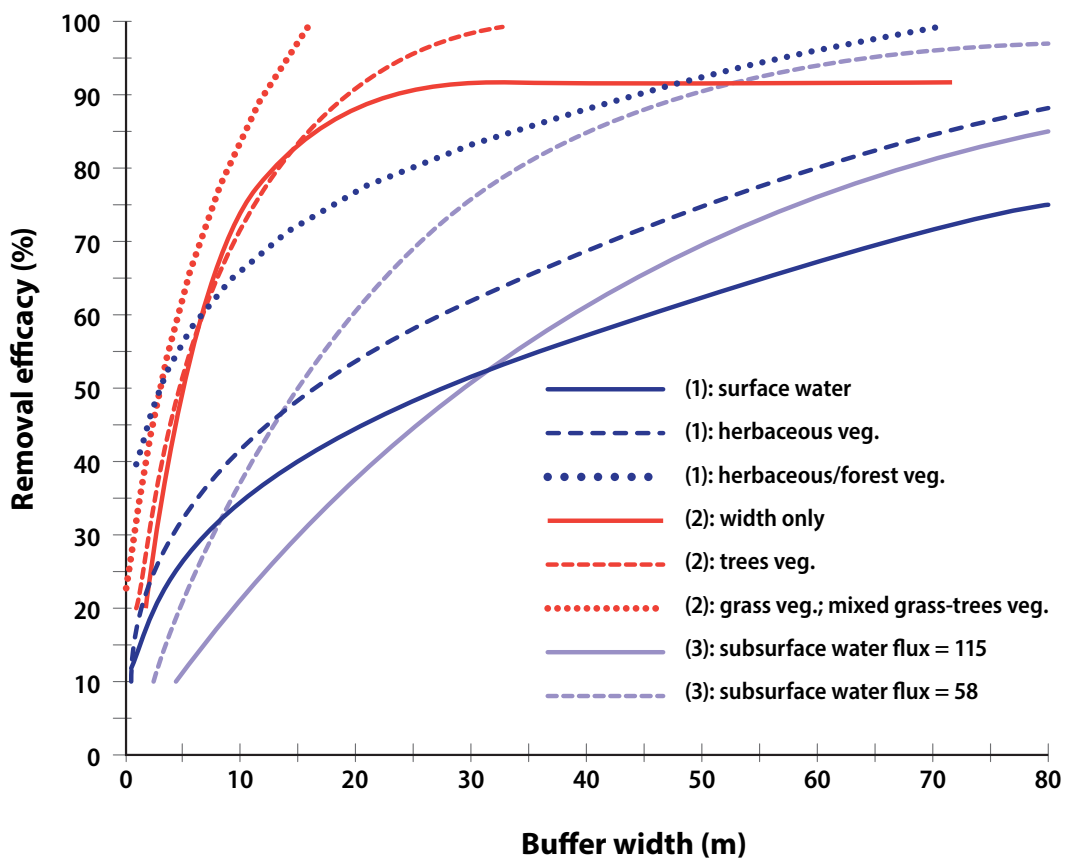


Figure 5.3. Relationships between nitrogen removal efficacy and riparian buffer width developed by three separate meta-analyses. Numbers in parentheses refer to different meta-analyses. See descriptive information in Table 5.1.

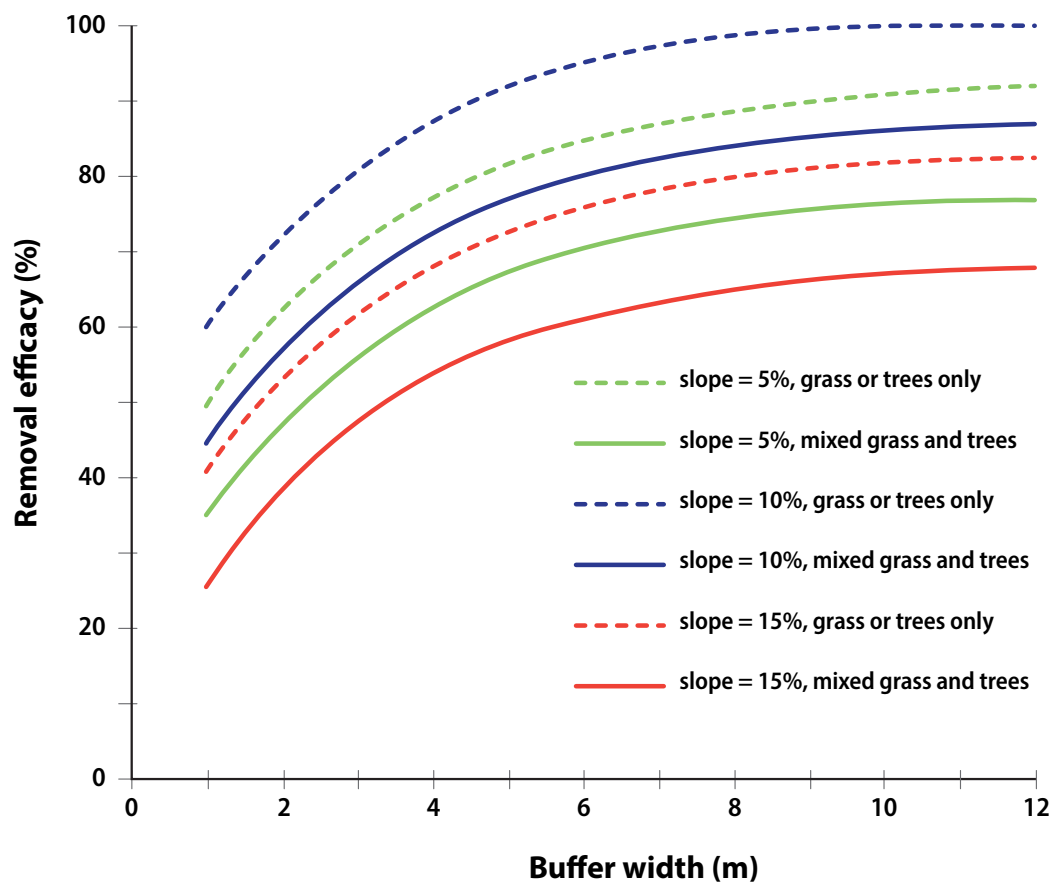


Figure 5.4. A result from meta-analysis of Zhang et al. (2010). Sediment removal efficacy as a function of buffer width, site slope, and buffer vegetation ($N = 81$, $R^2 = 0.65$, $P < 0.001$).

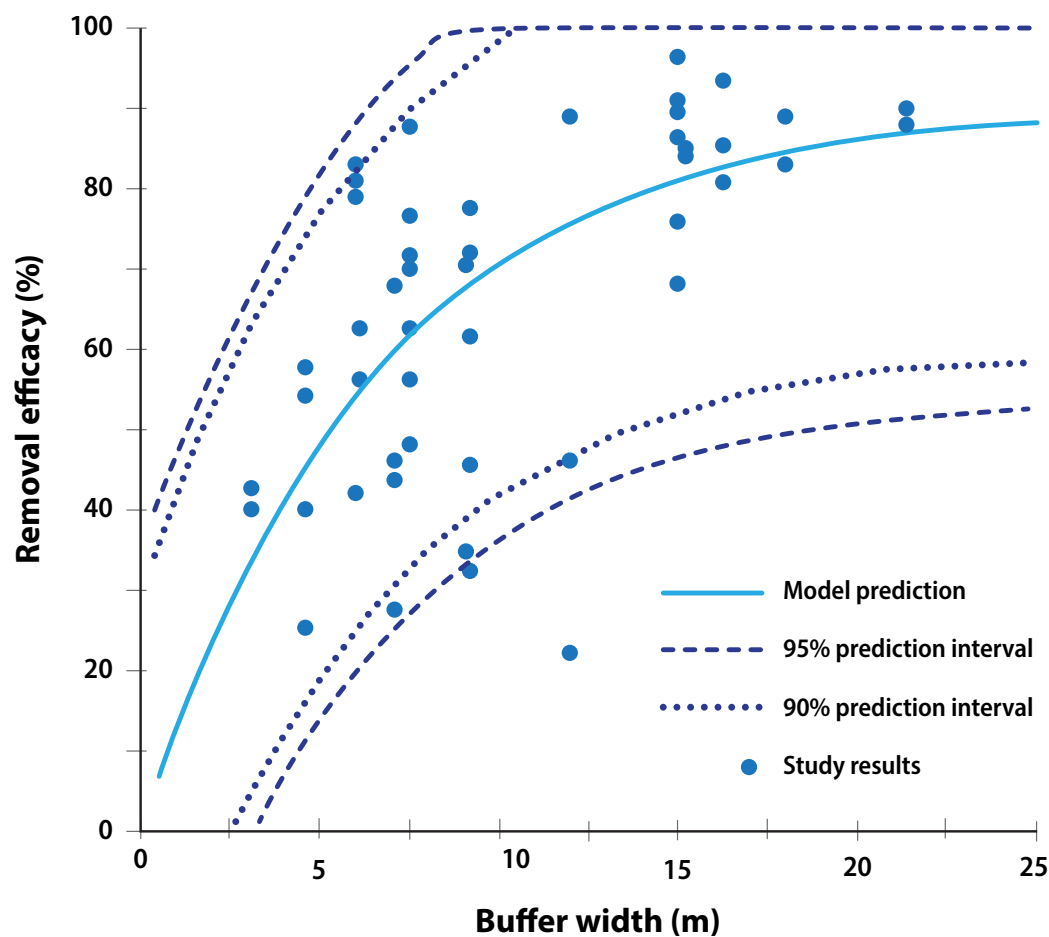


Figure 5.5. Meta-analysis of Zhang et al. (2010). Results of nonlinear regression for phosphorus removal efficacy as a function of buffer width ($N = 52$, $R^2 = 0.35$, $P < 0.0001$) with 90% and 95% prediction intervals.

5.6. Reanalysis of Meta-Analyses

A major assumption made by each of the meta-analyses was the type of equation that would result in the best fit to their data. Zhang et al. (2010), for instance, chose to use a nonlinear asymptotic equation of the form:

$$E_R = a \left(1 - e^{b \times width} \right) \tag{2}$$

where E_R is removal efficacy, *width* refers to buffer width, and *a* and *b* are coefficients determined through nonlinear regression. In equation (2), *a* determines the maximum removal efficacy possible (i.e., it is an asymptote). Zhang et al. (2010) conducted their regression such that *a* could be less than 100%. For sediment, pesticide, nitrogen, and phosphorus pollutants, *a* equaled 91, 93, 92, and 89.5 percent, respectively. Hence, we could not determine buffer widths needed for removal efficacies greater than these values of *a* in their models. This limitation was particularly problematic for pesticides and phosphorus because Zhang et al. (2010) was the only meta-analysis for those pollutants.

To determine buffer widths needed for higher removal efficacies (90, 95, 99%), we reanalyzed Zhang et al.'s data with a nonlinear equation of the form:

$$E_R = a + b \ln(width) \tag{3}$$

This form of model is the same used by Liu et al. (2008) and Yuan et al. (2009).¹ We performed linear regression in R (RCT 2013) using the `lm` function, but first we established that we could obtain the same regression results (same values for *a* and *b*) as Zhang et al. (2010) using equation (2). This confirmed that the data we downloaded from the internet were the same data used by Zhang et al. (2010). We then redid the regression

using equation (3). With the exception of sediment, the resulting models fit the data as well or better than the original models of Zhang et al. (2010) (Table 5.2). Graphical comparisons of our results and those of Zhang et al. (2010) are presented in Figure 5.6.

Table 5.2. Comparison of R^2 values for Zhang et al.'s (2010) model and our reanalysis using equation (3). *N* is the number of studies included in the meta-analysis.

Pollutant	<i>N</i>	R^2	
		Zhang et al. (2010)	Reanalysis
Sediment	81	0.37	0.31
Nitrogen	61	0.44	0.44
Phosphorus	52	0.35	0.39
Pesticides	49	0.60	0.61



Juvenile fish find shelter in a root wad/Terra Hegy, WDFW

¹ Xuyang Zhang, the lead author of Zhang et al. (2010), also recommended that we use equation (3) because equation (2) cannot model 100% removal efficacy (X. Zhang, California Department of Pesticide Regulation, personal communication, May 14, 2019).

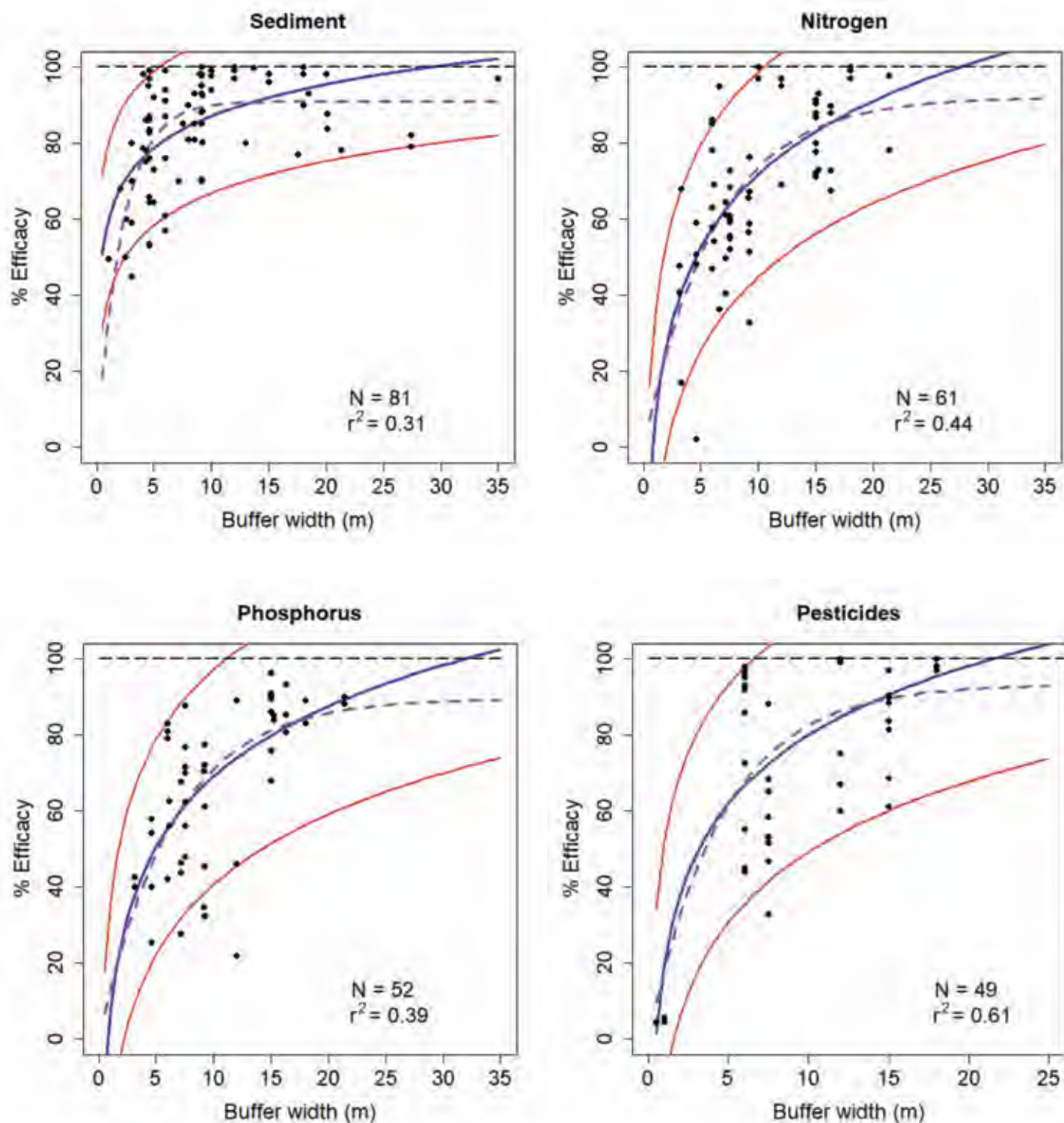


Figure 5.6. Relationship between removal efficacy and buffer width. Data from meta-analysis of Zhang et al. (2010) but reanalyzed using different form of nonlinear model. Line colors: blue: best fit model, red: 90% prediction interval, purple dashed: original model of Zhang et al. (2010), black dashed: 100% removal efficacy

We also reanalyzed two other meta-analyses – Mayer et al. (2007), and Sweeney and Newbold (2014) – for two reasons. The first reason was consistency across meta-analyses. The meta-analyses gave different answers for the relationship between removal efficacy and buffer width. For example, Zhang et al. (2010) predicted that buffer widths of 80 ft (24 m) are necessary for 90% removal efficacy of nitrogen, while Mayer et al. (2007) predicted buffer widths of 436 ft (133 m) for the same efficacy. Part of this discrepancy may be due to the type of equations adopted for their nonlinear or linear regressions, so we redid both meta-analyses using the same equation. Second, as noted earlier, a major assumption made by each of the meta-analyses was the type of equation that would result in the best fit to their data. We tested that assumption, and found that equation (3) often resulted in a better fit.

Mayer at al. (2007) chose to use a power function of the form:²

$$E_R = a \text{ width}^b \tag{4}$$

where *a* and *b* are coefficients determined through linear regression. We reanalyzed their data using equation (3). The resulting models fit the data as well or better than the original models of Mayer et al. (2007) (Table 5.3, Figure 5.7). For subsurface flow, the relationship between removal efficacy and buffer width was statistically insignificant (*P* = 0.30) and *R*² was only 0.02 for both their model and ours. We also note that both models produce somewhat absurd results – 60% of subsurface nitrogen can be removed with buffers only 2 ft wide but 90% removal requires buffers over 1200 ft wide. Hence, we will use neither model in further discussions of sub-surface nitrogen removal. For surface flow, the reanalysis resulted in a slightly better fit to the data – *R*² improved from 0.21 to 0.28.

We did not reanalyze the meta-analysis that Sweeny and Newbold (2014) did on studies of nitrogen removal from groundwater. While Sweeney and Newbold (2014)

Table 5.3. Comparison of *R*² values for Mayer et al.'s (2007) model and our reanalysis using equation (3). *N* is the number of studies included in the meta-analysis.

		Mayer et al. (2007)		Reanalysis	
Model	<i>N</i>	<i>R</i> ²	<i>P</i>	<i>R</i> ²	<i>P</i>
nitrogen, surface	23	0.21	0.03	0.28	0.009
nitrogen, subsurface	65	0.02	0.30	0.02	0.30

found a significant statistical relationship between nitrogen removal from subsurface flow and buffer width, other studies suggest the buffer width has little or no effect on nitrogen removal from subsurface flow (Hruby 2013, pp. 10-11).

For sediment removal, Sweeney and Newbold (2014) chose an equation of the form:

$$E_R = \frac{\text{width}}{k_{50} + \text{width}} \tag{5}$$

where *k*₅₀ equals the buffer width expected to remove 50% of sediments and it is determined through nonlinear regression. We reanalyzed their data using equation (3). The resulting model fits the data better than the original model of Sweeney and Newbold (2007). Their *R*² was 0.28 and the new *R*² is 0.33 (Figure 5.7).

Table 5.4 shows the buffer width needed to achieve desired levels of pollutant removal as predicted by meta-analyses and our reanalyses of meta-analyses. We combined predictions from multiple meta-analyses using a weighted average with the weights being the products of *N* and *R*². Note that values in Table 5.4 are predicted averages for removal efficacy. The actual efficacy realized by implementing a particular buffer width could be much better or worse. The amount of uncertainty in the realized removal efficacy is depicted by prediction intervals in Figures 5.6 and 5.7. The

² The equation *E_R* = *a width^b* can be transformed to the equation *ln(E_R)* = *a'* + *b ln(width)*, which is similar in structure to equation (3) and results in a similar fit to the data. Equation (3) was also the form used by Mayer et al. (2006).



Riparian areas capture pollutants/Marlin Greene, One Earth Images

reanalyzed meta-analysis of Zhang et al. (2010), for example, predicts that 90% of sediment can be removed with a 42 ft (13 m) wide buffer, however, according to the prediction interval, the buffer width needed for 90% removal could be as narrow as 8 ft (2.4 m) or as wide as 225 ft (69 m). Better models that include other independent variables, such as slope and vegetation

(e.g., Zhang et al. 2010), will reduce this uncertainty, but there is a trade-off. The application of more complicated models leads to more complicated management. If, for example, managers adopted a model that includes vegetation type or vegetation structure, then, in addition to buffer width, they must also manage the condition of vegetation within the buffer.

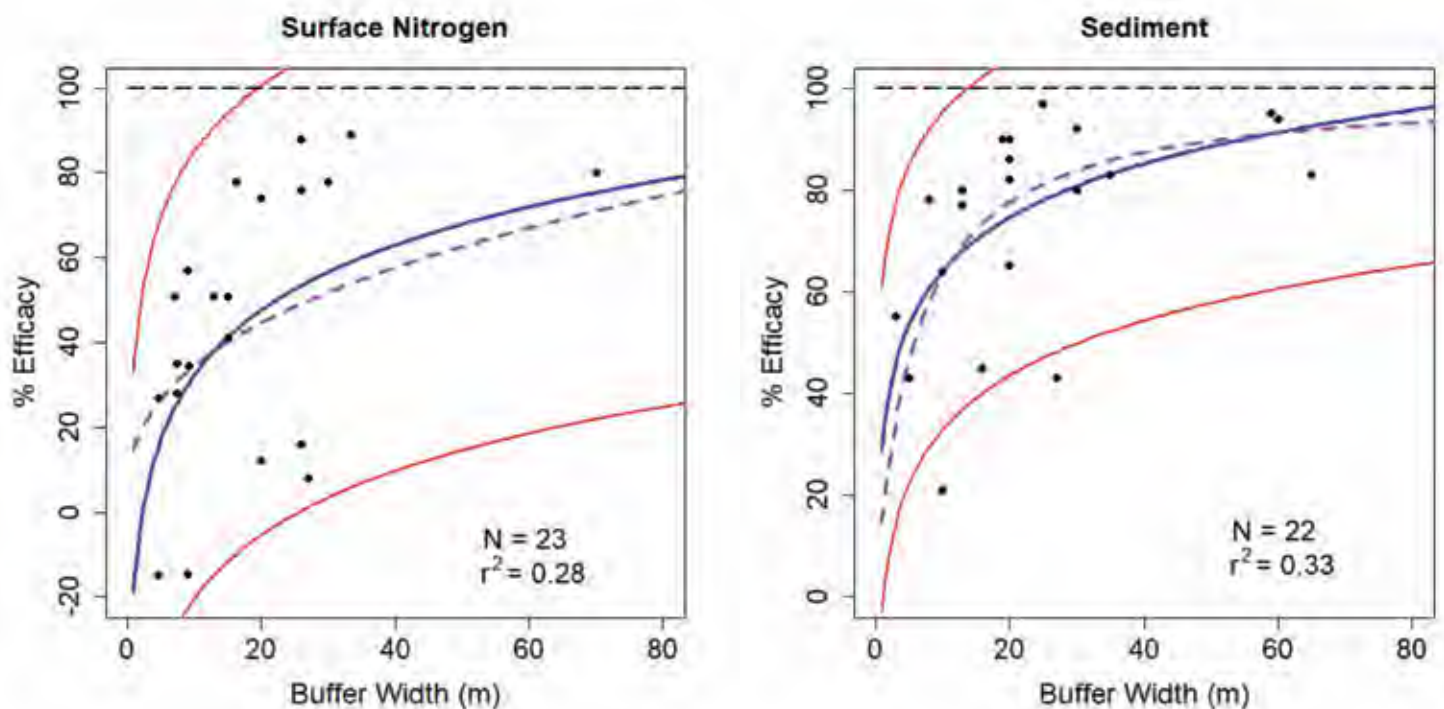


Figure 5.7. Relationship between removal efficacy and buffer width. Study results from meta-analyses reanalyzed using different form of equation in a linear regression. Left: nitrogen study results from Mayer et al. (2007). Right: sediment study results from Sweeney and Newbold (2014). Line colors: blue: best fit model, red: 90% prediction interval, purple dashed: original models from meta-analyses, black dashed: 100% removal efficacy.

Table 5.4. Buffer width in feet needed to achieve desired levels of pollutant removal from run-off. Buffer width calculated with model and/or data from the cited literature. Models had only one predictor variable, which was buffer width. Mean buffer width for sediment and nitrogen removal are weighted averages of widths determined by each meta-analysis. Weights were the product of *N* and *R*².

Average Removal Efficacy (%)				80	90	95	99
Pollutant	Meta-analysis	<i>N</i>	<i>R</i> ²	Buffer Width (ft)			
Sediment	Liu et al. (2008)*	79	0.34	18	39	56	76
	Yuan et al. (2009)	75	0.30	18	74	149	261
	Zhang et al. (2010)*, <i>reanalyzed</i>	81	0.31	18	42	64	89
	Sweeney and Newbold (2014), <i>reanalyzed</i>	22	0.33	94	181	251	326
	Weighted mean			25	62	101	153
Nitrogen, surface	Mayer et al. (2007), <i>reanalyzed</i>	23	0.28	283	444	556	666
	Zhang et al. (2010), <i>reanalyzed</i>	61	0.44	44	63	76	88
	Weighted mean			90	137	169	200
Nitrogen, subsurface	Sweeney and Newbold (2014) ‡	30	0.37	112	161	210	322
Phosphorus	Zhang et al. (2010), <i>reanalyzed</i>	52	0.39	50	72	87	101
Pesticides	Zhang et al. (2010), <i>reanalyzed</i>	49	0.61	33	48	59	68

* Nearly all the studies included by Liu et al. (2008) and Zhang et al. (2010) were the same studies.

‡ The parameter *q*, which represents subsurface water flux, was set to 58, which is the median value for 30 studies analyzed by Sweeney and Newbold (2014).

5.7. Conclusions

There is a consensus in the scientific literature that riparian areas reduce the flow of pollutants to aquatic ecosystems, and that pollutant removal functions are contingent on complex interactions between hydrology, soil, and vegetation, and are influenced by many other factors as well. Because hydrology, soil, vegetation and other factors exhibit high spatial and temporal variability, the efficacy of pollutant removal functions provided by riparian areas differs substantially among sites, as well as within sites. Determining the potential for riparian areas to protect water quality is further complicated by the disparate behavior of different contaminant types in the environment. While space limitations required

us to simplify this review of the scientific literature regarding pollutant removal functions of riparian areas, we provided the basic information needed for understanding these important ecological functions.

Our review of the literature presents a substantial body of scientific research with which to develop strategies, plans, or policies regarding the pollutant removal functions of riparian areas. The central problem faced by resource managers is determining the adequate riparian buffer width, composition, and structure to protect water quality with high degrees of efficacy, efficiency, and certainty. Riparian function is often simplistically characterized by buffer width and vegetation type, but these parameters only partially explain the effects that riparian areas have on pollutant removal. The current conservation paradigm remains strongly tied to the

premise that wider riparian areas are the only way to increase pollutant removal efficacy, but this is not always the case; other site-specific factors, such as conditions within the buffer, also exert a significant influence on removal efficacy. Therefore, consideration of the entire system (i.e., riparian area, uplands, vegetation, soils, ground and surface water pathways, topography, type of pollutant, etc.) is essential to developing cost-effective pollutant removal. In theory, buffer width and vegetation could be optimized for site conditions such that water quality is protected while minimizing economic costs for landowners.

Despite the many scientific uncertainties, management decisions must be made. Management decisions regarding pollutant removal by riparian buffers should be informed by science, but determining the “right” buffer width for pollutant removal cannot be purely scientific. Determining the “right” buffer width begins with choosing a desired removal efficacy, and that choice is normative. That is, the desired removal efficacy is a social choice influenced by cultural values, economic costs, and risk tolerance. Choosing a desired removal efficacy and determining the “right” buffer requires:

- 1) factual information regarding the anticipated impacts or outcomes of policy options (i.e., science);
- 2) an understanding of stakeholders’ priorities and preferences (i.e., values); and
- 3) a process for using science and values to explore tradeoffs amongst policy options (Wilhere and Quinn 2018).

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Okanogan National Forest/Scott Fitkin, WDFW

Chapter 6. Nutrient Dynamics in Riparian Ecosystems

By: Paul M. Mayer, Jana E. Compton, and George F. Wilhere

6.1. Introduction

Riparian ecosystems play a vital role in the dynamics of nutrients within watersheds, especially for the three primary macronutrients carbon (C), nitrogen (N), and phosphorus (P). Because they are positioned at the interface between the stream and upland areas, riparian ecosystems mediate the movement of materials and energy between land and water. Riparian areas can be sources or sinks of energy, water, nutrients, organic matter, and organisms within a watershed. Organic matter from riparian areas, an important source of energy and nutrients, makes its way into streams via plant litterfall, or through transport by water, wind, or animals. Organic matter in streams provides habitat and food for microbes, insects, fish, amphibians, birds, and other organisms, and decomposes to release plant-available inorganic nutrients like ammonium, nitrate, and phosphate. Riparian areas also store energy and nutrients from organic matter coming from upland and instream sources through biotic uptake, sorption and exchange, and slowing or trapping particles. Riparian areas also are sites with high rates of nutrient transformation, including conversion of inorganic nitrogen into the gases N_2 or N_2O via denitrification. Riparian ecosystems are influenced by upland activities that supply nutrients that follow flow paths through these ecosystems, eventually reaching streams via surface and subsurface flows. Age, vegetation composition, topography, soil type, and condition of the riparian ecosystem all factor into the fate and transport of nutrients. In addition, the position

in the drainage network and connectivity of the riparian area, along with disturbance and management history, affect nutrient processing rates.

Nutrients and the hydrological and biogeochemical processes that dictate their transport and fate are the subject of much current research in riparian ecology (Mayer et al. 2010a, 2014) because of their critical importance for growth and maintenance of life in the riparian ecosystem and the subsequent effects on stream biota and water quality. Although many micro- and macro-nutrients cycle through riparian areas, this chapter addresses only the three primary macronutrients C, N, and P.

Streams in the Pacific Coastal Ecoregion of Washington State are generally oligotrophic, well shaded, and sensitive to nutrient enrichment (Welch et al. 1998). When more N and P enters a riparian ecosystem than can be immediately utilized or stored, degradation of aquatic habitat conditions can occur and negative consequences within or beyond the riparian ecosystem may result. Excess N and P input to streams and estuaries may lead to harmful algal blooms, hypoxia, fish kills, and contamination of drinking water supplies. Although stream nutrient concerns have a somewhat lower profile in the Pacific Northwest (PNW) relative to other areas of the US, such as the Chesapeake Bay or Great Lakes watersheds, approximately 20% of assessed rivers and 8% of assessed lakes in Washington are regarded by the state as having impaired conditions related to an overabundance of nutrients (USEPA ATTAINS database).

Here, we describe nutrient cycles in riparian areas in the PNW, focusing on C, N, and P from natural and anthropogenic sources. Other nutrients, such as calcium, sulfur, or molybdenum, are not as widely studied but have been shown to be important in areas of the PNW for forest growth or other ecosystem processes (Silvester 1989; Chappell et al. 1991; Perakis et al. 2006). When possible, we discuss implications of common land management activities on nutrient dynamics by contrasting disturbed versus undisturbed riparian ecosystems. We also discuss new information gained from recent stable isotope studies and meta-analyses of riparian nutrient removal that have greatly improved our understanding of the permanence and effectiveness of nutrient removal processes in PNW riparian ecosystems.

6.1.1. Nutrient Dynamics in the Pacific Northwest

Figure 6.1 illustrates processes occurring in a largely undisturbed PNW forested riparian ecosystem and associated stream and upland. Water traveling through the riparian area (surface and subsurface flow) is the main transport mechanism for dissolved C, N, and P. These nutrients can be taken up directly by primary producers and decomposers, passively transported to groundwater or the hyporheic zone, or carried to surface waters via subsurface, overland, or channelized flow. The hydrologic regime dictates the timing and magnitude of nutrient movement into aquatic systems, and can create instream pulses of C, N, and P both in particulate and dissolved form (Kaushal et al. 2010).

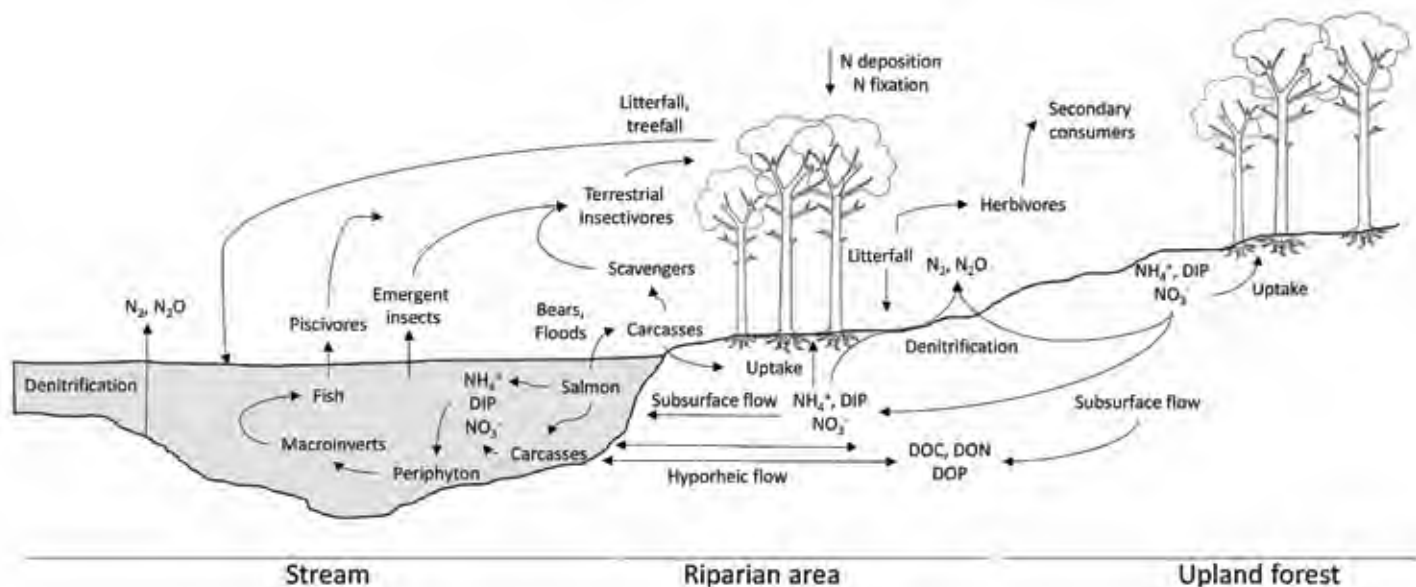


Figure 6.1. Nutrient cycle of an undisturbed PNW forested riparian ecosystem and connected stream and upland forest. Modified from Moyle et al. (2009). DIP = dissolved inorganic phosphorus; DOC, DON, DOP = dissolved organic carbon, nitrogen and phosphorus, respectively.



Most streams in the Pacific Northwest are nutrient-poor ecosystems/Ned Pittman, WDFW

Soil compaction and impervious surfaces typically reduce retention capacity of nutrients in space and time by preventing infiltration and thereby limit the interaction of nutrients with soils, roots, and soil biota. Riparian ecosystems exhibit a continuum of physical characteristics which have implications for nutrient dynamics. Riparian ecosystems along low-order streams, for example, are often narrower and steeper than those along mainstem rivers with wide, level floodplains. Consequently, surface and subsurface hydrological regimes controlling biogeochemical processes in riparian areas also differ along a continuum. Along small, steep forested streams, the water table is usually low and aerobic processes dominate, whereas level areas adjacent to larger rivers may provide water table conditions favoring anaerobic processes that reduce N via denitrification, a microbial transformation of dissolved nitrate N to gaseous molecular N (Burt et al. 2002; Hefting et al. 2004). The hyporheic zone is an area beneath the stream and riparian area where surface water and ground water continually interact. This zone can have a large influence on chemical characteristics of the surface water

and, therefore, plays a role in determining biological attributes of streams (Wondzell et al. 2011).

As nutrient molecules move downstream, they may be taken up by algae and microbes living on rocks and wood in the channel in slick mats called biofilms (Cardinale et al. 2002). The polysaccharide layers of biofilms are sites of active nutrient turnover where microscopic algae, fungi, and bacteria consume N and P, die and release nutrients that then move further downstream. Microbial communities may be consumed by grazers such as larval aquatic insects or snails, which in turn may be consumed by larger predators such as fishes or birds. As prey and predators are consumed or die, they release nutrients to the aquatic and terrestrial environments through decay and in this way C, N, and P cycle in a process of uptake and release called nutrient spiraling (Newbold et al. 1982). The distance a molecule moves downstream during a complete cycle is its spiraling length, a metric that explicitly relates nutrient utilization to nutrient supply (Newbold et al. 1982). Long spiraling lengths indicate that: 1) nutrient uptake is inefficient because the system is saturated with nutrients and organisms

can no longer fully exploit the incoming nutrient loads, 2) conditions are not optimal for uptake, such as when water flow is too fast, or 3) the stream does not support a community of organisms that effectively processes the nutrients.

In anthropogenically undisturbed Pacific Northwest watersheds, nutrients are ultimately derived from atmospheric and geologic sources, while plants play an important role in the initial uptake of N and P from these sources (McClain et al. 1998). Spatial variation in vegetation, geologic substrates, and human activities drive the variation in stream N and P concentrations and fluxes across the PNW (Wigington et al. 1998; Wise and Johnson 2011). The geology and geomorphology of a watershed and stream channel set the conditions for mineral composition of the groundwater reaching the stream because the shape and slope of the channel and banks affect water movement and velocity. Some bedrock types yield high stream P (Ice and Binkley 2003), leading to high regional P variability in riparian ecosystems and streams. Some types of vegetation can fix atmospheric gaseous N via symbiotic relationships with bacteria in their root systems, and in turn produce more biologically available N than they consume, thereby contributing to N loads in watersheds. A prime example is N₂-fixing Red Alder *Alnus rubra*, an important source of dissolved N in streams in western Oregon and Washington (Compton et al. 2003; Wise and Johnson 2011; Greathouse et al. 2014).

Nitrogen may occur in organic forms as microbial, plant, or animal tissue and in dissolved organic forms, or, if inorganic, primarily as nitrate (NO₃⁻) and ammonium (NH₃⁺), which are forms that can be assimilated by organisms into organic molecules. Forests in the PNW generally have fairly tight N and P cycles with little N or P lost or leached from the system. Rather, there are low rates of N and P inputs and outputs, but high rates of internal cycling (Sollins et al. 1980; Compton and Cole 1998). Triska et al. (1984) showed that N inputs

to a stream reach in an old-growth forest watershed in Oregon's Cascade Mountains were dominated by dissolved organic N from groundwater (69% of inputs), with litterfall and precipitation playing smaller roles.

Human activities like timber harvest, farming, or urban development alter nutrient cycles (Figure 6.2), producing higher fluxes, shorter storage durations, and higher concentrations of nutrients in subsurface flow, some of which will enter streams. Disturbances through forestry, grazing, agriculture or urbanization can alter the timing and routing of water through a landscape (Tague and Grant 2004), which can influence nutrient uptake and delivery to streams. Agriculture can contribute to excess nutrients in riparian and aquatic ecosystems through increased runoff of N and P from fertilizer and livestock manure (Wise and Johnson 2011). Point sources and urban stormwater runoff are the dominant sources of N within urban areas. For P, geologic materials dominate natural sources, with point sources such as urban runoff, farm manure, and fertilizer important in areas under anthropogenic land uses. Timber harvest increases stream nitrate and to a lesser extent phosphate concentration (Fredricksen et al. 1975; Scrivener 1975; Martin and Harr 1989). These increases generally persist for a short time, although Brown et al. (1973) saw increases in nitrate persist for six years post-timber harvest and burning.

Historically, a major source of allochthonous¹ nutrients and energy-rich carbon compounds was anadromous salmon (Cederholm et al. 1999; Gende et al. 2002). Anadromous, semelparous fish return from the ocean to spawn and die in their natal streams. The mass of every salmon carcass, of which 95% is accumulated in the marine environment (Naiman et al. 2002), is deposited in oligotrophic freshwater environments. The magnitude of nutrient and chemical energy losses to freshwater ecosystems caused by declines in salmon populations can best be appreciated by comparing current and historical salmon run sizes. Gresh et al. (2000)

¹ Allochthonous means originating or formed in a place other than where found. Hence, in the context of aquatic ecosystems, allochthonous nutrients found in a stream originated in terrestrial ecosystems. In contrast, autochthonous means originating or formed in the place where found.



Historically, carcasses of adult salmon delivered approximately 100,000 tons of nutrients to rivers and streams of Washington/Ned Pittman, WDFW

estimated that the current biomass of salmon runs for all Pacific salmon species (Chinook *Oncorhynchus tshawytscha*, Coho *Oncorhynchus kisutch*, Sockeye *Oncorhynchus nerka*, Chum *Oncorhynchus keta*, and Pink *Oncorhynchus gorbuscha*) in Puget Sound, the Washington Coast, and the Columbia River Basin are 25, 5, and 1% of historical biomass (circa early 1900s), respectively. This represents a loss of 122,470 US tons per year (111,104 metric tons) of marine-derived

nutrients and chemical-energy in these watersheds. Naiman et al. (2002) estimated that in the Willapa Bay Watershed the biomass of Chinook, Coho, and Chum Salmon carcasses in streams decreased from 2,920 to 226 US tons (2,649 to 205 metric tons per year), and that marine derived N and P decreased by more than 90%.

Figure 6.2 represents nutrient cycling in a watershed with more human-associated disturbance, including an

absence of salmon returns; by comparing Figures 6.1 and 6.2, changes in the cycling loop and intra-system transfers are evident when salmon are missing. Much of the cycling of marine-derived nutrients is mediated by predators and scavengers that move large amounts of marine-derived nutrients substantial distances into the terrestrial environment either as salmon carcasses or as metabolic waste products, i.e., urine and feces (Naiman et al. 2002). In several small streams on the Olympic Peninsula, Cederholm et al. (1989) observed that Coho Salmon carcasses were consumed by 22 species of mammals and fish (e.g., American Black Bear *Ursus americanus*, Northern River Otter *Lontra canadensis*, Mink *Mustela vison*, Bald Eagles *Haliaeetus leucocephalus*, and Ravens *Corvus corax*), and that 40% of salmon carcasses were moved by scavengers from the water to riparian areas. Flooding also can deposit salmon carcasses in riparian areas (Ben-David et al. 1998). Salmon carcasses provide N and P nutrients for microbes, plants, and animals, and influence all trophic levels in riparian ecosystems (Willson and Halupka 1995; Compton et al. 2006). Trees and shrubs in riparian

areas along spawning sites in the Kadashan and Indian rivers of southeast Alaska derived approximately 23% of their foliar nitrogen from decayed salmon carcasses, and growth rates of Sitka Spruce *Picea sitchensis* were significantly increased (Helfield and Naiman 2001). On average, 17% of the nitrogen incorporated into the riparian vegetation of a stream in western Washington was derived from carcasses of spawning salmon, and significant percentages of marine-derived N (up to 30%) and C (up to 39%) were found in aquatic insects, Cutthroat Trout *Oncorhynchus clarkii*, and juvenile salmon (Bilby et al. 1996).

Other animals subsidize riverine food webs by transporting nutrients across watersheds or by altering the hydrology (Chapter 8 in this document; Naiman and Rogers 1997; Masese et al. 2015). As ecosystem engineers, American Beaver *Castor canadensis* have a significant influence on stream nutrients. Beaver can influence biogeochemical cycles by impounding streams and changing hydrologic regimes and organic matter and sediment transport (Pollock et al. 2007).

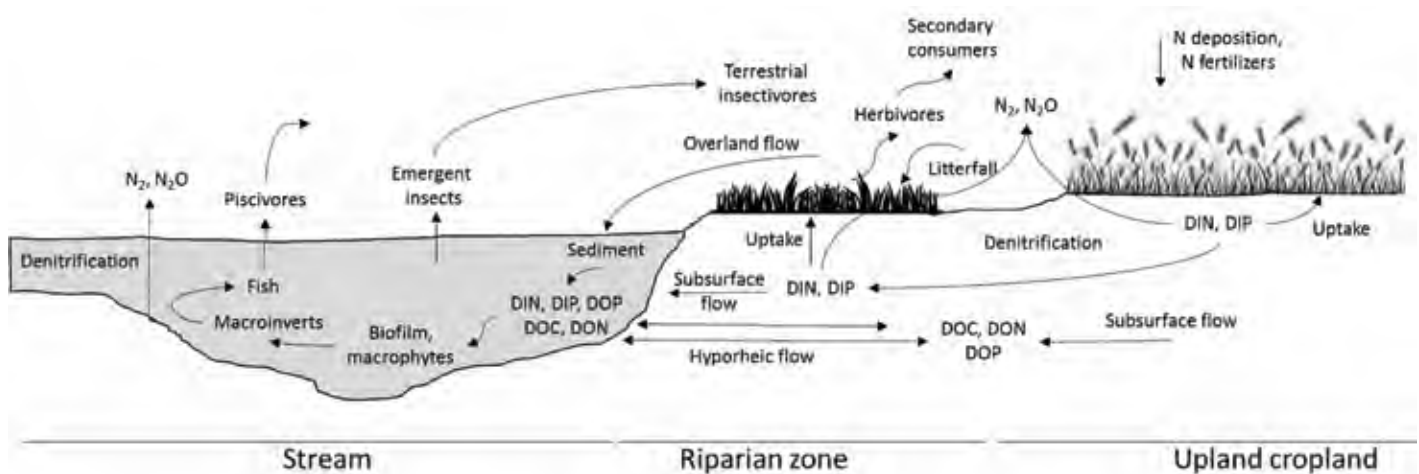


Figure 6.2. Nutrient cycle of a disturbed PNW riparian ecosystem and connected stream and upland cropland. Much of the cycling of marine-derived nutrients is facilitated by predators and scavengers that move nutrients into the terrestrial environment either as salmon carcasses or as urine and feces. Modified from Moyle et al. (2009). DIP = dissolved inorganic phosphorus; DIN = dissolved inorganic nitrogen (nitrate and ammonium); DOC, DON, DOP = dissolved organic carbon, nitrogen and phosphorus, respectively.

Retention of total N and P increased 72% and 43%, respectively after Beaver populations recovered in a Minnesota watershed (Naiman et al. 1994) and organic matter (carbon) retention increased three-fold after a stream was impounded by Beaver (Naiman et al. 1988). However, Beaver impoundments also influence N dynamics by flooding riparian forests, creating anoxic conditions in forest soils leading to an increase in denitrification and subsequent reduction in N (Naiman et al. 1988). Elk *Cervus canadensis*, deer (*Odocoileus* spp.), and livestock can also be important sources of N and P when found in close proximity to streams.

Riparian vegetation can affect uptake and delivery of nutrients to streams. Riparian plant roots can slow water movement and stabilize soils as well as take up dissolved nutrients. The types of vegetation and growth patterns in riparian areas determine the amount and timing of litterfall and woody material delivery to a stream. The height and density of vegetation dictate shading and solar input to the stream, thus affecting conditions for plant growth and N and P uptake. The key limiting nutrients for primary production in PNW streams are N and P (Welch et al. 1998), but there has not been enough experimental work conducted across the region to determine precisely when and where this occurs.

Shallow groundwater adjacent to stream channels often is a hot spot for N removal processes and a storage zone for other solutes.

6.1.2. Carbon

The cycling of C in riparian and aquatic ecosystems is complex and can differ among locations and through time because C can be available in different forms and is produced by different sources, thereby affecting its transport and fate. Carbon is tightly linked to N and P, driving biological transformations of these nutrients. Organic C regulates ecosystem functions in streams and rivers because dissolved organic carbon (DOC) is a primary energy source for microorganisms. Riparian vegetation in forests influences DOC composition and contributes a substantial proportion of stream organic C budgets (McDowell and Likens 1988). DOC in streams is a mixture of recalcitrant, (i.e., difficult to process components) and more easily metabolized labile fractions that drive biogeochemical processes involving nitrogen (Kaushal and Lewis 2005). For example, availability of dissolved and particulate organic C can limit denitrification, a microbial process critical to maintaining water quality, which has important implications for managing N in streams (Newcomer et al. 2012). Denitrification occurs only under anaerobic conditions where microbes shift from respiring oxygen to respiring nitrate, releasing nitrous oxide, and inert N₂ gas. These conditions may be ephemeral, fluctuating in response to water tables and associated changes in redox potential (Mayer et al. 2010b).

Anoxic conditions also promote the production of methane. Production of methane and nitrous oxides, increase in riparian areas with increased organic C supply (Kaushal et al. 2014). Dissolved organic carbon also can increase biological oxygen demand, thereby reducing oxygen for fish (Stanley et al. 2012).

Various organic C types from biofilm, leaves, and soil organic matter may have differential effects on ecosystem functions in forested streams (McDowell and Likens 1988), agricultural streams (Royer and David 2005), and urban streams. For example, C derived from

grasses supports more denitrification than C from tree leaves (Newcomer et al. 2012). Because the microbes that influence the transport and fate of N in riparian ecosystems require C as an energy source, C and N are inextricably linked in a biogeochemical sense.

Shading of small headwater streams in forested watersheds can obscure 95% of sunlight (Murphy 1998); hence, in-stream productivity is typically light-limited. Consequently, the main energy source for such streams is allochthonous chemical energy contained in litter from riparian areas (Connors and Naiman 1984; Bisson and Bilby 1998). In headwater streams, litter directly supports an animal community comprised predominantly of invertebrate detritivores which, in turn, support a community of invertebrate predators (Wallace et al. 1997). Detritivores, microbes, and physical breakup convert the coarse particulate organic material (CPOM) of litter to fine particulate organic material (FPOM) which is utilized by invertebrate communities downstream (Bisson and Bilby 1998; Richardson and Danehy 2007). Headwaters comprise 60 to 80% of the cumulative length of a watershed's drainage network (Benda et al. 2005); hence, headwaters contribute a substantial amount of chemical energy to mainstem rivers and associated biota. For example, Wipfli (2005) estimated that every kilometer of fish-bearing stream received enough energy from headwaters to support 100 to 2,000 young-of-the-year salmonids.

Carbon cycles through riparian ecosystems via CO₂ uptake from the atmosphere through photosynthesis, litterfall, decomposition and/or consumption. Riparian litter is a critically important source of C for streams as energy for invertebrates and microbes that form the basis of food webs. Deciduous-dominated riparian forests grow quickly and initially deliver more litter to streams and have a more pronounced seasonal litter contribution than coniferous-dominated forests (Hart et al. 2013). Conifers, however, play an important structural role as large wood in streams. Deciduous species like Red Alder can increase fine litter flux and



The main energy source for small headwater streams is allochthonous chemical energy provided by leaf litter/Marc Hayes, WDFW

nutrient delivery to terrestrial and aquatic food webs, thus complementing the year-round shade and wood provided by conifers (Hart et al. 2013).

Chemical energy, required by heterotrophic organisms (those that do not produce their own food from sunlight), is contained within the various C compounds of organic matter. The fundamental effects of organic matter on ecosystem composition, structure, and functions have motivated conceptual theories to describe riverine ecosystems (Pingram et al. 2012). The River Continuum Concept (RCC; Vannote et al. 1980) describes the balance of allochthonous C (produced externally to the stream) to autochthonous C (produced in-stream) in riverine ecosystems from headwaters to mainstem rivers. This balance plays a key role in structuring the invertebrate community. According

to RCC, in narrow headwater streams (first to third order), nearly all C is allochthonous produced by litter from riparian vegetation because shade severely limits the production of autochthonous C produced through in-stream photosynthesis. Because medium-sized streams (fourth to sixth order) are wider, shading decreases, in-stream photosynthesis increases, and the density of litter inputs decreases. Hence, the quantities of allochthonous and autochthonous C may be about equal. In large rivers ($\geq$ seventh order), shading effects only a small portion of surface water, however, turbidity and water depth limit photosynthetic production. Consequently, according to RCC, the main source of energy in large rivers is allochthonous C from upstream. The RCC also posits that the quantity and quality of organic matter, which changes along the river continuum, affects the composition of the aquatic invertebrate community.

Litter from riparian areas is clearly an important source of limiting nutrients and organic matter for aquatic ecosystems. Consequently, providing adequate amounts of litter to streams is an important issue for riparian area management and addressing this issue requires an understanding of litter delivery into streams. FEMAT (1993:V-26) developed a conceptual model, known as the FEMAT curves, that depicts relationships between riparian ecological functions, including litterfall, and distance from a stream channel. Bilby and Heffner (2016) studied factors influencing litter delivery into streams in young and mature conifer forests of the western Washington Cascades and found that litter travel increased with increasing tree height, topographic slope, and wind speed. They estimated that riparian buffer widths needed to capture 95% of annual litter input from mature conifer forests to streams are between 60 to 83 ft (18 to 25 m) depending on a site's slope and wind exposure. The mean tree height of their three mature forest sites was 154 ft (47 m). Hence, riparian buffer widths needed to meet the 95% capture objective range from 39 to 54% of mean tree height.

Bilby and Heffner (2016) warn that they may have underestimated litter travel distances because they released litter from only the bottom of the tree canopy, but litter travels farther with increasing height, and therefore, litter produced within the tree canopy is likely to travel farther.

While stream flows carry organic matter, insects, and other invertebrates downstream to subsidize food webs in higher order streams, there may also be upstream movement of aquatic organisms that subsidizes food webs in lower order streams. In a Welsh mountain stream, for example, amphipods *Gammarus pulex* showed net upstream movement whereas stonefly (*Trichoptera* spp.) females showed no upstream flight preference, but females moving upstream contained twice as many eggs (Dudley-Williams and Williams 1993). In many cases, however, such as with mayflies (family Baetida), seasonal upstream movements of adults via an aerial pathway are pronounced (Hershey et al. 1993). Such upstream movement of nutrients and chemical energy may be important, but has been little studied.

Large wood in stream channels can affect nutrient cycling by slowing the downstream transport of water, sediment, organic matter, and other materials (Chapter 3). Large wood in riparian areas ultimately decomposes, providing nutrients to the forest floor thereby increasing moisture holding capacity (Harmon et al. 1986). Woody material in streams can be a direct source of labile C to streams that can fuel microbial processes, though most C in wood is relatively recalcitrant, taking years or decades to decompose. Wood slows the flow of water thereby extending the residence time of water in the channel and facilitating accumulation of finer organic and inorganic sediments (Chapter 2) that support biofilms.

6.1.3. Nitrogen

Nitrogen is a component of proteins, necessary for all life, and often is a limiting nutrient for both terrestrial and aquatic organisms. N limitation of plant growth is common in PNW forests (Peterson and Hazard 1990). Ultimately, N comes from atmospheric N_2 , which has a very strong triple bond that, aside from lightning and industrial processes, only a few specialized N-fixing organisms can break.

Nearly all N in lotic ecosystems of Washington is derived from allochthonous sources, and in undisturbed headwater watersheds, the source of nearly all N is terrestrial. Nitrogen can enter a river or stream via several pathways: litterfall, movement of soluble N from riparian soils into groundwater and hyporheic zones, and leaching and subsurface transport from upland soils (Compton et al. 2003). Litter may include leaves, leaf fragments, flower parts, fruit, cones, nuts, bark,

branches and twigs (Benfield 1997), however, leaves account for 72% of total litter in broad-leaved forests and 80% in needle-leaved forests (Xiong and Nilsson 1997). Litter may enter surface waters through direct fall, lateral movement along the ground, or mobilization during floods.

For a headwater stream in the western Cascades of Oregon, Triska et al. (1984) found that more than 90% of annual N inputs to the stream were derived from biotic processes in the adjacent forest. Seventy-three percent of N entering the stream was dissolved organic N in water flowing through the subsurface from forest to stream and 21% was contained in organic matter (e.g., leaf litter, needles, and coarse woody debris) from the riparian forest. The headwater stream exported 74% of its annual N inputs to downstream waters; 22% of the exported N was contained in particulate organic matter. Edmonds et al. (1995) found that nitrate concentrations in the waters of an undisturbed watershed were



N-fixation by Red Alder is an important component of nutrient cycling in forests of western Washington and Oregon/Ned Pittman, WDFW

seasonal, with in-stream concentrations being highest in the fall and lowest in the summer when N uptake by terrestrial vegetation was greatest.

Red Alder fixes N₂ and enriches soil with N compounds through root and nodule secretions. Red Alder leaves contain N concentrations roughly 2 to 3.5 times greater than leaves or needles of other tree species (Tarrant et al. 1951). Because aquatic ecosystems in undisturbed watersheds are often N-limited, Red Alder can be a major source of allochthonous N to aquatic ecosystems, and more Red Alder litter can increase ecosystem productivity. For example, Wipfli and Musslewhite (2004) found that headwater streams with more Red Alder canopy cover exported greater biomass of both terrestrial and aquatic invertebrates to fish-bearing waters than riparian areas with less alder. This subsidy of prey from headwaters to fish-bearing streams is needed to maintain fish productivity (Wipfli and Baxter 2010).

Nitrogen cycles in the environment through multiple redox states, in solid, dissolved, and gaseous forms, and originates from multiple sources, making for one of the most challenging biogeochemical cycles to monitor and characterize (Figure 6.3). Shallow groundwater adjacent to stream channels often is a hot spot for N removal processes and a storage zone for other solutes (Hinkle et al. 2001; Zarnetske et al. 2011). The groundwater-surface water interface is characterized by dynamic gradients of dissolved oxygen, N, and organic C concentrations where biogeochemical reactions take place, including metabolism of organic C, denitrification, and nitrification (Sobczak et al. 2003). Denitrification is generally considered the most important biological process through which ecosystems lose N. Denitrification, and disturbances like tree harvest and fire, remove N from an ecosystem, whereas N uptake by plants eventually returns N to the system through litterfall or senescence and subsequent microbial decay. Organic C is required as an energy source for denitrification. Small streams can lose nitrate

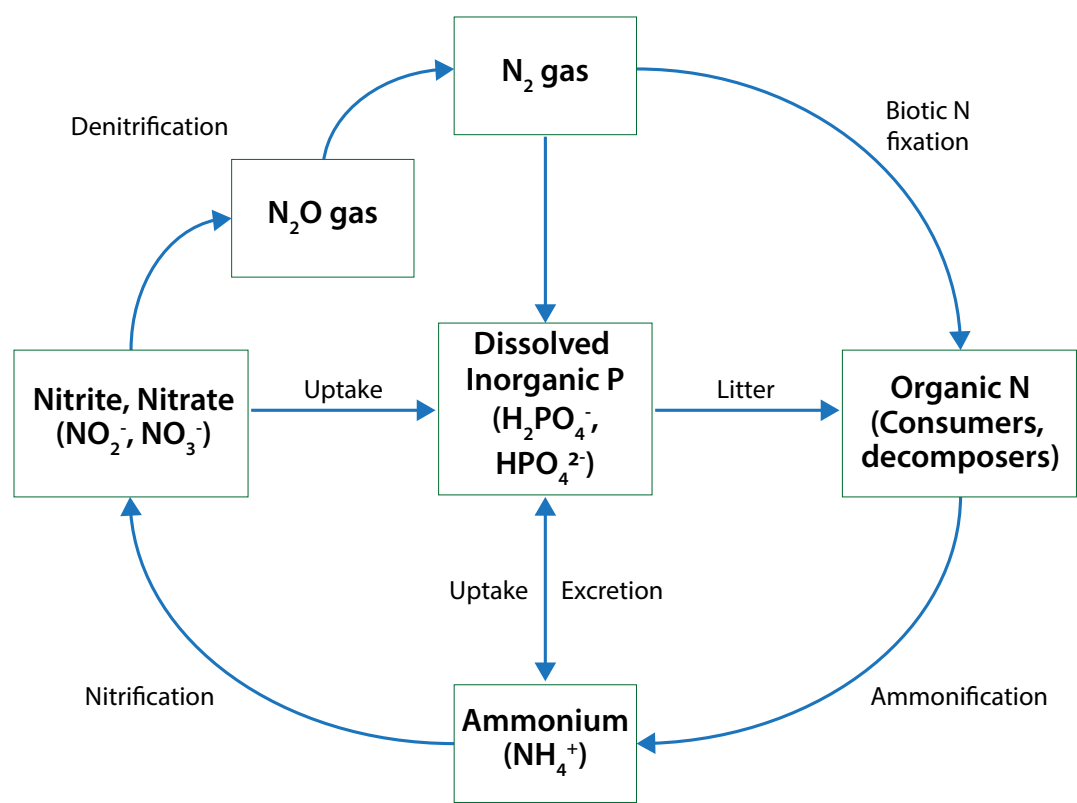


Figure 6.3. Nitrogen cycle pools and processes in ecosystems.

N efficiently because of their high ratio of streambed area to water volume, which brings more surface water in contact with the hyporheic zone. Small streams have a large cumulative influence on N transformation and loss because they account for most of the stream length within a network (Alexander et al. 2000; Peterson et al. 2001). Larger streams lose nitrate N because of longer transport distances over which more biological reactions can occur that consume N coupled with longer water residence times and higher N concentration which fuels the denitrification along with organic C (Mulholland et al. 2008).

Increased groundwater-surface water interaction can alter dissolved oxygen concentrations and redox conditions (Striz and Mayer 2008; Zarnetske et al. 2012), transporting N- and C-containing organic matter to microbes in subsurface sediments, leading to N loss via denitrification under favorable oxidation-reduction conditions (Hedin et al. 1998). The conditions that favor denitrification may change rapidly over time and space. Therefore, "hot spots" may form where denitrification occurs in small patches of the stream (e.g. under leaf packs) or "hot moments" where denitrification rates are high but for short periods of time due to rapid dynamic water movement (McClain et al. 2003; Vidon et al. 2010). However, biochemical processes in urban riparian soils such as denitrification may be impaired because of increased rates of erosion and limited groundwater-surface water interaction due to high proportions of impervious surfaces (Groffman et al. 2002).

The importance of riparian vegetation on transforming N inputs has been examined (Sweeney et al. 2004; Mayer et al. 2007; Sweeney and Newbold 2014). Riparian area characteristics such as width of vegetation, soil carbon, and hydrologic flowpaths, can influence the amount of N removed. Mayer et al. (2007) surveyed the available scientific literature containing data on riparian management and N concentration in streams and groundwater to identify relations between N uptake and riparian width, hydrological flow path, and

vegetative cover. Removal efficiencies ranged from <0 (i.e., where the riparian ecosystem appeared to be a N source) to 100%, with a median removal rate of 91%. Wide vegetated riparian areas (>165 ft; 50 m) more consistently removed significantly higher proportions of N entering riparian areas than narrow bands of vegetation (0 - 82 ft; 0 - 25 m). The critical conclusions from this review were that riparian areas were effective at trapping and removing N when they were vegetated, wider, and allowed for subsurface movement of water where the interaction of nutrients dissolved in the water had prolonged contact with soils. Therefore, the hydrologic connection of riparian areas and streams is key to effective nutrient capture. Where channels are incised, riparian areas tiled for drainage, or where floodplains are disconnected via reinforced banks or channelization, nutrients will flow downstream with little interaction with riparian areas.

Subsurface hydrology (saturated vs. unsaturated soil conditions) and redox condition appear to be significant determinants of N-removal efficiency, regardless of vegetation (Mayer et al. 2007; Mayer et al. 2010b). When the water table fluctuates in response to precipitation events, buried relict hydric soil may become saturated, producing sub-oxic or anoxic conditions (Hefting et al. 2004; Weitzman et al. 2014), facilitating N removal. Where flow paths move through wetland riparian soils, great potential exists to remove large quantities of N in proportion to the loads (Jordan et al. 2011); where flows occur via deeper groundwater dynamics or via tile



*Riparian vegetation: Red Elderberry *Sambucus racemosa*/ Ned Pittman, WDFW*

drainage, N in solution may bypass the C-rich riparian soils and flow through zones where less potential exists for nutrient removal (Wigington et al. 2005). Hydrologic connectivity between riparian areas and streams is a critical factor in determining N removal rates.

Denitrification rates in the stream channel are linked to the organic C content of benthic sediments, respiration rates, and extent of stream water interaction with the streambed (Alexander et al. 2000; Mulholland et al. 2008), conditions that can be fostered by woody material (e.g., sticks, branches or tree trunks), and debris dams in streams. Woody material may function as microsites or hotspots of elevated biogeochemical cycling including denitrification (Groffman et al. 2005), and provides substrates for bacteria and fungi, which in turn consume N in streams (Ashkenas et al. 2004).

Biofilms are a matrix of algae, bacteria, and fungi embedded in a slick polysaccharide film that coats hard substrates in streambeds. These microbial communities consume, respire, and reduce inorganic N (Mulholland et al. 1995). Physical habitat heterogeneity and the biodiversity of the biofilms influence N uptake (Cardinale et al. 2002; Cardinale 2011). Biofilm structure, composition, and capacity for biogeochemical cycling are influenced by substrate composition, light penetration, nutrient concentration, flow rates, seasonality, sediment composition, and the community of invertebrate grazers in the vicinity (Sabater et al. 2002). Biofilms formed on wood substrates have been found to have higher respiration rates and greater N demand than biofilms developed on rock substrates (Sabater et al. 1998). Lazar et al. (2014) found that biofilms on wood substrates in a forested stream had significantly higher denitrification rates than those on non-organic substrates such as stone. In an old-growth forest system in Oregon, aquatic mosses and biofilm on large wood showed the highest N uptake rates among biota while, both vertebrate and invertebrate consumers took up substantial amounts of N, especially small invertebrate grazers (Ashkenas et al. 2004).

Furthermore, N in the stream was transported to the upland through uptake by terrestrial plants, likely through long, subsurface flow paths, demonstrating a strong link between terrestrial and aquatic systems (Ashkenas et al. 2004).

In addition to the biofilms on the streambed, microbial communities within the hyporheic zone can be hotspots for N dynamics. At the HJ Andrews Experimental Forest in Oregon, Zarnetske et al. (2011) found that the hyporheic zone was an important site for N dynamics in small forested streams, with residence time determining the dominance of different N transformation processes. Water pathways with residence times of less than 7 hours tended to be dominated by DO and DOC use as well as ammonium and nitrate production, while pathways with longer residence times removed N via denitrification. Further modeling suggested that water residence times and oxygen uptake rates of microbes are important determinants of whether hyporheic zones are net sources or sinks of nitrate N (Zarnetske et al. 2012). In large rivers like the Willamette, hyporheic zones can be important areas for nitrate removal from regional groundwater prior to entry into surface flow (Hinkle et al. 2001), as well as important for N removal and cooling as water moves in and out of hyporheic areas on its path downstream (Fernald et al. 2006).

The relationships between land use and N transport and fate can be complex, and are mediated by aquatic and riparian biota. Sobota et al. (2012) showed that N uptake differs substantially across forested, agricultural, and urban streams in the Willamette River basin in Oregon. Most nitrate N in forested streams was transported downstream without being taken up. N storage was high in algal biomass in unshaded agricultural and urban streams but turnover and subsequent recycling back to the stream may ultimately be high (Sobota et al. 2012). Collectively, this work indicates that uptake via heterotrophic organisms living on large wood is critical to long-term N capture in forested streams. Once the canopy is opened up, autotrophic algal production

becomes a more important process for uptake of excess nutrients, which leads to shorter-term storage and potential for negative consequences associated with freshwater algal blooms.

6.1.4. Phosphorus

Phosphorus (P) is an important component of adenosine triphosphate (ATP) and necessary for energy transformations in plant and animal cells. Like N, low P availability often limits primary production on land and can be particularly limiting to productivity in freshwater. This is because P tends to form complexes and be retained in soils and thus does not move as readily into ground and surface waters from the landscape as does nitrate N. P cycles in the environment through multiple organic and inorganic forms (Figure 6.4). P occurs in the environment in organic forms (e.g., organo-phosphate and polyphosphates like ATP) in plant and animal biomass, sewage, and pesticides. Inorganic forms of

P, such as phosphate (PO_4^{3-}), and orthophosphate, are biologically reactive and thus can be used directly by plants and microorganisms (Carpenter et al. 1998). Orthophosphate is derived from phosphate-bearing minerals, fertilizers, detergents, and industrial chemicals. In the Pacific Northwest, bedrock is the major source of stream P loads, with fertilizer, manure, and wastewater inputs important in some locations (Wise and Johnson 2011). Overabundance of P can result in abnormally high primary production in water, leading to water quality problems such as algal blooms, production of cyanotoxins, and low oxygen events (Carpenter et al. 1998; Jacoby and Kann 2007).

P is commonly a limiting nutrient in aquatic ecosystems because it is highly insoluble and has an affinity for binding to soil particles. Nevertheless, riparian areas are sources of allochthonous P to streams in undisturbed watersheds. The amount of P that is contributed by riparian areas to aquatic habitats through litterfall

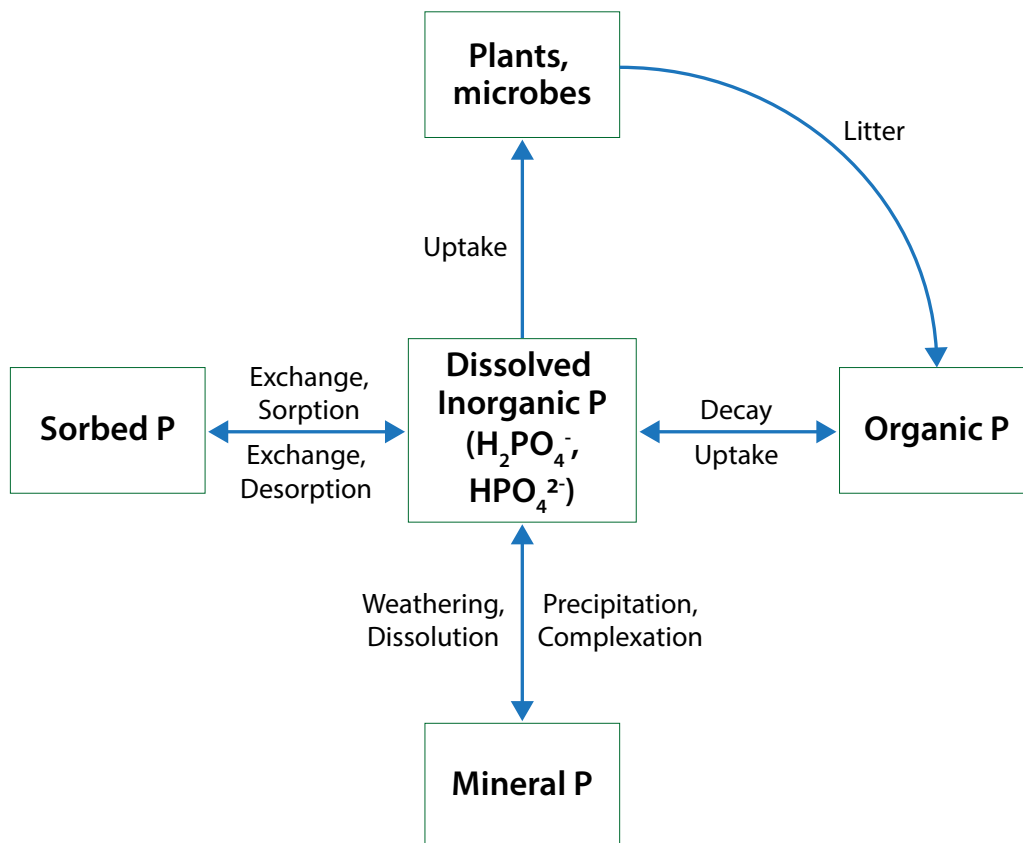


Figure 6.4. Phosphorus cycle pools and processes in ecosystems.

relative to other sources under natural, undisturbed conditions has yet to be quantified for riparian ecosystems in the Pacific Northwest.

P attenuation refers to declines in P concentration in water and soil through physical, chemical, and biological processes. Mineral content and pH are important factors determining P attenuation in soil. Because of their volcanic origins and the weathering environments, many soils in the PNW can bind tightly to large quantities of anions like phosphate, replacing reactive soluble P forms for particulate P forms, which are less biologically reactive (Johnson and Cole 1980; Bohn et al. 1985). Sorption, the chemical attachment of molecules to soil particles, may occur quickly (e.g., days) and includes adsorption and substitution between P and other anions on mineral surfaces. Sorption may also occur slowly (e.g., weeks), such as mineral dissolution and precipitation reactions between P and soil cations such as Ca and Mg or Al, Fe, and Mn oxide compounds depending on soil pH (Bohn et al. 1985). Phosphate is most soluble in slightly acid to neutral pH soils. Under reducing conditions, Fe is reduced and the P-Fe oxide compounds may dissolve, thereby releasing P (Denver et al. 2010). Minimally disturbed forests have a relatively tight P cycle, with low inputs from precipitation, and even lower leaching rates (Yanai 1992; Compton and Cole 1998). In the volcanically influenced soils of the Cascades, most of the ecosystem P is contained in soil, and organic and inorganic forms of sorbed P are the dominant forms as opposed to primary minerals or microbial P (Compton and Cole 1998). There is substantial recycling of P by plants and soil and biotic release of organic P via phosphatase enzyme activities is an important component of this cycle (Giardina et al. 1995). Several studies have shown that Red Alder increases rates of P cycling (Giardina et al. 1995; Zou et al. 1995), further supporting the important role that Red Alder plays in regulating both N and P nutrient cycles of the PNW. Vegetated riparian areas generally are expected to retain P by slowing water flow and by plant and microbial uptake.

Unlike N, which is ultimately constrained by atmospheric fixation and regulated by biologic cycling, P availability is controlled by weathering and a complex set of chemical and biological processes. P retention is regulated by the equilibrium P concentration (EPC), the concentration at which P sorption equals desorption (Hoffmann et al. 2009). Once soil P has reached its sorption capacity, excess P may be exported in water (Domagalski and Johnson 2012). Biological processes also play a role in P attenuation and release (Schechter et al. 2013). Bacteria, fungi, algae, and plants incorporate P into biomass; however, plants vary in P demand and uptake effectiveness, exhibiting numerous strategies for sustaining growth and maintenance (Shen et al. 2011). P is released from organic matter through decomposition, which is dependent on pH, litter quality (C:N:P ratios), Ca content, redox potential, soil moisture, and temperature (Schechter et al. 2013). Increases in P loading as well as soil disturbance and erosion have the potential to reduce this generally tight P cycle and increase transfer to aquatic ecosystems (Figure 6.2).

Microbial and plant uptake represent short-term, transient P pools (Richardson and Marshall 1986). Phosphate may be assimilated into plant tissues or in microorganisms but released upon death and senescence. Peat accumulation and P sorption and precipitation are important long-term P sequestration mechanisms (Richardson and Marshall 1986; Reddy et al. 1995). Long-term storage of P depends on sorption to inorganic sorbents; P sequestration is mainly associated with adsorption to Fe and Al oxides in acidic soils or precipitation of Ca phosphates in alkaline soils (Giesler et al. 2005). Phosphorus retention mechanisms differ widely depending on hydrological pathway through the riparian area. Sorption and desorption reactions are more important during subsurface flow, while sedimentation of particulate P may be the major retention mechanism during overland flow. Significant amounts of P can be stored in stream sediments and may be resuspended and released during storms. Retention of total P in riparian areas is controlled

mainly by sedimentation processes, dependent on morphology (e.g., width) and vegetation characteristics. However, riparian areas can become a net source of dissolved P released from soil or from plant material (Hoffman et al. 2009). Retention of dissolved P in riparian areas is often not as significant as retention of particulate P (Hoffman et al. 2009). Inundation of riparian areas or floodplains can deposit particulate P whereas plant uptake may temporarily immobilize P (Hoffman et al. 2009). Overall, riparian ecosystem retention efficiency varies widely and some riparian areas may become sources of P, especially orthophosphate (Schechter et al. 2013). Total P moving through the soil is not necessarily related to the width of the riparian area but rather on flow path and soil types (Hoffman et al. 2009; Schechter et al. 2013).

6.2. Hydrologic Connectivity and Nutrient Dynamics

Nutrients cycle at various spatial and temporal scales. Soils, vegetation, and water flows largely dictate the sources and processing of nutrients. Nutrients may enter the riparian ecosystem from the atmosphere (e.g., nitrogen oxides produced from fossil fuel combustion or ammonia released from agricultural areas), from terrestrial sources when rainwater flushes nutrients from upland soils and vegetation, or from floods that

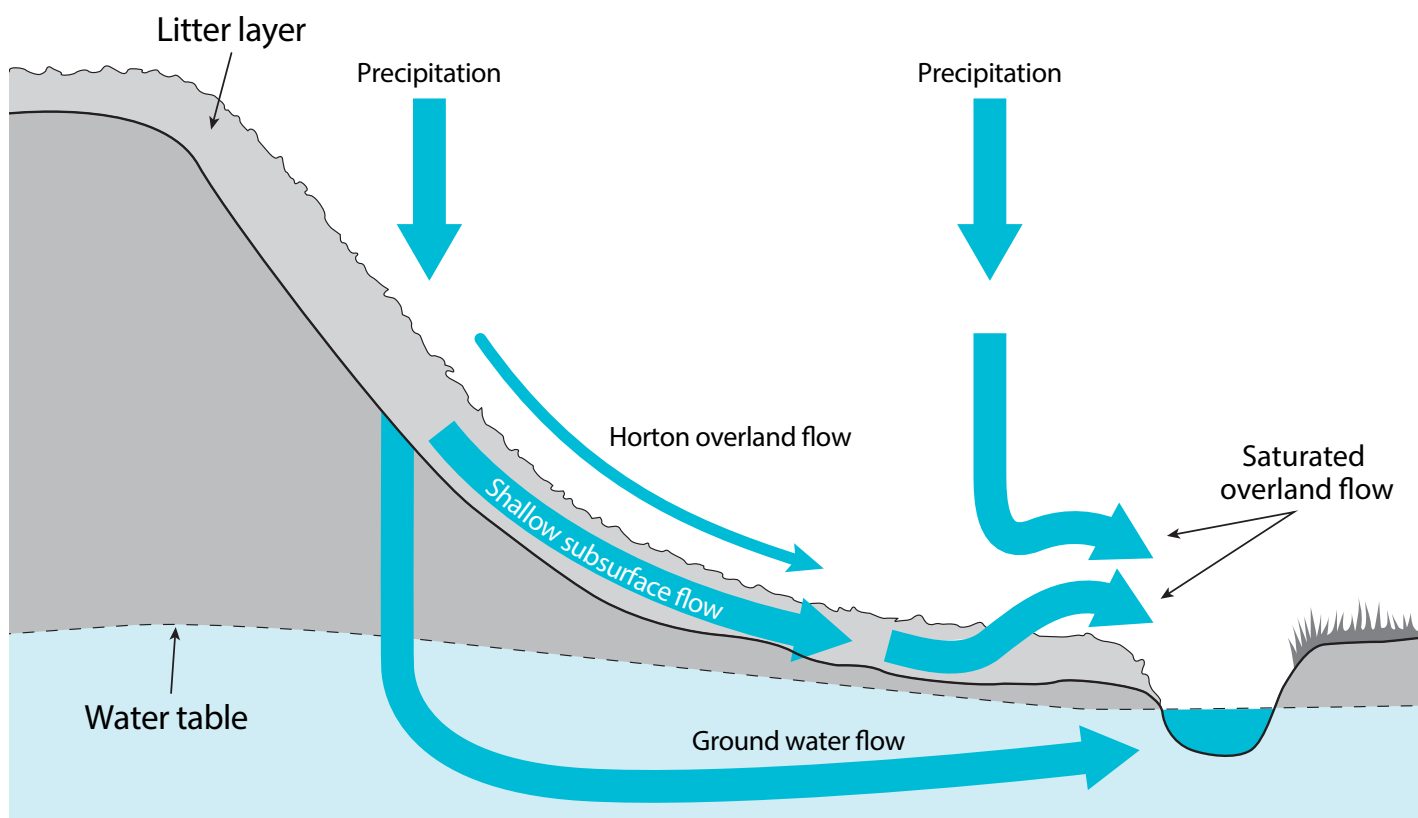


Figure 6.5. Water flow paths. Precipitation reaches a stream as surface runoff and by infiltration into the ground where it contributes to groundwater flow. The amount of water following each flow path depends on the capacity of the soil to absorb water, the amount of storage in surface depressions, and the amount, intensity, and duration of precipitation (image adapted from Stream Corridor Restoration Handbook; FISWRG, 1998).

bring in nutrients from upstream areas (Figure 6.5). As water moves downstream, it moves into and out of the hyporheic zone, carrying with it dissolved nutrients that react with the sediments and biota living in the interstitial spaces of the sediments (Fernald et al. 2006). Wondzell (2011) suggests that hyporheic exchange is likely to be most important in small streams but that hyporheic exchange through sand-bedded streams is substantial and may have an important influence on nutrient loads of large rivers. Regardless, large fractions of N are removed via denitrification in hyporheic sediments at all scales from headwater streams to large rivers (Peterson et al. 2001; Mulholland et al. 2004; Alexander et al. 2007).

Hydrology is the driving force for a range of physical and biogeochemical processes controlling retention and flux of nutrients entering the riparian ecosystem (Chapter 2). Nutrients may originate from neighboring areas via local flow systems throughout the riverscape, from regional groundwater flow systems, especially along reaches of the higher stream orders, or from a recirculation of river water in riparian areas during flooding (Dahl et al. 2007). Depending on flood intensity and frequency,

water may overflow the streambanks and move into the floodplain where sediments may be deposited or, conversely, litter, woody material, and sediments may be mobilized and transported into the main channel.

Discharge volume, stream flow velocity, and temporal variability in flow, coupled with nutrient concentrations dictate the mass loading of each nutrient flowing downstream. Headwater streams commonly make up 75% or more of the total stream channel length in drainage basins (Benda et al. 2004) and have a disproportionately profound influence on the water quality and quantity for downstream ecosystems (Peterson et al. 2001). Alexander et al. (2007) found that fluxes from first-order headwater streams accounted for 70% of water volume and 65% of the N flux occurring from second-order streams. Research comparing perennial, intermittent, and ephemeral stream nutrient cycling processes indicates that flow intermittency can affect the concentrations, fluxes, and forms of nutrients moving from streams into downstream ecosystems (Von Schiller et al. 2011).

In western Oregon and Washington, floodplains experience extremes in water and sediment flux (Naiman et al. 2010). Floodplains often have saturated soils and shallow, upwelling groundwater. Such wet conditions influence N processing by creating anoxic, denitrifying conditions in organic soil horizons (Burt et al. 2002). However, many floodplains of the PNW are highly altered by human activities and are often artificially disconnected from the stream channel via levees constructed to convert lands to agriculture or other uses. Subsequently, nutrient exchange during flood events between aquatic and riparian ecosystems, via both mobilization and deposition of dissolved and suspended organic matter, is severely altered. River restoration often focuses on reconnecting floodplains and associated riparian areas to stream channels in order to restore natural hydrology and re-establish nutrient cycling functions (Bernhardt et al. 2005; Craig et al. 2008). The hydrologic interactions of uplands and

Many floodplains in the Pacific Northwest are highly altered by human activities and are often artificially disconnected from stream channels by levees. Subsequently, natural flooding processes and nutrient exchange, both deposition and production, are severely altered often with negative consequences to riparian habitat.

riparian soils control nutrient cycling and transport (Mayer et al. 2007; Weitzman et al. 2014). Therefore, it is critical to maintain riparian vegetation and to control soil erosion and nutrient runoff from uplands (Mayer et al. 2007; Hoffman et al. 2009; Zhang et al. 2010; Sweeney and Newbold 2014).

Impacts to riparian ecosystems may include historic events not well documented and not easily recognized today. Such impacts may lead to erroneous understanding of baseline conditions or misidentification of pristine areas. For example, recent research suggests that legacy sediments, referring to sediments deposited in floodplains from historic upland erosion in response to deforestation and construction of milldams and ponds, have altered nutrient cycling in riparian ecosystems throughout the mid-Atlantic region of the US (Walter and Merritts 2008; Merritts et al. 2011). Much of the fine sediment carried by these streams during storms is from streambank erosion,

which often includes legacy sediments, thereby contributing substantially to sediment and nutrient loads in streams (Gellis and Noe 2013). While milldams may not have been as common in the Pacific Northwest, splash dams created to move logs downstream were common throughout the region historically until the mid-20th century (Phelps 2011). These dams and other historic logging activities may have altered riparian systems in ways not easily recognized today but which may have had a significant legacy effect on sediment deposition in floodplains. For example, splash dam releases exceeded the effects of 100-year flood events in headwater regions and were comparable to 100-year flows in lower reaches (Phelps 2011). Splash dams also may have contributed to simplification of stream channels when rocks and debris jams were removed to facilitate log transport (Sedell and Luchessa 1981; Wohl 2000). Overall, the long-term effects of splash dams are not well documented nor are they accounted for in current riparian assessments.



South Fork Sauk River/Wendy Cole, WDFW

Precipitation and runoff are master variables regulating transport and transformation of C, N, and P in watersheds (Dosskey et al. 2010; Vidon et al. 2010). The interaction between land use and climate variability can increase the amplitude and frequency of nutrient pulses, effecting rapid and large changes in concentrations and fluxes of materials (Kaushal et al. 2014). Shifting patterns in runoff and temperature due to land use and climate variability can amplify pulses of greenhouse gases (GHG) such as CO₂, CH₄, and N₂O emanating from watersheds (Kaushal et al. 2014). For example, Vidon et al. (2014) showed strong N₂O pulses in response to storm events in a riparian wetland. Warming increases production of some GHGs in wetlands (Inglett et al. 2012) because temperature affects reaction kinetics and equilibria. Higher stream temperatures may increase rates of both bacterial consumption of nutrients and production of GHGs in streams and rivers (Kaushal et al. 2014). Recent research shows that groundwater may also warm in response to climate (Menberg et al. 2014).

Most N and P enters receiving waterbodies during storm events and during cooler seasons when temperatures are lower than optimal for microbial activity (Kaushal et al. 2010) or when plants are senescent. During drought, residence times may be long, leading to more denitrification in riparian soils, however N loads may be small overall because stream flow may be much lower than normal (Mayer et al. 2010b; Filoso and Palmer 2011). However, drought may also lower moisture levels in riparian soils, potentially reducing the occurrence of anoxic conditions required for denitrification (Groffman et al. 2003). Conversely, high flow conditions during “flashy” storm events may greatly compromise nutrient retention processes (Booth 2005) flushing far more solutes downstream including N and P (Cooper et al. 2014). Consequently, high flows are also responsible for the vast majority of particulate C, N, and P transport in most streams (Alexander et al. 2000; Moore and Wondzell 2005).

Stream channel geomorphology and geologic setting, especially stream channel width, depth, and sediment lithology strongly influence groundwater behavior. In turn, nutrient movement in riparian ecosystems is dependent upon groundwater, which can be highly variable and follow preferential flow paths. Striz and Mayer (2008) showed that groundwater movement may shift considerably depending on seasonal precipitation trends. Streams may be gaining, that is, receiving water from the uplands when precipitation is high, or losing surface water to the ground when soils are dry and drought conditions prevail. Water movement through deep groundwater flow paths back to the stream can take years or decades (Hinkle 2009) and in some cases there is very little exchange with regional deep groundwater (Vaccaro 2011).

Mass removal of nutrients and contaminants in streambed sediments is dependent upon residence times because microbial processes, such as denitrification, require time for complete reaction (Zarnetske et al. 2012). Nutrient concentrations in soils and water may vary on time scales across minutes and hours as plants or algae take up nutrients. Yet, seasonal and annual cycles are also evident based on flow and temperatures. Nutrients may also vary on spatial scales of millimeters to meters depending on plant distribution or litter deposition, and can also vary at regional and global scales depending on land use, geomorphology, and precipitation patterns.

A better understanding of the role hyporheic connections play in the processing of nutrients will improve our ability to design riparian management strategies that protect water quality.

6.3. State of Riparian Nutrient Dynamics Science

Recent advances in stream nutrient research reveal spatially and temporally variable processes and resulting pulses of nutrient transformation, storage, and release that can differ among locations and through time at the same locations. We also know that freshwater and riparian ecosystems vary tremendously across the PNW based on soils, climate, organisms, and human activity. Because most stream nutrient research originates from case studies, the application of case study results to novel conditions should be done cautiously.

Most studies of riparian nutrient dynamics have been conducted in forested watersheds; grassland and desert ecosystems in our region are less well studied but share some common processes and dynamics. Much of the information provided here demonstrates that riparian areas can have important effects on nutrient transfer from land to water, which subsequently have implications for ecosystem goods and services (e.g., water for drinking, swimming, fishing, boating, etc.) and habitat conditions for aquatic species.

Generally, if the goal of riparian management involves nutrients, management should include efforts to shorten nutrient spiraling lengths, increase nutrient retention, provide substrates to support riparian food webs, and maintain natural shading in order to minimize algal blooms. However, stimulating algal and plant growth is one way to shorten nutrient spiraling lengths by enhancing nutrient uptake, at least temporarily as nutrients will be returned after senescence. A longer-term goal of riparian management is to avoid excessive nutrient delivery to streams. Maintaining riparian



The larvae of many caddisfly species use silk to make protective cases, which are often strengthened with gravel, sand, and twigs/
Ned Pittman, WDFW

vegetation, soil conditions, and flowpaths, etc. will facilitate the removal of nutrients from surface and subsurface flow before entering the channel. If nutrient input is successfully controlled, light levels promoting algal blooms become much less of an issue.

Some of the critical gaps in our understanding occur where physical sampling for detecting water and material movement is most difficult. This occurs in the soil subsurface, the streambed, and hyporheic zones where determining flow dynamics requires multiple sampling wells (Striz and Mayer 2008) or surrogate measures such as stream temperature (Stonestrom and Constantz 2003). A better understanding of the role hyporheic connections play in the processing of nutrients will improve our ability to design riparian management strategies that protect water quality (Hinkle et al. 2001; Zarnetske et al. 2011, 2012), particularly by expanding these studies to better

represent the range of conditions in Washington. However, the use of stable isotopes of N, P, C, and also O and H in water have helped to illuminate some of the more obscure processes like water movement into and out of trees (Brooks et al. 2010) and the uptake of N along entire stream reaches (Ashkenas et al. 2004). Satellite monitoring data (e.g. GRACE) and lidar imaging, which can provide high-resolution topographic data for inaccessible areas, are proving to be valuable tools for the study of nutrient dynamics at the watershed scale. Drone technology may eventually further provide local and current information on condition and environmental variables. Coupling these new data sources with the development of powerful computer models (e.g., VELMA) that predict watershed-scale nutrient movement (Abdelnour et al. 2011; Abdelnour et al. 2013) will greatly enhance our ability to extrapolate field level data to watershed scales and to test land use riparian management scenarios and climate change impacts on nutrient cycling behavior.

6.4. The Role of Management

Litter from riparian areas is clearly an important source of limiting nutrients and chemical energy for aquatic ecosystems. Inorganic nutrients, such as those in artificial fertilizers, do not mimic the foodweb role of litter because inorganic nutrients feed the autotrophic components of foodwebs, such as algae. Litter feeds heterotrophic components of foodwebs, such as benthic macroinvertebrates, many of which are prey for resident salmonids and juvenile salmon. Consequently, providing adequate amounts of litter to streams is an important issue for riparian area management. The results of Bilby and Heffner (2016) suggest that 95% of full litter delivery to streams can be achieved with buffer widths between 40 to 60% of site-potential tree height, depending on site

conditions. Numerous factors dictate the transport and fate of nutrients through riparian systems. Managing riparian systems to limit negative impacts of nutrients on downstream resources is inherently complex. The role of management is largely to offset the impacts of human activities that increase nutrient loads and runoff, exacerbate the impacts of nutrients, and/or alter the fluxes of nutrients. Table 6.1 identifies impacts of human activities in the context of factors influencing riparian areas and describes practical management and restoration approaches that are known to mitigate nutrient impacts. The primary objective with respect to offsetting nutrient impacts among all categories of land use is to maintain existing riparian systems, restore degraded systems, and plant riparian buffers where they do not currently exist. Overall, management should focus on where in the watershed important nutrient dynamics that affect aquatic system integrity (or fish life) occur, and how to reduce or ameliorate various human disturbances that can affect nutrient dynamics at those places.

Although salmon runs and associated nutrient fluxes have declined over time in Oregon, Washington, Idaho, and California (Gresh et al. 2000), salmon could still play an important role in stream ecosystems by greatly increasing the quantity of salmon carcasses planted in streams or by greatly increasing harvest escapement (Gende et al. 2002). Addition of inorganic nutrients will not mimic the food web role of salmon in PNW watersheds because they do not directly mimic the complex organic matter from salmon carcasses supplied to heterotrophs such as aquatic insects and juvenile salmonids (Compton et al. 2006). Maintaining structures, such as large wood, and processes that retain nutrients are expected to allow greater utilization of salmon-derived nutrients in aquatic food webs.

Table 6.1. Major factors influencing nutrient dynamics in riparian ecosystems and the role of management in reducing impacts

Factors influencing riparian areas	Impacts of human activities	Role of management in reducing impacts
Land use - agriculture	Excess nutrient application and leaching into groundwater and surface water	Improve nutrient management to reduce nutrient loading - right time, right place, right source, right rate (4Rs)
	Compaction and vegetation damage from poor livestock management near streams	Protect and restore riparian areas to attenuate sediment and nutrient loads
	Riparian disturbance or lack of natural vegetation in riparian area	Protect and restore riparian areas to reduce light inputs that drive algal overproduction and eutrophication
Land use - urbanization	Impervious surfaces increase nutrients and sediment transfer to surface waters	Disconnect direct runoff from impervious surfaces to streams to control nutrient and sediment inputs
	Increased nutrient application via yard fertilizer and pet waste	Educate the public and incentivize behaviors to reduce nutrient loads
	Leaky and ineffective sewer and septic systems	Improve sewer systems, sewage treatment, storm drainage, and septic systems
Land use - forestry (harvest and road building)	Small increase in nutrient loadings	Seek alternatives to clear cutting and protect riparian areas
	Small to moderate increase in sediment transport	Seek alternatives to clear cutting; improve harvest practices, slope and soil management, and road construction; and protect riparian areas
Forest age and composition	Recent clear-cuts may lose the most nutrients	Extend harvest rotations because mature forests likely retain more nutrients than young forests
	Red Alder fixes large amounts of N, which remains in the system and contributes to productive soils of the Coast Range and western Cascades mountains	Recognize the role that Red Alder forests can play in stream nutrient levels
Climate and seasonality	Rapid movement of water during fall and winter rains, sometimes bypass riparian zones	Slow water movement across the landscape
	Rapid N cycling during the summer but low flows mean this inorganic nitrogen accumulates in the soil, fall rains displace this N and transport it to streams	Consider timing of fertilizer applications
	Spring season usually has peak algal blooms because nutrient supplies are high as is light availability before full leaf out.	
	Slower processing of nutrients in cold weather, although conifer trees take up nutrients year round	
Elevation and topography	Steep slopes lead to higher rates of runoff and sediment transport	Minimize disturbance to vegetation and soils on steeper slopes through forest and pasture management

Table 6.1. CONTINUED
Major factors influencing nutrient dynamics in riparian ecosystems and the role of management in reducing impacts

Factors influencing riparian areas	Impacts of human activities	Role of management in reducing impacts
Hydrology	Reduced connection between the channel and floodplain can limit nutrient uptake	Reconnect flood plains to increase water residence times, which can increase ground water-surface interactions and nutrient uptake
Nutrient concentrations, forms, and inputs	High concentration and multiple sources of bioavailable nutrient forms may overload capacity of riparian systems to process nutrient loads	Consider terrestrial versus atmospheric sources; carefully manage synthetic fertilizer and manure applications, and balance N and P
Soil properties and geology	Low permeability reduces infiltration and interaction with soils	Practice good soil management because rich, fertile soils can contribute organic carbon for denitrification
	Sandy soils can transmit more water and nutrients (e.g., pumice soils and septic systems)	Recognize that some soils are better at adsorbing P (e.g., volcanic and highly weathered soils)
Biota	Declines in salmon runs reduces supply of nutrients and organic matter for invertebrates, birds, mammals, and other fish	Restore salmon populations, which increases nutrients in ecosystem: nutrients are assimilated by vegetation, consumed by animals, and converted by microbial processes

6.5. Conclusions

Riparian areas are important sources and sinks of organic matter and nutrients for streams. Numerous sources of C, N, and P exist, each taking various organic and inorganic forms, and each moving through the environment continuously along multiple paths at various temporal and spatial scales. Transfers may be via subsurface flow, direct input of materials via litterfall, treefall, or animal movement. Nutrient and energy subsidies from riparian areas to streams and rivers have profound effects on the composition, structure, and functions of aquatic ecosystems.

In watersheds where excess nutrients are polluting surface waters, hydrology and flow paths are critically important when considering potential for nutrient removal by riparian areas. If a riparian area is physically disconnected from the stream, flow paths may not carry materials through the riparian area, particularly

into the hotspots with appropriate conditions for denitrification, and thus N removal will not occur as readily. Thus, maintaining hydrologic connections between riparian areas and stream channels are critical. This includes allowing natural seasonal patterns of flow including flooding.

Historically, many watersheds in Washington have seen substantial inputs of salmon-derived N, P, and organic matter. Riparian areas serve as the critical connection for transferring these nutrients to uplands via animal consumption, plant uptake, and biogeochemical cycling.

Results of a large review of riparian ecosystem studies across the globe indicated that vegetated riparian areas were more effective in trapping N than unvegetated ecosystems, but that the type of vegetation did not matter tremendously. Wider riparian areas were more effective in N removal across studies (see Chapter 5).

N-fixation by Red Alder is an important component of nutrient cycling in forests of western Washington and

Oregon. In the PNW, deciduous riparian forests tend to produce more litter with higher nutrient content and nutritional quality for stream food webs than conifer riparian areas. However, conifers have a longer lifespan, produce larger wood and are a more consistent source of shade. In riparian areas with a mixture of deciduous and conifer trees, deciduous species enhance litter flux and nutrient delivery to terrestrial and aquatic food webs, thus, complementing the provision of shade and large wood by conifers. Both the food web and structural roles of tree species should be considered in riparian management plans in order to support aquatic production.

Structurally diverse habitats with variability in geomorphology and soils are likely to support correspondingly diverse biota including vegetation, animals, and microbial communities that will be best able to process and assimilate nutrient loads. Headwaters are especially controlled by riparian processes and thus, are important zones of active nutrient processing that can significantly affect downstream transport of nutrients. Therefore,

maintaining riparian areas in headwater systems may be disproportionately important to stream function. Similarly, maintaining hydrologic connection of streams with their floodplains is important because rich, organic sediments are deposited on floodplains during flood events. Conversely, channelization and stream incision from erosion disconnects streams from their floodplains, causes flashy flows, further incises stream channels while starving floodplains of regular resupply of organic matter, and can lower groundwater tables below the rooting zone thereby contributing to the reduction of riparian vegetation in arid climates.

While more research will be necessary to answer important questions about nutrients in riparian ecosystems, the science is very clear about the importance of the condition of riparian areas on the flows of nutrients through stream systems. Riparian areas and their streams are much more than conduits for nutrients from the uplands to downstream systems; they are vitally important locations for the short- and long-term supply, storage, and transformation of nutrients.



Perennial fruiting bodies, or conks, of a polypore fungi/Ned Pittman, WDFW

6.6. Literature Cited²

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Big Creek Trail/Rachel Blomker, WDFW



Chapter 7. Riparian Areas of the Columbia Plateau

By: George F. Wilhere

This chapter is dedicated Karin Divens who passed away unexpectedly on 12 October 2017. Karin made a significant contribution to this chapter by organizing a two-day, multi-disciplinary workshop that advanced our scientific understanding of riparian areas in the Columbia Plateau Ecoregion. Karin was an effective and well-respected habitat biologist at WDFW, who brought not only science to her work but a full heart.

7.1. Introduction

The Columbia Plateau Ecoregion (sensu Omernick 1987),¹ is classified as a cold desert (Sleeter 2012), and covers about one-third of Washington State (Figure 7.1). In the driest parts of the ecoregion, a rain shadow cast by the Cascades Mountains limits precipitation to 6 to 9 in (15 to 23 cm) per year, and even wettest parts of the ecoregion, the Palouse Hills Subregion, receive only 18 to 23 in (46 to 58 cm) per year (Bryce and Omernik 1997). Uplands of the Columbia Plateau are covered by either shrub-steppe or steppe² vegetation (i.e., sagebrush and bunchgrass communities, respectively), and, most notably, lack trees (Franklin and Dyrness 1988). The ecoregion's desert climate confines nearly all trees to riparian areas.³

Seventy-five years ago Daubenmire (1942) wrote, "The vegetation of the unforested regions in the Pacific

Northwest has been less thoroughly studied and is consequently less perfectly understood than is that of the forested areas." The situation has not changed. Most of what is known about riparian areas in the Pacific Northwest is based on research conducted in forested ecoregions. During my review of the scientific literature, I found far less information about the composition, structure, and functions of riparian ecosystems in unforested ecoregions, such as the Columbia Plateau, than I found for forested ecoregions. However, many of the basic principles and qualitative relationships that have emerged from research in forested ecoregions are also valid in unforested ecoregions. For instance, while there are significant quantitative differences among ecoregions in the amount of wood or shade provided by riparian areas, the physical processes of large wood recruitment and stream shading should be very nearly the same. On the other hand, processes that are strongly affected by groundwater, such as nutrient dynamics and pollutant removal, should be different. To clarify current

¹ There are several different delineations of ecoregions (e.g., USFWS 1994; Bailey 1995; Olson et al. 2001). For this report WDFW used the ecoregions of Omernick (1987). The only non-forested ecoregion in Washington is the Columbia Plateau. Forested ecoregions surrounding the Columbia Plateau in Washington are the Eastern Cascades, North Cascades, Okanogan, Northern Rockies, and Blue Mountains.

² Steppe is also referred to as grassland or prairie. The steppe region of southeastern Washington is called the Palouse.

³ A notable exception is the Juniper Dunes Wilderness Area, which preserves the northernmost Western Juniper Trees *Juniperus occidentalis* in North America. This 7100-acre area contains no surface water.



The amount of rain received by the Columbia Plateau Ecoregion each year is insufficient to support trees in the uplands/Justin Haug, WDFW



Figure 7.1. Boundary (in red) of the Columbia Plateau Ecoregion. State boundaries are white. Aerial photography for Washington State done in 2015 by the National Agriculture Imagery Program.

scientific understanding, throughout this chapter I point out differences between riparian areas in forested and unforested ecoregions.

The Columbia Plateau Ecoregion is comprised of both arid and semi-arid subregions (hereafter collectively known as drylands). Due to lack of information, I make few subregional distinctions regarding riparian areas. Most of what is known about the ecology of

dryland riparian areas is based on research conducted in desert ecoregions of the southwestern United States (Patten 1998). Although these ecoregions have climate, hydrology, soils, and vegetation different from the Columbia Plateau, many of the basic principles and qualitative relationships that have emerged from research in other desert ecoregions should be valid for the Columbia Plateau.

7.1.1. Dryland Riparian Areas

Decades ago, the term “riparian” referred exclusively to areas adjacent to surface waters with moist soils that support distinctive vegetation (e.g., Thomas et al. 1979, Anderson 1987). Later definitions expanded the meaning of riparian. Sedell et al. (1989) and Naiman et al. (1992), for example, divided the “riparian ecosystem” or “riparian area” into two zones: a “riparian zone” with moist soils supporting wetland and riparian-dependent vegetation, and an upland “zone of influence” that significantly influences the exchanges of energy and matter between terrestrial and aquatic

ecosystems (Figure 7.2). In forested ecoregions, the potential vegetation of both zones is commonly forest, and the ecological functions of the zones are similar. In the Columbia Plateau, vegetation within riparian ecosystems often exhibits an abrupt demarcation between the two zones. Phreatophytic⁴ trees and shrubs and hydrophytic⁵ herbaceous plants are confined to moist streamside areas, but the upland zone of influence may consist of sagebrush or bunchgrass communities. Consequently, the functions of the two zones may be quite different. Along some reaches, the riparian zone and zone of influence may both reside within a floodplain and exhibit similar composition and structure. For our purposes, the phrases riparian ecosystem and riparian area are synonymous.

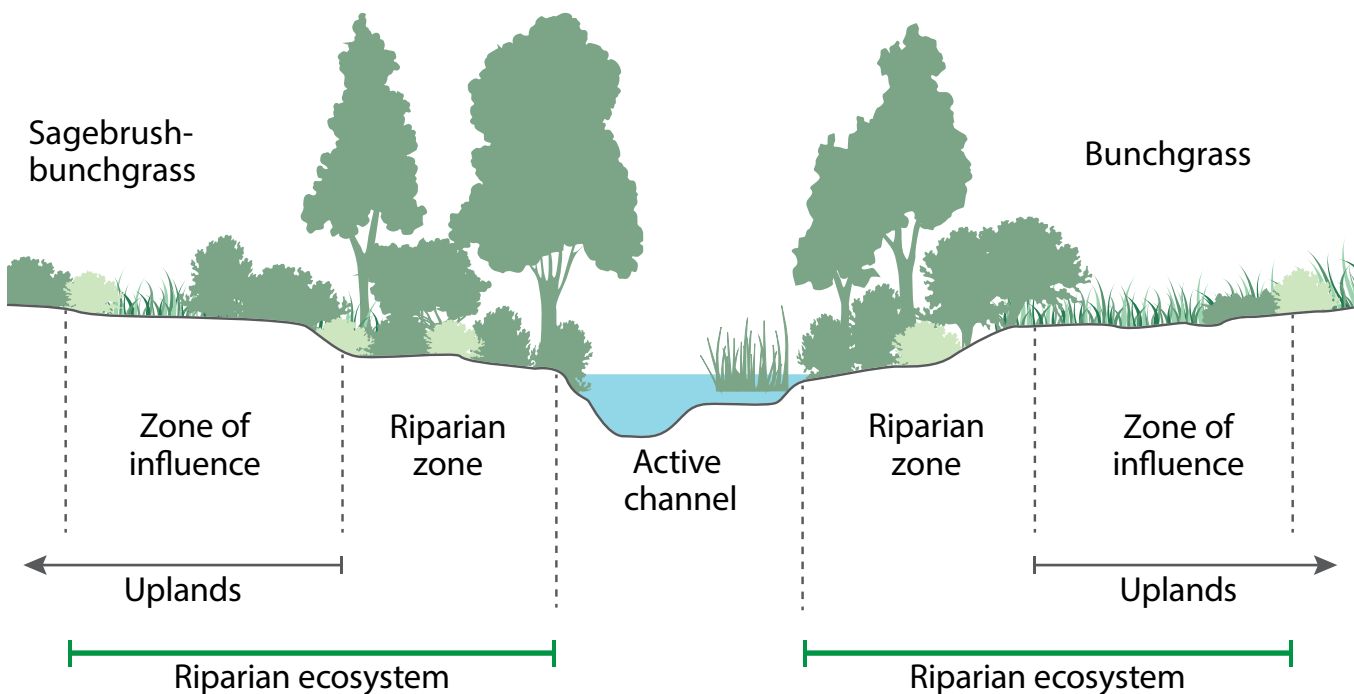


Figure 7.2. Dryland Riparian Ecosystem. The riparian ecosystem consists of two zones: riparian and zone of influence. The riparian zone extends from the edge of the active channel towards the uplands. This zone includes areas where terrestrial biota are influenced, at least periodically, by surface or subsurface waters. Beyond this is the riparian “zone of influence.” This includes areas where ecological functions significantly influence the stream (diagram modified from USFS 2004).

⁴ A phreatophytic plant is a species that obtains water from the subsurface zone of saturation either directly or through the capillary fringe (Thomas 2014).

⁵ Hydrophytic plants are those that are adapted to growing conditions associated with periodically saturated soils. They include obligate wetland plants that almost always occur in wetlands under natural conditions, facultative wetland plants that usually occur in wetlands but are occasionally found in non-wetlands, and facultative plants that equally likely to occur in wetlands or non-wetlands (Lichvar et al. 2012).



In the semi-arid Columbia Plateau Ecoregion, trees are generally confined to riparian areas/Scott Fitkin, WDFW

In dryland ecoregions, riparian ecosystems are the ultimate expression of groundwater and surface-water interactions (Webb and Leake 2006). Soil moisture and water table elevation are key variables in the survival of riparian-dependent plants. Stream discharge affects soil moisture by saturating soils and recharging the alluvial aquifer during overbank flooding, and stream stage (i.e., surface elevation) directly affects water table elevation.

In dryland ecoregions, trees and dense shrubs exist only near surface water, such as a river, stream, or lake. In the Columbia Plateau, surface streamflow is highly dependent on its source. Rivers and perennial⁶

streams generally originate in the adjacent mountainous ecoregions (Omernik and Gallen 1986), and their peak flows, if unaffected by dams, generally occur during fall or winter storms and/or during spring snowmelt (Reidy Liermann et al. 2012). Within the Columbia Basin, the flow source of most streams is groundwater (Reidy Liermann et al. 2012), and consequently, during the hot, dry summer, many streams originating within the ecoregion are intermittent (Daubenmire 1942; Bryce and Omernik 1997). This spatial and temporal variability in local hydrology affects the distribution, abundance, and species of plants in dryland riparian areas.

⁶ A perennial stream is one which flows continuously. An ephemeral stream, or section of stream, is one that flows only in direct response to precipitation. It receives no water from springs and no long-continued supply from melting snow or other surface source. An intermittent stream is one that flows during protracted periods when it receives water from some surface or subsurface source, such as melting snow or a spring (Meinzer 1923).

The diversity⁷ of riparian climax plant communities in the Columbia Plateau Ecoregion is greater than the diversity in surrounding forested ecoregions. In forested ecoregions, the potential natural vegetation of nearly all riparian areas along rivers and streams is forest. The species composition may vary, but the climax community's structure ultimately attains a closed-canopy of trees, with the upland zone of influence most often dominated by conifer species. In the Columbia Plateau, differences in hydrology and geomorphology manifest substantial site-level differences in composition and structure of riparian vegetation (Hough-Snee et al. 2015). A rudimentary classification system based on overstory conveys obvious differences in vertical structure: tall tree, short tree, tall shrub, shrub, grass-like, grass, and forb (Figure 7.3; Crawford 2003). The main tall tree types have an overstory consisting of Black Cottonwood *Populus trichocarpa*, White Alder *Alnus rhombifolia*, or Quaking Aspen *Populus tremuloides*. Short tree types have an overstory of Thinleaf Alder *Alnus incana*, Water Birch *Betula occidentalis*, or Black Hawthorn *Crataegus douglasii*.⁸ Tree vegetation types are usually multi-layered with shrub and herbaceous layers under the tree canopy. Common shrubs are Redosier Dogwood *Cornus sericea*, Common Snowberry *Symphoricarpos albus*, Lewis' Mockorange *Philadelphus lewisii*, and Woods' Rose *Rosa woodsii*. Tall shrub vegetation types include those dominated by willow species (e.g., Yellow *Salix lutea*, Sandbar *S. exigua*) which can be up to 20 ft (6 m) tall.

The structural diversity of riparian vegetation in the Columbia Plateau causes differences in site-level functions. Large wood recruitment, for instance, cannot occur in all riparian areas, and the amount of stream shading will vary considerably due to site-to-site variation in vertical structure.



The most diverse and productive biological communities of the Columbia Plateau are riparian areas/Rex Crawford, WNHP



Nearly all woody vegetation in riparian areas of the Columbia Plateau consists of deciduous shrubs and trees/Scott Fitkin, WDFW

⁷ Measures of biological diversity take into account two factors: species richness (i.e., the number of different types) and evenness (i.e., the relative abundance of different types). While the richness of riparian climax plant communities in forested ecoregions may be comparable to that of dryland ecoregions, the relative abundance of different riparian climax plant communities is more even in dryland ecoregions. This results in a greater diversity of types.

⁸ Black Hawthorn might also be considered a tall shrub. Crawford (2003) reported Black Hawthorn in riparian areas to be 6 to 20 ft (2 to 6 m) tall, and Daubenmire (1970) found Black Hawthorn up to 27 ft (8 m) tall.



Figure 7.3. Different riparian vegetation structure types: A) tall tree, B) short tree, C) tall shrub, D) shrub on an intermittent stream, E) grass-like, F) forb/Rex Crawford, WNHP

7.2. Historical Context

Because western Washington and Oregon have a substantial amount of national park, wilderness, and roadless areas, the scientific literature contains many descriptions of unmanaged, natural riparian areas within forested ecoregions (e.g., Fonda 1974; Campbell and Franklin 1979; McKee et al. 1982; Sedell and Swanson 1984; Pabst and Spies 1999; Latterell and Naiman 2007; Fox and Bolton 2007). In the Columbia Plateau Ecoregion, however, nearly all riparian areas have been significantly impacted by human land use (grazing, intensive agriculture), resource exploitation (Beaver *Castor canadensis* trapping, timber harvest), water management (dams, diversions, reservoirs), or invasive species (Reed Canary Grass *Phalaris arundinacea*, Russian Olive *Elaeagnus angustifolia*). Daubenmire wrote in 1942, “few typical remnants of the original prairie and desert remain. These relics of the primeval vegetation likewise seem to be heading toward nearly complete extermination within a few years . . .” In short, the conditions of natural riparian areas in the Columbia Plateau Ecoregion are effectively unknown to science.

7.2.1. Beaver Trapping

The first major ecological impacts of Europeans on riparian areas in the Columbia Plateau Ecoregion were due to American Beaver (hereafter Beaver) trapping. In the early 1800s, Beaver hats were very fashionable and in high demand across Europe. The Hudson’s Bay Company was determined to profit from that demand, and to obtain Beaver skins it managed a network of forts or trading posts throughout the Pacific Northwest (and throughout western North America). Several were established in and around the Columbia Plateau:

Spokane House at the mouth of the Little Spokane River in 1810; Fort Okanagan at the confluence of Okanagan and Columbia rivers in 1811; a temporary post from 1812 to 1813 near confluence of Snake and Clearwater rivers; Fort Nez Percés⁹ near the Walla Walla and Columbia rivers’ confluence in 1818; and a temporary post at The Dalles from 1829 to 1830 (Meinig 1968). Most Beaver skins traded at these forts were obtained from the surrounding forested ecoregions.

Fort Nez Percés was situated near the center of the Columbia Plateau, and its district, which was delineated by The Dalles to the west, Priest Rapids to the north, and the Deschutes, John Day, and Grande Ronde watersheds to the south, was considered poor “fur country.” Nevertheless, between 1827 and 1831 about 1,150 Beaver skins per year were traded at Fort Nez Percés (Meinig 1968). During that period, the number of Beaver skins traded per year at Fort Nez Percés dropped by 50%. Given the locations of trading posts and the high demand for Beaver skins, if Beaver could be trapped profitably in the Columbia Plateau, then they probably were. North of the Columbia Plateau, Beaver were also heavily exploited, and impacts to Beaver populations are indicated by trends in Beaver skins. The number of Beaver skins traded at the Hudson’s Bay Company’s Fort Colville (founded in 1825) dropped precipitously from 3600 per year in 1826 to 438 per year in 1850 (Johnson and Chance 1974).

The Hudson’s Bay Company’s annual Snake Country Expeditions operated out of Fort Walla Walla (formerly Fort Nez Percés). One goal of these expeditions was to create a “fur desert” which was intended to discourage America’s westward expansion into lands controlled by Great Britain (Lorne 1993). George Simpson, the Hudson’s Bay Company’s governor at Fort Walla Walla, wrote in 1824, “. . . we have convincing proof that the country is a rich preserve of Beaver and which for

⁹ In 1818 the North West Company opened a fur-trading post near the mouth of the Walla Walla River at the current location of Wallula, Washington. Originally called Fort Nez Percés, it was renamed Fort Walla Walla when the North West Company and the Hudson’s Bay Company merged in 1821 (Denfeld 2011).

political reasons we should endeavor to destroy as fast as possible" (Ott 2003). In 1825 the trapper Peter Ogden and his party collected 3,577 Beaver skins in the Crooked River watershed, a semi-arid portion of the neighboring Blue Mountains Ecoregion, and on two subsequent expeditions trapped more Beaver in this area (Buckley 1993). During the 1825 expedition, Odgen noted that the Crooked River's tributaries were well lined with willows and aspen. By 1910, if not sooner, Beaver had been eliminated from some tributaries of the Crooked River, and the willow and aspen had vanished (Buckley 1993). The eradication of Beaver from dryland riparian areas is thought to have caused a cascade of adverse effects upon riparian ecosystems that I discuss in Section 7.3.

7.2.2. Open Range Grazing by Livestock

Open-range grazing by livestock was the next major ecological impact of Europeans in the Columbia Plateau Ecoregion. Around 1730, Native Americans on the Columbia Plateau acquired horses descended from those brought by Spanish explorers (Carlson 1940). In 1805, Lewis and Clark saw about 700 horses in one Indian village and thousands more in the nearby hills (Galbraith and Anderson 1971). Daubenmire (1970) believed that while most villages were on rivers, the impacts to riparian vegetation by horses were probably not extensive. A few cattle were brought to the Okanogan Valley in 1825 and to the Walla Walla Valley in 1834 (Carlson 1940). By 1855, roughly 200,000 cattle inhabited the Columbia Plateau of Washington (Daubenmire 1970). Sheep herding developed in the 1880s (Daubenmire 1970), and great numbers of sheep were brought to eastern Washington in 1892 (Galbraith and Anderson 1971). By the late 1800s, damage to rangeland from overgrazing was evident. Based on his 1893 expedition from Spokane to Steven's Pass, the botanist John Leiberg wrote, "We will never know the complete flora of these regions. Sheep and cattle are

rapidly destroying the native plants and by the time private explorations reach these regions the flora will have been totally exterminated by such agencies" (as cited in Mack 1988; Weddell 2001).

Open-range management of livestock invariably results in excessive utilization of riparian areas (Ohmart 1996), and the destructive impacts of unmanaged grazing in riparian areas are well-documented (Kauffman and Krueger 1984; Ohmart 1996, Belsky et al. 1999). Riparian areas in arid and semi-arid lands of the western United States cover only 1 to 2% of land area, but produce 20% of available forage and nearly 80% of forage actually consumed by cattle (Fisher 1995). Therefore, it is reasonable to assume that the damage observed by Leiberg was greatest in riparian areas.

Restoration projects can indicate the density of woody plants that existed historically in riparian areas prior to intensive livestock grazing. For example, two years after the cessation of grazing within riparian areas in northeastern Oregon, the mean crown volume of willows and Thinleaf Alder tripled in size and that of Black Cottonwood increased nine-fold (Case and Kauffman 1997). Furthermore, shrub density increased by 50%. One possible reason for the severe impacts of grazing in the Columbia Plateau is that, unlike the Great Plains, Bison (*Bison bison*) have been rare or absent from the Columbia Plateau for close to 10,000 years (Jones 2000). According to Daubenmire (1970) and also Mack and Thompson (1982), ungulates played no significant role in the evolution of plant species in steppe and shrub-steppe communities of the Columbia Plateau, and consequently present-day vegetation cannot endure intensive grazing by livestock.

The impacts of both Beaver trapping and open-range livestock grazing may have acted synergistically to degrade riparian areas. Baker et al. (2005) suggest that Beaver and willow (*Salix* spp.) are mutualists because willow is an important food source for Beaver, and Beaver create environmental conditions suitable

as willow habitat. Baker et al. (2005) believed this relationship can persist indefinitely within a given area. They also speculated that heavy browsing by native ungulates or livestock disrupt the Beaver-willow mutualism, thus leading to degradation of the riparian ecosystem. Ohmart (1996), based on personal observation, suggested that overgrazing by livestock causes an imbalance in the Beaver-vegetation relationship that leads to collapse of riparian forests. A similar relationship has also been observed in Yellowstone National Park (Beschta and Ripple 2016) where decades of intensive grazing by Elk *Cervus canadensis* during the absence of Wolves *Canis lupus* resulted in riparian plant communities that could no longer support Beaver. The reintroduction of Wolves has led to a recovery of Beaver in Yellowstone (Beschta and Ripple 2016).

Today in the Columbia Plateau Ecoregion, the most severe impacts from grazing are caused by wild or feral horses (hereafter collectively known as wild horses). Until the mid-1900s, wild horses inhabited open rangelands in various parts of the Columbia Plateau. Today wild horses are confined to Native American reservations where the number of wild horses has fluctuated greatly over the past 140 years. The reservation of the Yakama Nation, for instance, supported roughly 16,000 horses in 1878, but a round up in 1957 left 300 horses on the reservation (Adams 2004). By 2010, the number of horses had rebounded to 12,000 (YN 2010), but the current carrying capacity of the Yakama Nation's reservation is only about 1,000 horses (Mapes 2010). Consequently, wild horses have destroyed rangelands, cultural resources, and wildlife habitats, including riparian areas (NTHC, no date). Wild horse populations also exceeded the carrying capacities of the Colville and Umatilla reservations (AP 2012; Tribal Tribune 2013). Effective management of wild horses on Native American reservations has been hampered by continual controversy regarding the most practical and ethical means of reducing their population sizes.

7.2.3. Wood Harvest and Wheat

The Donation Land Claim Act of 1850 and Homestead Act in 1862 were major impetuses for settlement of Oregon and Washington states. Settlers needed wood for fuel and construction. On the Columbia Plateau the closest source of wood, and in some places the only practical source, was riparian areas. Historians have little information on wood harvest in riparian areas by early settlers on the Columbia Plateau, however, the practices of pioneers and settlers on the Great Plains, as described by West and Ruark (2004), are likely to be similar to their practices on the Columbia Plateau. West and Ruark (2004) state that pioneers on their way west stripped virtually all trees from the Platte River valley, that riparian areas on the Great Plains were an important source of winter fuel for settlers, and that by 1900 most of the trees in riparian areas of the Great Plains had been harvested. Daubenmire (1970) speculated that Black Cottonwood, the largest tree species in the Columbia Plateau, was much more abundant before the arrival of settlers.

Impacts of Beaver trapping and open-range livestock grazing may have acted synergistically to degrade riparian areas. Baker et al. (2005) suggest that Beaver and willow are mutualists because willow is an important food source for Beaver, and Beaver create environmental conditions suitable as willow habitat.

River commerce on the Columbia and Snake rivers may have also impacted riparian areas. By 1859, steamboats were travelling upriver as far as Wallula, Washington and could reach Lewiston, Idaho at high water (Meinig 1968, cited in Evans 1989). Historians do not know how much wood was burned to power steamboats in the Columbia Basin, but estimates from other western watersheds suggest severe impacts to riparian forests along the Columbia and Snake. On the upper Missouri River in Montana, for instance, riparian forests along its banks were denuded of usable trees by the turn of the century (Evans 1989).

The soils and climate of the Palouse Hills subregion are suitable for dryland wheat agriculture. Consequently, the next major impact to riparian areas was converting native vegetation to wheat. The first wheat was planted in 1877, by 1895 most of the tillable land in the subregion had been plowed (Kaiser 1961), and

during the 1970s industrial agriculture expedited the destruction of the last refugia for native plant communities (Black et al. 1998). Agriculture in the Palouse Hills had four major impacts on riparian areas, which were all poorly documented: 1) fields were plowed to the very edge of streambanks, thereby destroying riparian vegetation, 2) many ephemeral channels were plowed through and filled (Kaiser 1961; Bryce and Omernik 1997), 3) perennial and intermittent stream channels became deeply incised (Rockie 1939), and 4) some channels were filled with sediment from soil erosion (Rockie 1939; Bryce and Omernik 1997). Rockie (1939) reported a Nez Percé Indian telling him that some dry channels in the Palouse Hills were once perennial streams containing trout. According to Bryce and Omernik (1997), the original channel substrate, riparian vegetation, and flow regime (i.e., perennial or intermittent) are impossible to know in areas of intensive agriculture.



The least arid subregions of the Columbia Plateau support productive grasslands/Alan Bauer

7.2.4. Large-scale Irrigation Projects

Across the Columbia Plateau, the most obvious human impacts to native habitat types, including riparian areas, are those associated with irrigation projects. The U.S. Bureau of Reclamation manages two major projects on the Columbia Plateau, the Yakima and Columbia Basin, which service about 1,135,000 acres (459,318 ha) of farmland (USBR 2017a; 2017b). Another 37,000 acres (14,973 ha) are irrigated with water impounded by dams on the Snake River (USACE 2002). All 1.17 million acres (473,482 ha) of irrigated farmland were once shrub-steppe or steppe vegetation. However, these projects did not record how many acres of riparian area have been lost because ephemeral or intermittent stream channels were filled for agriculture or converted to irrigation ditches.

Construction of the Yakima Project began in 1906, and the last of 11 dams on the Yakima River or its tributaries was completed in 1939 (USBR 2017a). The Yakima Project's biggest impacts to riparian areas are along the Naches and Yakima rivers. Storage reservoirs and water diversions located upstream have truncated the rivers' natural hydrographs. This has substantially reduced river-floodplain interactions, such as inundation and lateral channel migration, which in turn have led to channel simplification and degraded aquatic and riparian habitats (Snyder and Stanford 2001; YSPB 2004).

Construction of the Columbia Basin Project began in 1933 with Grand Coulee Dam, and the first irrigation water was delivered in 1952 (USBR 2017b). The Columbia Basin Project includes a network of canals, drains, and wasteways over 5,800 miles (9,334 km) long. The reservoir behind Grand Coulee Dam, Lake Roosevelt, inundated roughly 84 miles (135 km) of riparian habitat within the Columbia Plateau Ecoregion

along the Columbia, Spokane, and Sanpoil rivers.¹⁰ Roughly 460 miles (740 km) of the Columbia River lie within the Columbia Plateau Ecoregion, but only 51 miles (82 km) of riparian habitat, the Hanford Reach, have not been inundated by reservoirs. When the dams were built, there was apparently some hope that vegetation would re-establish along new reservoir margins, but water level fluctuations appear to be too extreme for most plants to tolerate (Evans 1989). The other major impacts to riparian areas from the Columbia Basin Project are dramatic changes in hydrology. The groundwater table around lower Crab Creek, for instance, has risen between 50 and 150 ft (15 and 46 m) since 1952. Furthermore, the formerly intermittent lower Crab Creek is now perennial with four to five times the flow that occurred prior to irrigation (KWA 2004), and, as a consequence, willow species, which are adapted to the natural hydrologic regime, no longer regenerate along lower Crab Creek (Ortolano and Cushing 2000). In contrast, due to groundwater withdrawals, the groundwater table around upper Crab Creek (the Odessa subarea) has fallen 150 ft (46 m) (KWA 2004). I found no records on how the water table changes may have affected stream flow in upper Crab Creek.

Decades of hydrological alteration by dams and water diversions have altered vegetation composition and structure of riparian areas. Black Cottonwood and willow are successional pioneers that require barren sediments of disturbed alluvial floodplains for seedling germination (Patten 1998). Such conditions are produced by floods, but dams reduce peak flows and the erosive forces that scour sediments. Furthermore, the survival and growth of Black Cottonwood seedlings is highly dependent on water table elevation and its seasonal rate of change (Braatne et al. 1996). If the water table declines more rapidly than seedling root growth, then seedlings die. Braatne et al. (2007), for example, found that dams on the Yakima River created

¹⁰ Estimated with Google Earth. Distance estimated along Spokane River comports with that reported by Ortolano and Cushing (2000).

hydrological conditions unsuitable for Black Cottonwood seedlings. They studied river reaches near Cle Elum, Union Gap, and Wapato and found: 1) no seedlings in any reaches, 2) Black Cottonwood stands less than 25 years old were extremely limited, 3) riparian areas were dominated by older age classes, and 4) altered hydrology promoted invasion of the floodplain by exotic tree species such as Silver Maple *Acer saccharinum*, Norway Maple *Acer platanoides*, and Chinese Elm *Ulmus parvifolia*. Hence, one could confidently infer that historical conditions have been altered by regulated flows. If artificial flow regimes are not changed, then as older individuals senesce and die, cottonwoods may be eliminated from some sections of the Yakima River. This would have adverse effects on multiple riparian area functions: streambank stability, shading, large wood recruitment, and detrital nutrients. Exotic tree species currently found along the Yakima River cannot provide the same ecological functions as Black Cottonwood because they cannot establish themselves in the barren, saturated sediments of recently disturbed floodplains.

Dams have also altered the flow of wood through watersheds. Historically, wood was transported from forested headwaters to dryland reaches of rivers and streams. This process is known to have occurred in other semi-arid and arid regions of the United States.

"We will never know the complete flora of these regions. Sheep and cattle are rapidly destroying the native plants and by the time private explorations reach these regions the flora will have been totally exterminated by such agencies."

- Botanist John Leiberg, 1893

Minckley and Rinne (1985) present historical evidence for the movement of large wood in desert rivers of the American southwest: wood originated in forested headwaters, moved sporadically through desert riparian areas during flood events, and was ultimately deposited at the mouth of the Colorado River in Mexico. Minckley and Rinne (1985) identified interception of large wood by dams as a major cause of large wood reduction in semi-arid and arid river basins. At artificial reservoirs in eastern Washington, such as Keechelus, Kachess, Cle Elum, Easton, Bumping, Clear, and Rimrock lakes, large wood that could potentially interfere with dam operations is removed and burned (W. Meyer, Washington Department of Fish and Wildlife, personal communication; B. Renfrow, Washington Department of Fish and Wildlife, personal communication). Large wood in dryland sections of the Wenatchee and Okanogan rivers may be effected in this way as well. How wood management at dams and smaller water diversions affects in-stream large wood in eastern Washington has not been investigated.

7.2.5. Invasive Non-native Plants

An ongoing historical anthropogenic impact is the introduction of exotic invasive plant species. After their botanical survey of the Columbia Plateau in 1893, Sandberg and Leiberg were not troubled by the meager abundance of exotic species at that time (Mack 1988), however, by 1929 about 200 exotic species were known to exist on the plateau (Mack 1988). Riparian areas in dryland landscapes are more vulnerable to invasion by exotic plant species than adjacent upland areas (Loope et al. 1988; Hood and Naiman 2000), and invasive plants in riparian areas can impact a variety of ecological processes: hydrology, sediment dynamics, nutrient dynamics, and species competition. Two invasive species of particular concern are Reed Canary Grass and Russian Olive.¹¹

¹¹ Other invasive species of concern in the Columbia Plateau Ecoregion are Crack Willow *Salix fragilis*, Yellow Flag Iris *Iris pseudacorus*, and Purple Loosestrife *Lythrum salicaria*.

Reed Canary Grass occurs as both exotic and indigenous strains (Tu 2006). The European cultivar has been present in the Pacific Northwest since the 1880s (Stannard and Crowder 2001), and, as of 2016, it is found in all Washington counties except Douglas (WSDA 2016). Reed Canary Grass forms dense stands that can exclude all other plant species, and such stands exhibit substantially higher transpiration per unit ground surface area than other species (Gebauer et al. 2015). This could alter water availability in riparian areas. Reed Canary Grass also has higher roughness values than native sedge species (Martinez and McDowell 2016). This could lead to greater sediment deposition and channel narrowing.

As of 2016, Russian Olive is found in most counties east of the Cascade crest and is most common in Grant County (WSDA 2016). In the late 1800s, it was introduced into the Pacific Northwest as an ornamental plant (Giblin 2006), but the species did not become prominent outside cultivated areas until two to five decades later, depending on location. Unlike many tree and shrub species in dryland riparian areas, Russian Olive does not require disturbed soils for germination. Hence, it can grow on sites where woody vegetation would not naturally occur (Katz and Shafroth 2003). It is also shade tolerant, and consequently, Russian Olive can establish beneath the canopy of native riparian trees or shrubs and compete with them for resources. Russian Olive exhibits about two times higher transpiration per unit basal area than cottonwood trees (Hultine and Bush 2011). This could alter water availability in riparian areas. The species is a nitrogen fixer that adds nitrogen to the soil. Tuttle et al. (2016) found that stands of Russian Olive had higher exotic plant ground cover than stands of native tree species, and they believed that the difference was due to higher available soil nitrogen that benefited fast growing exotics plants. Finally, according to Lesica and Miles (1999), Beaver foraging behavior indicates that Russian Olive is much less palatable than native cottonwood. They found that 77% of cottonwood trees along a river in Montana were damaged by Beaver

but only 22% of Russian Olive trees were damaged. If Russian Olive replaces native cottonwood, then Beaver population density could be adversely affected.

7.2.6. Value of a Historical Perspective

Current scientific understanding of riparian ecosystems in the Columbia Plateau Ecoregion is mostly based on present-day conditions, which are unlikely to accurately represent historical composition and structure. History indicates that past human impacts in the Columbia Plateau may have erased fully functioning riparian ecosystems from many watersheds. For example, records of the U.S. Army cavalry at Fort Simcoe on the Yakama Indian Reservation from the 1850s describe small valleys with broad floodplains dissected by multi-threaded stream channels that are absent today. These valleys—such as the Wenas, Ahtanum, and Cowlitz—historically contained a network of streams, wetlands, and Beaver ponds that supported extensive groves of willow, Redosier Dogwood, Black Cottonwood, and aspen. Cattle were said to be lost for weeks in these tangles (P. Harvester, Washington Department of Fish and Wildlife, personal communication). These same streams are now reduced to a single, incised channel with minimal riparian vegetation. The loss of riparian habitats indicated by the Fort Simcoe records is very likely to have occurred in other parts of the Columbia Plateau.

Rivers and streams of the Columbia Plateau Ecoregion have been degraded by a variety of human activities. This has adversely affected anadromous salmon—their populations are threatened with extinction and fisheries produce a small fraction of historical harvest. In response, salmon habitat restoration projects are occurring throughout the Columbia Plateau. Habitat restoration requires ecological reference information to determine site-level restoration potential, establish desired conditions, and formulate measures of success

(White and Walker 1997). Ecological reference information is generally based on historical conditions, natural areas, or minimally disturbed sites (White and Walker 1997; Stoddard et al. 2006; Higgs et al. 2014). In the Columbia Plateau Ecoregion, which lacks national parks, wilderness, or roadless areas containing natural reference sites, historical information may be the only basis for reference conditions (Wohl 2005).

Because the Columbia Plateau lacks undisturbed watersheds, even small ones, ecologists have a poor understanding of the composition, structure, and functions of natural riparian ecosystems. Historical reconstruction using journals of early explorers and naturalists, General Land Office survey notes, and historical drawings or photos (Figure 7.4) are ways to develop qualitative descriptions of riparian plant



Figure 7.4. Historical drawings and paintings can provide invaluable information for riparian area restoration. A 1847 painting by Paul Kane of Upper Palouse Falls (top) shows extensive, uninterrupted small tree or tall shrub vegetation along the river banks. A recent photo by Jack Nisbet (bottom) although taken in winter, shows large gaps in small tree or tall shrub vegetation along the banks.

communities (McAllister 2008). Much work needs to be done on deducing the likely historical conditions of riparian areas in the Columbia Plateau. Studies of historical conditions in the Columbia Plateau, however, must be cognizant of one important caveat. If hydrology of a riparian area has been significantly altered by human activity, then the vegetation that site supported historically may have no relationship to the vegetation the site is capable of supporting now. Irrigation systems have altered hydrology in riparian areas throughout the Columbia Plateau, making some drier and others wetter. At such places, information on historical vegetation will often be of little value in establishing desired future conditions for restoration.

7.3. Beaver

Beaver may play an essential role in the restoration and future conservation of dryland riparian areas (Dremmer and Beschta 2008; Pollock et al. 2014). The ecosystem benefits of Beaver in dryland riparian areas have been known for over 80 years. Scheffer (1938) reported that in 1936 the Soil Conservation Service transplanted 10 Beaver to the Ahtanum Creek watershed for the purposes of increasing water storage. The Beaver constructed several large dams, one of which was 90 ft (27 m) long, 10 ft (3 m) high, and stored 5 acre-feet (6,167 m³) of water. Scheffer (1938) implied that the dams reduced downstream flood damage and increased summer stream flows for irrigation. Finley (1937) reported the opposite situation for Silver Creek in eastern Oregon. Two trappers removed 600 Beaver in one winter. As a result, the Beaver ponds “disappeared,” the water table lowered, grassy meadows “died out” and streams containing trout went dry.

The observations of Scheffer (1938) and Finley (1937) are anecdotes. More rigorous scientific research into the connections between Beaver and riparian ecosystems have found that Beaver have numerous positive effects.



Beaver viewed with night vision camera/Ned Pittman, WDFW

Beaver dams store organic nutrients and large quantities of sediment, reduce channel incision, remove excess nutrients from water, increase surface water storage and base flows, reduce peak flows, increase groundwater recharge, raise water table elevations, expand the area of riparian vegetation, and increase the salmonid habitat capacity of small streams (Naiman et al. 1988; Pollock et al. 2003; Gibson and Olden 2014). For dryland riparian areas where the extent of riparian vegetation depends on shallow groundwater, the hydrologic and geomorphic effects of Beaver dams may be necessary for the mere existence of a riparian zone at many sites. In dryland riparian areas, most ecosystem functions occur within the riparian zone.

The dramatic effects of Beaver on hydrology was shown by Westbrook et al. (2006), a multi-year study of two Beavers dams on a fourth order stream running through a dry meadow in the Rocky Mountains of Colorado. One dam diverted over half and the other diverted 70% of the stream onto the floodplain and terrace. Both dams increased substantially the area flooded by annual peak flows. One dam caused the equivalent of a 20-year flood over 30 acres (12 ha) of the valley floor during a peak flow event with a 1.6-year recurrence interval, and the other dam caused the equivalent of a 200-year flood over 21 acres (8 ha) of the valley floor during a peak flow event with a 1-year recurrence interval. One of the dams

studied by Westbrook et al. (2006) was breached by high flows. Westbrook et al. (2011) subsequently found that overbank flooding caused by that dam had deposited nutrient-rich sediments in some areas and scoured soils in other areas downstream of the dam site. These bare sediments were colonized by willow and aspen seedlings, which may eventually establish riparian plant communities.

In sagebrush steppe of Wyoming, Cooke and Zach (2008) found that the number of Beaver dams was positively associated with riparian zone width, riparian shrub height and percent cover by emergent wetland vegetation. These responses can at least partly be explained by changes in hydrology caused by Beaver dams.

Eradication of Beaver has been implicated in stream channel incision and desertification of riparian zones that has occurred throughout arid and semi-arid ecoregions of western North American (Parker et al. 1985; Pollock et al. 2003), including the Columbia Plateau (Pollock et al. 2007). According to Pollock et al. (2007), the exact mechanism that caused widespread incision of streambeds remains uncertain, however, incision almost invariably coincided with widespread trapping of Beaver and the onset of intensive livestock grazing. Channel incision, whatever the ultimate cause, occurs through an imbalance between sediment deposition and sediment mobilization. Assuming no changes in upstream sediment sources, incision is usually attributed to an increase in erosive forces or a decrease in channel resistance to erosive forces. The former can be caused by an increase in runoff, both can be caused by a decrease in channel roughness, and the latter can also be caused by loss of streamside vegetation. Therefore, channel incision can be prevented by controlling runoff caused by upstream land uses, maintaining roughness elements such as large wood, and retaining riparian vegetation. For many dryland riparian areas, Beaver are essential for the latter

two. Beaver dams act as massive roughness elements that reduce flow velocities, thereby reducing hydraulic forces that cause erosion. Reducing flow velocities also results in sediment deposition, which raises the streambed elevation and creates microsites suitable for germination of riparian plants.

Several studies have suggested that reintroduction of Beaver can reverse channel incision (Pollock et al. 2007; Beechie et al. 2008), primarily by restoring sediment retention processes in the channel (Pollock et al. 2014). Sediment aggradation caused by Beaver dams fills the incision and raises the streambed elevation. As the bed elevation increases, hydrologic connectivity between the channel and former floodplain is improved both by raising the water table elevation and by reducing bank height, which allows overbank flooding to recharge the floodplain's alluvial aquifer. Increased soil moisture allows riparian plant species vegetation to re-establish. Development of a well-vegetated riparian zone provides Beaver with more food and building materials, enabling construction of more dams (Pollock et al. 2014).

The aforementioned impacts of Beaver on aquatic and riparian ecosystems are immensely beneficial to fish; however, Beaver may also have detrimental effects on fish. Sediment deposition in Beaver ponds may harm spawning beds, and Beaver dams can block upstream and downstream fish movements (Pollock et al. 2003). Water temperature in Beaver ponds can be warmer than nearby flowing waters, especially where the stream is largely under a closed canopy forest (Robison et al. 1999), but in areas with open or no canopy (such as dryland riparian areas), water temperatures tend to be similar between Beaver ponds and unpounded reaches (Talabere 2002). Beaver ponds have also been found to provide productive habitats for non-native fish (Gibson et al. 2015) that may compete with or prey upon native fish.

7.4. Ecosystem Functions

FEMAT (1993) identified five key functions of riparian ecosystems that are important for fish habitats: streambank integrity affected by plant roots, litter fall that provides detrital nutrients, shading to limit stream temperatures, large wood recruitment, and pollution removal. Most of what is known about these key riparian functions was discovered through research conducted in forested ecoregions, in particular, the mesic forest ecoregions of the Pacific Northwest (e.g., Salo and Cundy 1987; Naiman and Bilby 1998; Richardson et al. 2005). Much of what is known about riparian areas in forested ecoregions is transferable to riparian areas in the Columbia Plateau, and therefore, where appropriate I repeat some of the knowledge and principles elucidated in chapters 1 through 6. However, as will become apparent, large gaps in knowledge remain.

In addition to FEMAT's key ecological functions, a sixth key function occurs in dryland riparian areas— alluvial water storage. Alluvial water storage occurs in riparian areas of all ecoregions, but it may be especially important in dryland ecoregions.

7.4.1. Streambank Stability

Streambank stability refers to a bank's resistance to change and its resilience after change (Bohn 1986). Streambank stability is the opposite of streambank erosion. Streambank erosion is commonly misinterpreted as a sign of adverse human impacts to riparian ecosystems, and it can be. However, a channel in dynamic equilibrium simultaneously exhibits both stable and unstable banks (Wohl et al. 2015). Streambank erosion is integral to a watershed's fluvial disturbance regime and necessary for long-term ecological sustainability (Florsheim et al. 2008) because

the opposing processes of bank stability and bank erosion maintain the diversity of aquatic and riparian habitats within a watershed. Bank stability is also associated with overhanging/undercut banks which shade the water and provide cover for fish (Bohn 1986; Ohmart 1996).

The stability of streambanks is influenced by soil characteristics, groundwater, and vegetation. For the purposes of riparian area management, I focus on vegetation. Rooted vegetation is essential for streambank stability (Hupp and Osterkamp 1996; Gurnell 2014). Plants are said to provide "root strength" or "root reinforcement" along streambanks (FEMAT 1993; Pollen-Bankhead and Simon 2010). Soil is generally strong in compression, but weak in tension. Woody and herbaceous plant roots are strong in tension, but weak in compression. Consequently, the root-permeated soil of streambanks behaves as a composite material with enhanced strength (Simon and Collison 2002). Dense root networks also physically restrain or bind soil particles. Exposed roots on the bank surface increase channel roughness which dampens stream flow velocities, thereby reducing fluvial erosion (Griffin et al. 2005). Reduction of stream velocities by roots may also cause sediment deposition, which further stabilizes streambanks.

The stability provided by roots is species dependent (Polvi et al. 2014). Simon et al. (2006), for instance, found that Lemmon's Willow *Salix lemmonii* provided 10 times more root reinforcement of streambanks than Lodgepole Pine *Pinus contorta*. The difference was due to the greater root density and larger root area of Lemmon's Willow. On the southeastern slope of the Cascades Range in Washington, Liquori and Jackson (2001) found that different riparian plant communities manifested differences in bank erosion and channel form. They identified two types of riparian plant communities: a scrub-shrub community that exists within an open-canopy Ponderosa Pine *Pinus ponderosa* forest, and a dense, closed-canopy fir forest. The

Ponderosa Pine forest is maintained by regular wildfires while the fir forest was created by fire suppression. The scrub-shrub community was associated with stream channels that had less bank erosion, lower width-to-depth ratios, more pools, and more undercut banks than channels within the fir forest community. The channel morphology of scrub-shrub riparian communities also resulted in slightly lower summer stream temperatures. In the semi-arid Sierra Nevada Mountains, Micheli and Kirchner (2002) found that riparian areas comprised of sedges and/or rushes had banks five times stronger than riparian areas comprised of sagebrush and grasses, and that bank strength was correlated with the root mass to soil mass ratio. Sedges and/or rushes enabled the formation of undercut banks, and increased the width of an undercut bank by a factor of 10.

The composition and structure of riparian vegetation affects channel morphology which, in turn, affects riparian vegetation (Corenblit et al. 2007; Osterkamp and Hupp 2010). Toledo and Kauffman (2001) observed the effects of one such interactive feedback loop in semi-arid northeastern Oregon. Upland plants were found along incised channels and wetland-obligate plants (mostly sedges) were found along unincised channels, which had two times greater root biomass than incised channels. Along unincised channels, approximately 40% of root biomass was deeper than 8 in (20 cm) in the soil, but along incised channels less than 25% of root biomass was below 8 in (20 cm).

Compared to forested ecoregions, there is less large woody debris, and woody debris play a much smaller role in the fluvial processes of dryland river and streams.

Denser roots at deeper soil depths result in a larger volume of reinforced soil. According to Toledo and Kauffman (2001), the severely degraded conditions at their incised sites were caused by a positive feedback loop in which an initial channel incision led to a lower water table. The resulting reduction in soil moisture altered riparian vegetation which shifted to an upland plant community with reduced root mass. Bank erosion subsequently increased which led to channel widening and further incision.

The studies reviewed thus far have reported on the bank strength provided by hydric or wetland-obligate shrubs and herbaceous plants (sedges and rushes) in dryland riparian areas. Trees are also important for bank stability. Rood et al. (2015) studied the amount of bank erosion after major floods along Elk River in British Columbia. They found that floodplain locations occupied by grassland or small shrubs exhibited substantial erosion (>75 m of bank erosion) after major floods but locations occupied by forest, including Black Cottonwood stands, exhibited much less change (<15 m of bank erosion). Rood et al. (2015) concluded that “only big plants can resist big flows,” and that other studies which demonstrated that grasses or shrubs are more erosion resistant had observed only low energy flows in smaller or shallower gradient streams.

Streambanks along incised channels of arid or semi-arid regions are particularly sensitive to changes in soil moisture. Much of the bank may be above the water table, and hence soils are unsaturated. Matric¹² suction above the water table, enhanced by transpiration of riparian vegetation, has the effect of increasing the apparent soil cohesion, and decreases in soil strength due to a loss of suction are a leading cause of bank failures in incised channels (Simon and Collison 2002).

¹² Matric suction is a negative pore pressure that induces water to flow in unsaturated soil. It results from the combined effects of adsorption and capillarity of the soil matrix. Water flows from a soil with low matric suction (a wet soil) to soil with a high matric suction (a dry soil).

7.4.2. Wood

The main role of wood in aquatic ecosystems is roughness element (Bisson et al. 1987). Roughness elements are obstacles in a channel that deflect flow and change its velocity. The size, shape, and strength of large wood make it very effective at redirecting hydraulic forces and the flow of materials, such as sediment and fine organic matter. In-stream large wood increases hydraulic complexity, i.e., creates a wider range of flow velocities, which causes pool formation, streambed scour, sediment deposition, and channel migration. The net result is a diversity of aquatic habitat types.

I could find no studies conducted in the Columbia Plateau describing the density of trees or their spatial distribution in riparian areas. However, riparian areas in the Columbia Plateau certainly contain less large wood than forested ecoregions, even historically, for three reasons. First, trees are smaller in the Columbia Plateau than in forested ecoregions of Washington. Canopy dominant trees in old-growth riparian ecosystems of mesic forested ecoregions can be well over 48 in (122 cm) diameter at breast height (dbh) and over 150 ft (46 m) tall, but the maximum size of Black Cottonwood in the Columbia Plateau is much smaller (see below). Second, trees are fewer in the Columbia Plateau because in the Columbia Plateau trees inhabit the riparian zone but often do not inhabit the zone of influence. In forested ecoregions, trees inhabit both zones. Third, along some streams, particularly in the most arid subregions of the Columbia Plateau, even the riparian zone is unsuitable for tree species. At such sites, the riparian zone consists of tall shrub, shrub, grass-like, grass, and forb vegetation types. Therefore, compared to forested ecoregions, there is less large woody debris, and woody debris plays a much smaller role in the fluvial processes of dryland river and streams.

Knowledge regarding wood in aquatic and riparian ecosystems of Columbia Plateau is extremely limited at present, nevertheless, the historical abundance of woody plants in riparian areas is thought to have been much greater than it is today (Wissmar et al. 1994; Kauffman et al. 1997; Wissmar 2004). Riparian areas in the Columbia Plateau are inhabited by a variety of woody plants—Black Cottonwood, Quaking Aspen, White Alder, Thinleaf Alder, Water Birch, Black Hawthorn, and Yellow Willow (Crawford 2003). Conifer trees, including Ponderosa Pine and Douglas-fir *Pseudotsuga menziesii*, are widely scattered in eastern Washington riparian areas and were likely more common historically than at present. They are currently restricted to canyons or valleys with steep rocky walls along mid- to high-gradient streams where they are inaccessible to harvest and where microclimates are conducive to supporting trees (Evans 1989). The main causes of reduced wood are explained in Section 7.2.

The size and quantity of wood recruited to a stream depends on the size and density of woody plants, their distances from the channel, and the recruitment processes that deliver wood to the channel. Only a few tree species in riparian areas of the Columbia Plateau qualify as large wood, which is commonly defined as greater than 4 in (10 cm) in diameter and greater than 6 ft (2 m) in length.¹³ Black Cottonwood is the largest riparian tree species in the Columbia Plateau Ecoregion and the largest deciduous species in western North America. The species has a typical lifespan of 100 to 200 years (Braatne et al. 1996), and can attain a dbh of about 30 to 35 in (76 to 90 cm) in the Pacific Northwest (Franklin and Dyness 1988), but sizes are smaller in the Columbia Plateau. The interior of British Columbia is less productive than the province's coastal ecoregion, and in the interior, Black Cottonwood attain an average size of 15 in (38 cm) dbh and 52 ft (16 m) tall at age 80 years, and 26 in (66 cm) dbh and 70 ft (21 m) tall at age 150 years (Roe 1958). Other tree species that might also

¹³ Large wood is also known as large woody debris (LWD) or coarse woody debris. There is no universal definition of LWD. Another common definition is greater than 4 in (10 cm) in diameter and greater than 3 ft (1 m) in length. Small wood is also known as small woody debris or fine woody debris.



Large trees in riparian areas are a major source of instream large woody debris/Jim Cummins , WDFW

function as large wood are Quaking Aspen, White Alder, and Peachleaf Willow *Salix amygdaloides*. Daubenmire (1970) reported that Quaking Aspen and White Alder grow to about 8 and 23 in (10 and 58 cm) dbh, respectively, in riparian areas of the Columbia Plateau.

Substantial amounts of small wood may be recruited to and stored in stream channels through Beaver activity. Most dryland riparian areas lack large trees, but in dryland riparian areas Beaver create large roughness elements from small wood that mimic some effects of large wood (see section 7.3). In effect, Beaver convert small wood to large wood. Beaver dams consist mainly of mud and small wood. Published information on small wood sizes in dams of North American Beaver is lacking. However, Beaver most often forage on trees ranging from 1.2 to 3.2 in (3 to 8 cm) in diameter (Collen and Gibson 2001), and a large proportion of woody stems used as food are also used in dam construction (Barnes and Mallik 1996). In Maryland, Bliersch and Kangas (2014) found that 98% of sticks (i.e., small wood) in a Beaver dam were less than 4 in (10 cm) in diameter and

that 46% of those sticks were probably placed in the dam by Beaver. The other 54% of sticks in the dam were due to passive capture of transported wood.

Large wood recruitment processes in riparian areas of the Columbia Plateau should be very similar to those in forested ecoregions. Therefore, the main processes should be tree mortality caused by disease or senescence, bank erosion, and wind throw. Maximum recruitment distances for large wood will generally be either riparian zone width or site-potential tree height, whichever is smaller. I found no studies on recruitment mechanisms of small wood, nevertheless, the main mechanisms should be direct fall of branches into a stream channel, mobilization by overbank flooding, and Beavers. Consequently, depending on the relative distribution of small and large wood sources within a riparian area, the recruitment distance for small wood could be greater than the distance for large wood. That is, shrubs that lie farther from the stream channel than trees, could contribute small wood via flooding or Beaver.

7.4.3. Detrital Nutrients

With respect to riparian ecosystems, *detrital nutrients* most often refer to nutrients derived from terrestrial litter. Litter may consist of leaves, bark, seeds, cones, flowers, fruit, nuts, twigs, and other small plant parts (Benfield 1997). Terrestrial litter in an aquatic system is also called allochthonous nutrients.¹⁴ Detrital nutrients are only one component of nutrient dynamics in riparian ecosystems. Riparian areas also mediate bi-directional exchange of dissolved nutrients between terrestrial and aquatic systems. Detrital nutrients in the larger context of nutrient dynamics (e.g., nitrogen cycle) are discussed in Chapter 6.

Besides research on marine derived nutrients (Naiman et al. 2002), the dynamics of macronutrients—nitrogen, phosphorus, and carbon (N, P, and C)—in riparian areas of the Pacific Northwest has been largely neglected by scientists (but see Naiman and Sedell 1980; Triska et al. 1984). I found one study related to nutrient dynamics in riparian areas that was conducted in the Columbia Plateau Ecoregion (e.g., Cushing and Wolf 1982; Cushing and Wolf 1984; Cushing 1988).

The availability of macronutrients has profound effects on the productivity, composition, and structure of ecosystems. In Washington, many streams and rivers in undisturbed watersheds are oligotrophic, i.e., exhibit low productivity associated with low N or P concentrations. Thut and Haydu reported in 1971 that roughly half of unpolluted surface waters in Washington were N-limited, and the other half were limited by P. Interestingly, N-limited waters, such as those in the Yakima River and lower Columbia River basins, most often arise from volcanic rock formations, while P-limited waters, such as those in the Okanogan River basin, flow from glacial deposits or granitic formations (Thut and Haydu 1971; Murphy 1998). Nutrient-limited waters are often sensitive to anthropogenic inputs of macronutrients, and when more N or P enters a stream

than can be immediately metabolized, degradation of aquatic habitats often results. Artificial fertilizers, which are inorganic nutrients, cannot mimic the foodweb role of detrital nutrients. Artificial fertilizers are used by plants, but litter feeds heterotrophs such as macroinvertebrate detritivores (shredders and collectors), many of which are prey for salmonids. Therefore, providing adequate amounts of litter to streams is an important issue for riparian area management.

According to Xiong and Nilsson (1997), in drier and less productive grasslands, a certain amount of litter may help to conserve soil moisture and thus increase plant growth. The same effect may be obtained in dryland riparian areas. Hence, in addition to providing nutrients, litter from riparian vegetation may also retain soil moisture.

Little is known about nutrient dynamics in dryland riparian areas. Nitrogen cycling, for instance, is driven by microbes in soils, and microbial activity depends on water availability. In forested ecoregions, nitrogen cycling is rarely limited by water availability. Hence, microbial processes are active in both uplands and riparian soils, and can occur year round. In arid regions, nitrogen cycling in uplands may cease when soil moisture approaches zero. This is also true of nitrogen cycling in riparian areas, however, nitrogen dynamics are more complex in riparian areas because they are closely linked to seasonal water table elevations which are affected by site and watershed-scale hydrology (Belnap et al. 2005).

Particulate and dissolved organic carbon are important sources of energy in aquatic ecosystems. Both support organisms near the bottom of the food web. In forested ecoregions, productivity of headwater streams is typically light-limited by a closed canopy (Connors and Naiman 1984; Murphy 1998), and consequently, the main source of energy is allochthonous chemical energy

¹⁴ Allochthonous means originating or formed in a place other than where found. In contrast, autochthonous means originating or formed in the place where found.

from riparian areas. In arid and semi-arid regions, the canopy over headwater streams tends to be more open, which allows more light to reach the aquatic ecosystem. Cushing and Wolf (1982) found that chemical energy for a small spring-fed stream in central Washington, Rattlesnake Springs, was predominantly autochthonous, i.e., produced within the stream by Watercress *Rorippa nasturtium-aquaticum*,¹⁵ Cattail *Typha latifolia*, and algae. Direct allochthonous inputs contributed 11% of total energy inputs, and all of it was consumed. Consequently, Cushing and Wolf (1982) concluded that the aquatic community exhibited both autotrophic and heterotrophic traits.

The amount of allochthonous carbon produced by dryland riparian areas varies considerably. The input rates of allochthonous organic matter (specifically, leaf litter from shrubs) in two dryland riparian areas were 1.1 oz/ft²/yr (350 g/m²/yr) at Rattlesnake Springs and 0.54 oz/ft²/yr (165 g/m²/yr) at Snively Springs (Fisher 1995). The former is about 1.2 to 2.1 times greater than the amount of leaf litter produced by riparian areas in mesic forests (Gregory et al. 1991; cited in Fisher 1995).

Nearly all N in lotic ecosystems in forested ecoregions of the Pacific Northwest is derived from allochthonous sources. Headwater streams in the western Cascades of Oregon, for instance, obtain more than 90% of annual nitrogen inputs from biotic processes in the adjacent forest (Triska et al. 1984). An important source of N in forests of western Oregon and Washington is N₂-fixing Red Alder *Alnus rubra*, which contributes both litter and dissolved organic N to streams (Compton et al. 2003). Small streams in the Columbia Plateau Ecoregion must also obtain N from allochthonous sources. The overstory of some riparian plant communities in that ecoregion consists of N₂-fixing White Alder *Alnus rhombifolia* or Thinleaf Alder *Alnus incana*. Evidence suggests that Black Cottonwood and willow species contain mutualistic organisms that fix nitrogen (Doty et al. 2009, Wuehlisch 2011). This helps to explain how these

species can survive and grow on recently disturbed, barren, floodplain sediments. Litter from these pioneering plants also provides nitrogen for other plant species in subsequent successional stages and deliver allochthonous nitrogen to the aquatic ecosystem.

The only study I could find on litter source distances was conducted in mature conifer forest in western Washington. Bilby and Heffner (2016) found that about 95% of litter delivered to streams comes from distances between 39 and 54% of mean tree height, depending upon forest type, topography, and wind. For Snively Springs, a spring-fed small stream with a riparian area comprised of dense willow and wild rose in central Washington, Cushing (1988) found that roughly 40% of litter fell directly into the stream from overhanging vegetation and 60% was blown laterally from plants some distance from the streambank. He did not measure distances. These proportions were affected by factors that influence wind, such as vegetation density and topography.

7.4.4. Shade

For an in-depth discussion of shade and water temperature refer to Chapter 4.

Numerous studies in dryland riparian areas have shown that salmonid species abundance is negatively correlated with stream temperature (Platts and Nelson 1989; Li et al. 1994; Ebersole et al. 2003a; Zoellick 2004). Even when primary and secondary production increase in response to reduced shading, salmonid populations often respond negatively to high temperatures (Tait et al. 1994). Shade is important because it directly affects stream temperatures. Other factors can significantly affect stream temperature, such as topographic shading, channel azimuth, channel form, groundwater flow, and hyporheic exchange, but for the purposes of riparian area management, I focus on shade provided by vegetation. Vegetation also affects local air temperature,

¹⁵ Watercress (*Rorippa nasturtium-aquaticum*) is an exotic plant in Washington State.



In the Columbia Plateau, some stream reaches have no shade from vegetation/Alan Bauer

humidity, and air movement, which all affect stream temperature (Cristea and Janisch 2007).

Shading of a stream is affected by the vegetation's height and foliage density and by the stand's depth (or width) and stem density. In general, a taller, denser, or wider strip of vegetation will shade a larger proportion of a channel for a longer time, at both daily and annual time scales. Riparian vegetation also enables the formation of undercut banks, which provide shade along streambanks that has been shown to lower water temperatures of individual pools (Ebersole et al. 2003a; Ebersole et al. 2003b).

The classification system based on overstory underscores the substantial differences in shading provided by riparian vegetation types: tall tree, short tree, tall shrub, shrub, grass-like, grass, and forb (Crawford 2003). The obvious implication of these vegetation types is that some stream channels in the Columbia Plateau receive little or no shade from vegetation, even historically. However, the actual historical condition of many riparian areas is unknown. Studies show that restoration of riparian areas, especially restoration of incised channels, can alter vegetation type, increase shading, and reduce water temperatures. How spatial variation in vegetation type and consequent shading currently affects salmonid habitat regionally is also unknown. Ecologists lack a map of current and potential riparian vegetation types across the Columbia Plateau that would enable managers to assess impacts on fish-bearing streams from insolation (see Macfarlane et al. 2017 for a first approximation).

7.4.5. Pollutant Removal

For an in-depth discussion of pollutant removal by riparian areas refer to Chapter 5.

The capability of riparian areas to remove certain pollutants from runoff is well documented (Barling and Moore 1994; Hickey and Doran 2004; Polyakov et al. 2005; Dosskey et al. 2010). Management of riparian areas for pollutant removal differs from the other ecological functions discussed in this document in that the primary focus is on mitigating activities occurring outside the riparian area. The pollutant removal function is unique in that it only exists in the presence of human activities that generate polluted runoff, and it is only necessary when runoff from upland activities threatens to degrade in-stream water quality. Major nonpoint-source pollutants removed with riparian "buffers"¹⁶ are sediments, excess nutrients (nitrogen or phosphorus), pesticides, and pathogens.

¹⁶ Riparian buffers are also known as riparian management zones (RMZs). "Buffer" refers to its purpose, which is to reduce or prevent adverse impacts to water quality, fisheries, and aquatic biodiversity from human activities occurring upslope of the buffer. Riparian buffers managed specifically for pollutant removal may also be called vegetated filter strips.

The processes in riparian areas affecting pollutant transport and fate are complex and often interrelated. Riparian areas can slow surface runoff and increase infiltration of water into the soil, thereby enhancing both deposition of solids and filtration of water-borne pollutants. Riparian areas also intercept and act on contaminants in subsurface flow through dilution, sorption, physical transformation, chemical degradation by various biogeochemical processes, and through uptake and assimilation by plants, fungi, and microbes. Hydrology, soils, and vegetation all affect pollutant transport and fate, but for the purposes of riparian area management I focus on vegetation.

Research on pollutant removal by riparian buffers conducted in arid or semi-arid ecoregions is very limited (Hook 2003). I could locate only three such studies (Tate et al. 2000; Fasching and Bauder 2001; Hook 2003), but all three have significant shortcomings. Hook (2003), for instance, simulated sediment-laden run-off from rangeland in western Montana. He reported that 20 ft (6 m) buffers removed at least 94% of sediment regardless of vegetation type in the buffer, but whether these simulations are realistic is unknown because he did not compare his run-off flow volumes and sediment concentrations to values from actual rangeland. Fasching and Bauder (2001), simulated sediment-laden run-off from tilled, bare cropland in central Montana. They found that 40 ft (12 m) wide buffers removed 75 to 80% of sediment during a simulated 50-year 24-hour storm event. However, while the buffer was 40 ft (12 m) wide, the bare cropland was only 15 ft (3 m) wide, which is certainly an unrealistic size for cropland. Tate et al. (2000) measured nitrate-nitrogen, total phosphorus, and suspended solids in run-off from irrigated pastures in the Central Valley of California. They reported that 33 ft (10 m) wide buffers did not significantly reduce nitrate-nitrogen concentration, total phosphorus concentration, or total suspended solid load. However, the strength of their inferences was compromised by extreme variability. Some buffered plots yielded higher

concentrations of all three pollutants than unbuffered plots, which they attributed to differences in soil and microtopography among plots.

Despite the large quantity of research conducted around the world, no widely accepted recommendations have emerged on minimum buffer widths needed to protect water quality. The lack of agreement amongst scientists is due, in part, to the surprising complexity of the biogeochemical processes that remove pollutants from surface and subsurface flows, the many different environmental conditions among research sites, the variety of methods used to study pollutant removal, and the shortcomings of some research (as described above). One way to cut through this variability and develop quantitative relationships between buffer width and pollutant removal efficacy is meta-analysis.¹⁷ I found five such meta-analyses in the literature (Mayer et al. 2007; Liu et al. 2008; Yuan et al. 2009; Zhang et al. 2010; Sweeney and Newbold 2014).

The number of studies in the five meta-analyses ranged from 52 to 88. I could determine the geographic locations of all studies included in four of the meta-analyses; only one study was conducted in an arid or semi-arid region (i.e., Tate et al. 2000, cited in Zhang et al. 2010). Four meta-analyses analyzed sediment studies, three meta-analyses analyzed nitrogen studies, and 1 one meta-analysis (Zhang et al. 2010) analyzed phosphorus and pesticide studies. All meta-analyses show that: 1) removal efficacy increases as buffer width increases, 2) removal efficacy varies among pollutants, and 3) relationships between buffer width and removal efficacy follow a nonlinear law of diminishing returns. In other words, the marginal removal efficacy decreases as buffer width increases. Comparing the four pollutants, buffer width that resulted in 90% removal was narrowest for sediment and widest for nitrogen (surface and subsurface combined). See Chapter 5 for a complete summary of their results.

¹⁷ Meta-analysis refers to various approaches for drawing statistical inferences from many separate but similar experiments (Mann 1990).

Only one study from arid or semi-arid ecoregions was included in the meta-analyses. Therefore, actual removal efficacy versus buffer width relationships may be quite different for riparian buffers in the Columbia Plateau. Differences in soil, hydrology, and vegetation between arid or semi-arid ecoregions and other ecoregions are significant, and are likely to affect pollutant removal. Because soils in arid ecoregions with biological crusts may be less permeable (Warren 2014) and vegetation tends to be less dense, especially in the upland zone of influence, the meta-analyses may underestimate buffer widths needed for a given level of removal efficacy. This issue can only be resolved through research on pollutant removal by dryland riparian areas.

7.4.6. Alluvial Water Storage

Alluvial water storage, also known as bank storage, is an ecological function of riparian areas that is thought to be especially important for small streams in dryland ecoregions (Pollock et al. 2003). However, the idea that alluvium can supply enough water to maintain base

flows is controversial because empirical data to support it are lacking (S. Wondzell, U.S. Forest Service, personal communication).

Alluvial water storage is thought to be part of a cyclic process. During annual floods, stream stage exceeds water table elevation, and surface waters flow into shallow alluvial aquifers (Winter et al. 1998). During the dry season, as stream stage declines, water flow reverses from aquifers to surface water, and the released water may comprise a substantial portion of the stream's base flow (Brunke and Gonser 1997; Whiting and Pomerants 1997). By absorbing some floodwaters, alluvial aquifers may also reduce the impacts of flood events (Whiting and Pomerants 1997). The water volume in bank storage depends on the duration of flooding, the area of inundated floodplain, hydraulic gradients between surface water and the aquifer, soil infiltration rate, the permeability and porosity of alluvial sediments, floodplain width, and thickness of the bank storage layer (Whiting and Pomerants 1997; Chen and Chen 2003).



Autumn foliage, brown grass, and low flows annually coincide in Columbia Plateau Ecoregion/Scott Fitkin, WDFW



Alluvial fans, such as these emanating from side canyons, store water from spring snow melt that contributes to a river's base flow during the dry season/Scott Fitkin, WDFW

On the semi-arid plains of Alberta, Meyboom (1961) found that groundwater released from bank storage is a substantial portion of dry-season stream flow in the Elbow River. Bank storage was 73% of total groundwater discharge during normal base-flow recession, and during late summer, discharge from bank storage comprised 50 to 70% of the river's daily mean discharge. On the eastern edge of the Great Plains in central Iowa, Kunkle (1968) determined that base flow characteristics of Four Mile Creek were related mainly to the adjacent alluvial sand reservoir. Bank storage discharge accounted for 37 to 42% of the annual base flow.

Hydrological studies in the Yakima River basin (Synder and Stanford 2001, and studies cited therein) have suggested that prior to irrigation projects extensive exchange between surface and ground waters occurred in riparian areas and floodplains. Annual inundation of floodplains, including riparian areas, would recharge shallow surficial aquifers, including the alluvial aquifer. Synder and Stanford (2001) asserted for the Yakima River, "Based on fundamental hydrologic principles, there is no question that groundwater recharge of this nature would not only have maintained base flows, but would have provided areas of cooler thermal refugia." A salient characteristic of alluvial water

storage is residence time, which can vary from days to years, depending upon floodplain width and hydraulic connectivity of alluvial sediments (Whiting and Pomereants 1997). The historical hydrology of rivers in the Columbia Plateau was water entered alluvial aquifers during spring peak flows and exited the aquifer weeks later during the low flows of late summer and fall of that same year (Synder and Stanford 2001). The historical timing and magnitudes of aquifer recharge and discharge may have been altered by dams, diversions, and levees.

Riparian and floodplain vegetation affect alluvial water storage in four ways. First, vegetation may reduce water storage through evapotranspiration. In fact, removing riparian vegetation can increase annual water yield from a watershed (Salemi et al. 2012). However, the timing of the additional surface water may not coincide with annual low flows when it is most needed. Second, through root growth and decay, vegetation creates soil macropores that increase soil permeability (Fisher and Binkley 2000) and thus enhance infiltration of floodwaters. Third, vegetation increases the residence time of floodwaters in floodplains by increasing surface roughness (Thomas and Nisbet 2007). The increased residence time provides more time for floodwaters to percolate through soils and into the alluvial aquifer. Vegetation increases surface roughness through stems, organic litter, large woody debris, and by altering micro-topography. Fourth, riparian vegetation helps to maintain cooler temperatures of shallow groundwater. Heat conduction from the soil surface into groundwater affects groundwater temperatures. Consequently, shallow groundwater temperatures are cooler in winter and warmer in summer. During the summer, shade from riparian vegetation and the riparian microclimate, which is cooler than adjacent uplands, may result in cooler groundwater. Stanford et al. (2002), for example, collected data suggesting that intact riparian forest moderated the rate of increase in groundwater temperatures along several reaches of the Yakima River.

Alluvial aquifers typically underlie floodplains (Vaccaro 2011), including riparian areas. The alluvial water storage function of floodplains has been degraded by dams that reduce flood magnitudes, levees that reduce the area of flooding, and the channelization or loss of distributary channels across alluvial fans. To replace natural recharge pathways, water managers are trying artificial recharge of shallow alluvial aquifers (USBR & WDOE 2012; WWBWC 2013). While artificial recharge may replace the aquifer recharge function of floods, it cannot replace the fluvial disturbances caused by flooding that are needed to maintain riparian vegetation and aquatic habitats.

7.5. Conclusions

The goal for riparian areas of the Columbia Plateau Ecoregion is the same as the goal for forested ecoregions—maintain or restore key ecological functions. However, management to achieve that goal is more complicated in dryland riparian areas for three reasons. First, there is a greater diversity of plant communities within riparian ecosystems of the Columbia Plateau than in the surrounding forested ecoregions—the vegetation heights of dryland riparian ecosystems range from sedges to tall trees. Several key ecological functions of riparian areas—namely, shade, wood, and detrital nutrients for aquatic habitats—are dependent on vegetation height. The other three functions—bank stability, pollutant removal, and alluvial water storage—are largely dependent on processes occurring at or below the soil surface. In forested ecoregions, the total capacity of a riparian area to provide five of the key functions typically occurs within a site-potential tree height (FEMAT 1993). In other words, with respect to aquatic habitats, full function for five of the key riparian ecological functions is typically provided by an area that is one site-potential tree height wide.¹⁸

¹⁸ Site-potential" is a concept related to forest productivity. A site's productivity is often expressed as the height a particular tree species growing on that site is expected to attain by a specified age. FEMAT (1993) defined site-potential tree height as the average maximum height of the tallest dominant trees (200 years old or greater).

In dryland ecoregions, the width of the riparian ecosystem is based on the ecological function that creates the widest zone of influence. At most sites, this will be either the wood (large and small) or pollutant removal functions. For grass, herb, shrub, and small tree vegetation types, the zone of influence based on wood, which depends on vegetation height, will be narrower than the zone of influence based on pollutant removal. Therefore, if pollutants, including sediments due to ground disturbance, are a concern at a particular site,

then riparian ecosystem width should be based on the desired removal efficacy for pollutants created at that site. If, for instance, surface run-off containing excess nitrogen is a concern and a 95% removal is desired, then the zone of influence is 170 ft (52 m) wide, measured from the active channel, see Table 5.4. If pollutant removal is not a concern, then riparian ecosystem width should be based on site-potential vegetation height (i.e., trees or shrubs), which should provide maximum wood and shade for aquatic habitats.



Some trees (Pinus ponderosa) have all the luck/Scott Fitkin, WDFW

The second reason management of riparian ecosystems is more complicated in the Columbia Plateau Ecoregion is water. The existence of dryland riparian areas depends on soil moisture and water table elevations. Many dryland riparian plant communities evolved under an annual hydrological cycle of flooding followed by gradual recession of stream flows. This cycle has been disrupted by dams and water diversions. The consequences of water management on riparian areas were documented by Braatne et al. (2007) who found an unsustainable age-class distribution of cottonwoods along the Yakima River. Two long-term impacts for these reaches of the Yakima could be reductions in shade and large wood for aquatic habitats. Water management is likely to have caused adverse changes to riparian plant communities along other rivers and streams in the Columbia Plateau. Under state law (RCW 90.03), in-stream flows are managed only to maintain flows above a specified minimum flow. Little consideration is given to mimicking the natural seasonal hydrograph for the sake of riparian ecosystems. To restore riparian ecosystems and aquatic habitats in the Columbia Plateau, that may need to change.

Third, management will be more complicated because many riparian areas in the Columbia Plateau have been highly altered by human activities, and ecologists do not know their historical or “properly functioning” conditions. Lacking such information will hamper the success of site-scale riparian restoration projects and regional restoration plans. An initial step toward grappling with this issue might be a subregional or WRIA-level mapping of potential riparian vegetation types. The mapping could include the capacity to support Beaver (e.g., Macfarlane et al. 2017) and the vegetation that would develop in the presence of Beaver. The map would serve three purposes: 1) a vegetation guide for riparian restoration projects, 2) a historical baseline for fish habitat conditions in the Columbia Plateau, and 3) habitat restoration objectives for the recovery of salmon and other aquatic species.

Historical information on riparian areas will serve three other purposes. First, knowledge of historical conditions will enable an accounting of lost ecosystem services. The losses incurred by fisheries are well recognized, but losses of wildlife, both game and nongame species, due to altered riparian areas have not been rigorously evaluated. Another major ecosystem service is the contribution to perennial stream flow from short-term storage of water in shallow alluvial aquifers that lie beneath floodplains (USBR & WDOE 2012; WWBWC 2013). Losses of this ecosystem service caused by disconnecting floodplains from streams also have not been rigorously evaluated. Second, knowledge of historical conditions may enable an estimate of the past quantity and quality of salmon habitats. Historical knowledge of past salmon habitats can be used in salmon recovery plans to establish habitat restoration objectives and priorities. The third purpose is partly political. Knowledge of past habitat loss can influence policy decisions to conserve remaining habitats or to restore habitats where practicable.

7.6. Acknowledgements

In May 2017, WDFW held a two-day workshop in Yakima, Washington on dryland riparian areas. WDFW thanks the following experts for participating: Tim Beechie, Rebecca Brown, Rex Crawford, Ben Floyd, Alex Fremier, Nate Hough-Snee, Thomas Hruby, Duncan Patten, Joe Rocchio, and Steve Wondzell. We are also very grateful to Tim Beechie, Alex Fremier, Perry Harvester, Nate Hough-Snee, Tom Hruby, Duncan Patten, Joe Rocchio, Amanda Stahl, Steve Wondzell, and four anonymous reviewers from the Washington Academy of Sciences for reviewing this chapter.

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Chapter 8. Watersheds

By: Derek B. Booth

8.1. Introduction

This chapter on watershed-scale processes and management looks beyond the typical site-by-site perspective at which riparian management and stream protection is normally applied. This chapter also considers the interactions between site-specific treatments, whose collective effects may be greater (or less) than anticipated by the individual actions themselves, and it uses these insights to offer a broader approach to riparian management for the protection of aquatic systems. Given this expanded focus, the conditions and influences discussed here may lie outside the framework of normal guidance and regulatory mandates, but they nonetheless affect the health and productivity of riparian areas and their associated aquatic systems. Thus, the conceptual framework provided here should be useful when considering the likely effects of riparian management policies or practices.

The purpose of this chapter is to explore the relationship (and the importance) of watershed-scale management to achieving the goal of abundant, self-sustaining fish and wildlife populations. It assumes that a broader watershed-scale perspective on aquatic ecosystems will ultimately enhance the beneficial effects of management applied at all scales.

The chapter is divided into four primary sections:

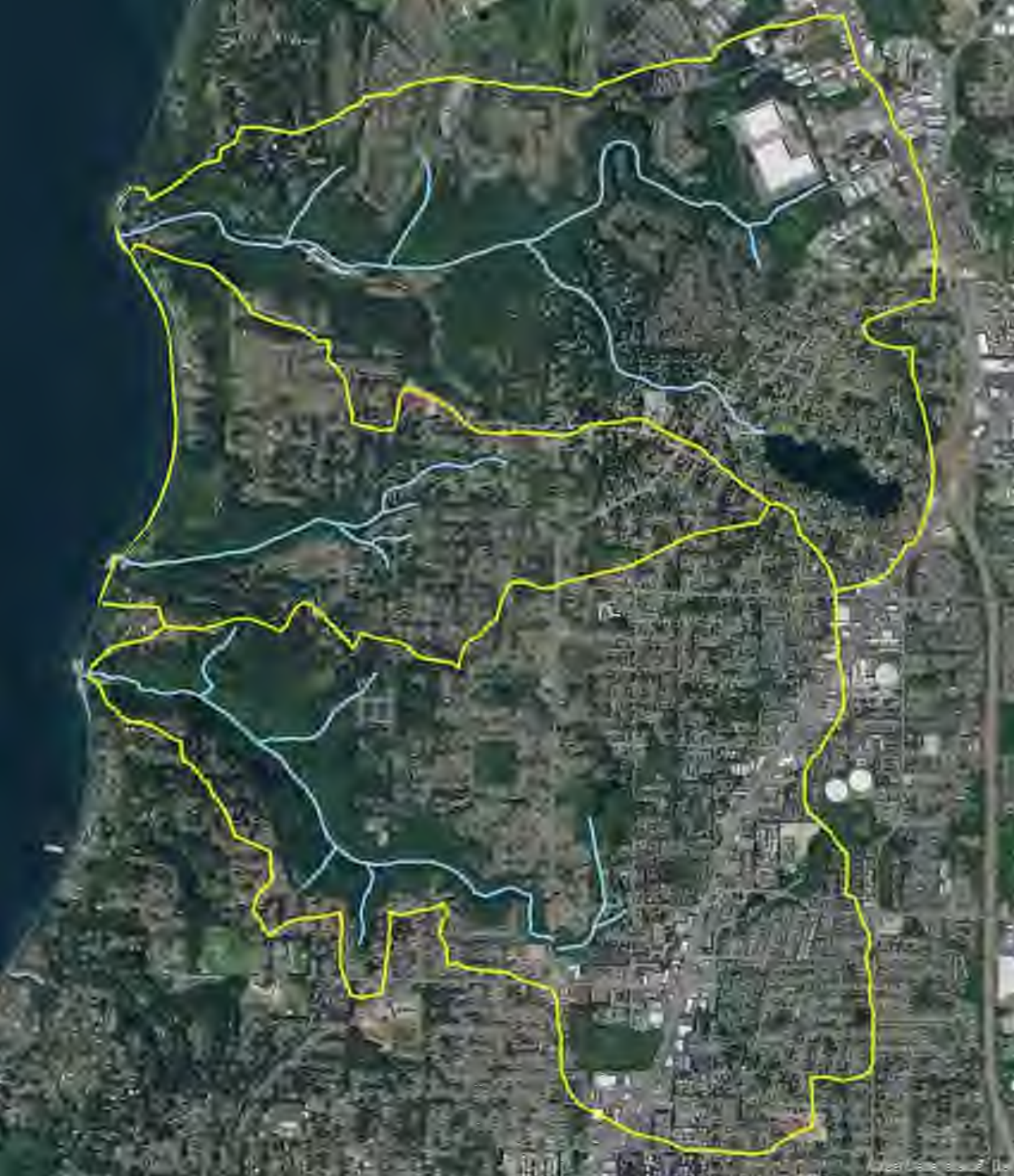
1. A conceptual framework that identifies the key watershed processes and their primary influences on riparian ecosystems and their watercourses, a perspective with a long history in the scientific literature.

However, advances in the discipline of landscape ecology over the past two decades—particularly the recognized importance of interrelationships between landscape elements in both spatial (e.g., connectivity and discontinuities) and temporal (e.g., disturbances and recovery) domains—have changed how biological and physical scientists view aquatic ecosystems and the riverine landscape that they occupy.

2. A discussion of how riparian management at the site scale, the emphasis of the other chapters in this document, can best support ecological functions and improve habitat conditions for fish and wildlife, even if a complementary set of watershed-scale management actions (e.g., land use at the watershed scale) cannot be implemented.

3. A description of how individual site-scale management actions, and their recognized site-scale benefits, relate to one another across a channel network and/or landscape. In other words, how do the consequences and overall value/benefit of isolated actions integrate along a channel network? Are the effects of individual actions simply additive, or are there synergistic effects that are revealed by a landscape ecology perspective?

4. Guidance, developed from an understanding of watershed processes and the perspective of landscape ecology, for improving the management of riparian ecosystems. This goal is complicated by the fact that most watersheds are managed under diverse and often uncoordinated responsibility: different landowners and managers have different goals and objectives. Furthermore, many of these managers have neither responsibility nor a process by which to coordinate their



Three watersheds (outlined in yellow) in urban areas of north Seattle/Terry Johnson, WDFW

actions, especially over the long durations necessary for riparian management actions to achieve their greatest effects. This chapter offers no prescription for resolving these challenges, but it proceeds under the belief that greater awareness of these interactions will ultimately lead to more successful protection of riparian systems, streams, and their biota.

8.2. Conceptual Framework

This chapter seeks to integrate the functions of riparian ecosystems into the overall landscape in which they interact—the riverine landscape or *riverscape*. This riverine landscape differs from the contributing watershed of the river or stream: although the flux of water and water-borne biota respect the drainage divides of a watershed almost exactly, other components do not. In particular, mobile organisms (e.g., birds, and large mammals such as American Beaver *Castor canadensis*, and bear (*Ursus* spp.)), wind-borne seeds, and wildfire all have the potential to affect and be affected by landscape elements both within and beyond the boundaries of any given watershed, and so they must be included in any comprehensive

conceptual framework (Figure 8.1). Despite these watershed-crossing elements, the lotic (flowing-water) environment itself is strongly organized by the unidirectional flow of water, a property that is distinct from terrestrial environments, and so rivers commonly display systematic patterns in the downstream direction (e.g., the “river continuum” of Vannote 1980.) They also display systematic cross-stream patterns, notably the spatial, physical, and ecological relationships between the channel and its adjacent floodplain; and to a less visible but still significant degree in the vertical dimension as well, particularly the interaction of shallow groundwater with stream water in the hyporheic zone (Boulton et al. 1998).

Landscape ecology is the scientific discipline best suited to this larger perspective of the riverine landscape: “...we perceive a need to conceptualize rivers not as sampling points, lines, or gradients, but as spatially continuous longitudinal and lateral mosaics. As such, heterogeneity in the river landscape, or riverscape, becomes the focus of study” (Fausch et al. 2002:485) (Figure 8.2). The foundational premise of landscape ecology is that both biotic and abiotic elements of the landscape interact with one another, and those interactions are spatially mediated (Malanson 1995).

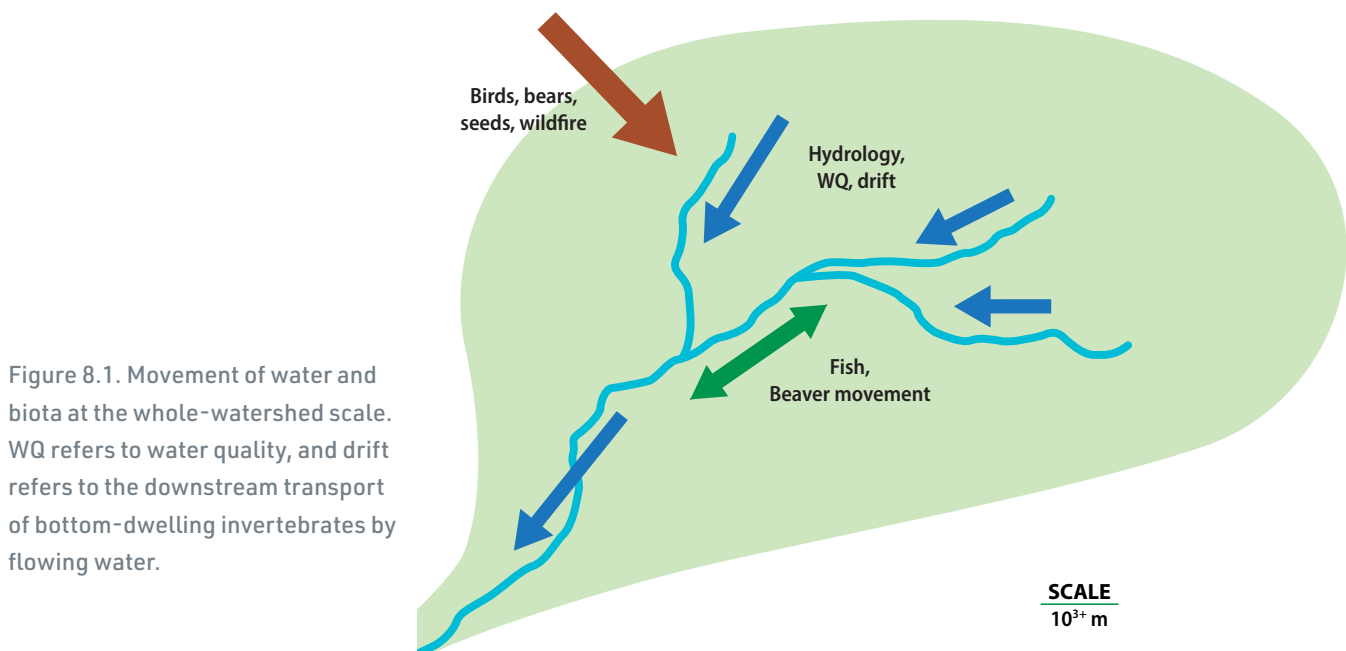


Figure 8.1. Movement of water and biota at the whole-watershed scale. WQ refers to water quality, and drift refers to the downstream transport of bottom-dwelling invertebrates by flowing water.



Figure 8.2. An example of landscape heterogeneity at multiple scales in an aerial view that includes the urban centers of Renton (west edge, labeled a) and Issaquah (northeast corner, b); suburban development throughout the south-central and northwest parts of the image (c); agriculture and rural-residential development, particularly in the valleys of May Creek and McDonald Creek trending NW across the center of the image (d); and extensive forest lands of Cougar, Squak, and Tiger Mountains (e) in the north-central and east parts. At finer spatial scales within the largely undeveloped areas in the eastern part of the image, fragmentation is nonetheless widespread from roads, utility lines, and clearing for residential lots and subdivisions (f).

This perspective emphasizes the importance of spatial heterogeneity; it also acknowledges the key role of episodic disturbances in determining the flux of energy and materials, the movement of organisms, and the creation of unique dynamics within the watershed (Wiens 2002).

At a finer spatial scale, water and biota interact across the permeable and dynamic boundary between riparian areas and a watershed's uplands (Figure 8.3, left panel). These areas comprise multiple components. Within riparian areas, these components include surface waters, in-channel bars and islands, floodplains, marshes, wet meadows, alluvial forests, and woody debris. For the uplands, these components might include unstable slopes, aquifer recharge areas, wetlands, seeps, forests, and areas of intensive human modification. Both areas also include the vast variety of organisms that occupy one or more of these habitats.



River running through rural residential area/Jane Atha, WDFW

Riparian areas occupy a particularly dynamic and disturbance-prone region (Figure 8.3, right panel) that can experience decadal, annual, or even more frequent flood events that locally alter, rearrange, or obliterate its components altogether.

In the natural state, riverine landscapes exemplify the new paradigm in ecology (sensu Talbot 1996), in which ecological systems are widely recognized as non-deterministic, open systems in continual states of flux, rather than internally regulated, homeostatic systems exhibiting equilibrium conditions. Yet, despite their highly dynamic nature, riverine landscapes provide predictable ecological conditions. Although individual landscape components exhibit high turnover, largely as a function of interactions between fluvial dynamics and successional phenomena, their relative abundances in the river corridor as a whole tend to remain constant over ecological time. [From Ward et al. 2002:518.]

So, for example, a flood may scour a gravel bar at one location in a river and deposit sediment in another; but along any given channel reach the relative frequency of pools and bars may not vary substantially over time. The resulting transience and diversity of habitats provide a variety of habitats that, although ideally

always present in aggregate, are not necessarily static in place or time (Robinson et al. 2002). Thus, managers should recognize this dynamic equilibrium as the key attribute of a truly functional riparian-aquatic ecosystem and make the protection of its dynamic *behavior* (rather than any specific *feature*) the overarching goal of riparian management.

Existing policies, however, generally do not facilitate management for dynamic conditions:

Policies setting underlying riparian goals that are essentially static and homogenous have become an integral part of many of the management guidelines that drive the goals for riparian management on federal, state and private lands in western Washington. Discussions [at a statewide forest management symposium] did not indicate that current management and policy guidelines necessarily preclude practices that might produce dynamic and heterogeneous riparian conditions. Because they promote uniform conditions over large areas, however, current policy and management guides do little to encourage treatments that would lead to ecologically diverse landscapes that could maintain critical functions that were formerly produced by natural disturbance regimes... [From Ryan and Calhoun 2010:viii-ix].

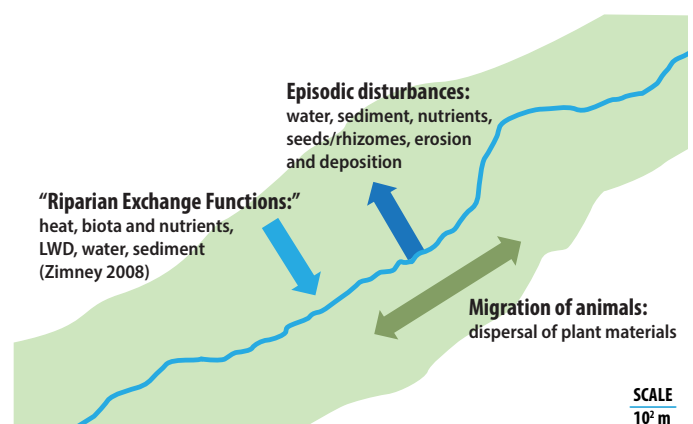
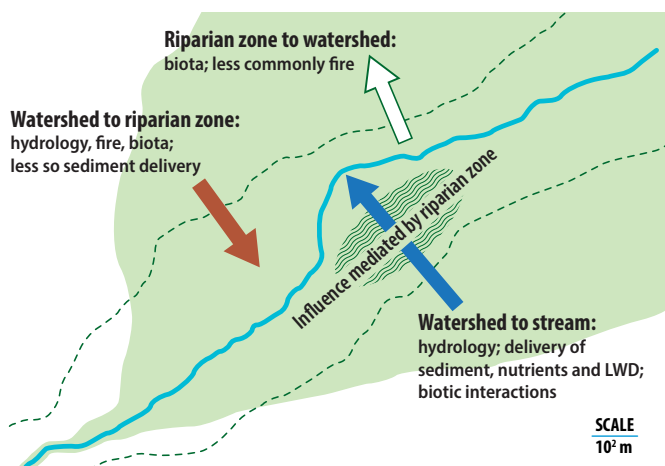


Figure 8.3. Movement of water, biota, and other elements of the aquatic system from the watershed into and through riparian areas (left) and between riparian areas and the stream (right).

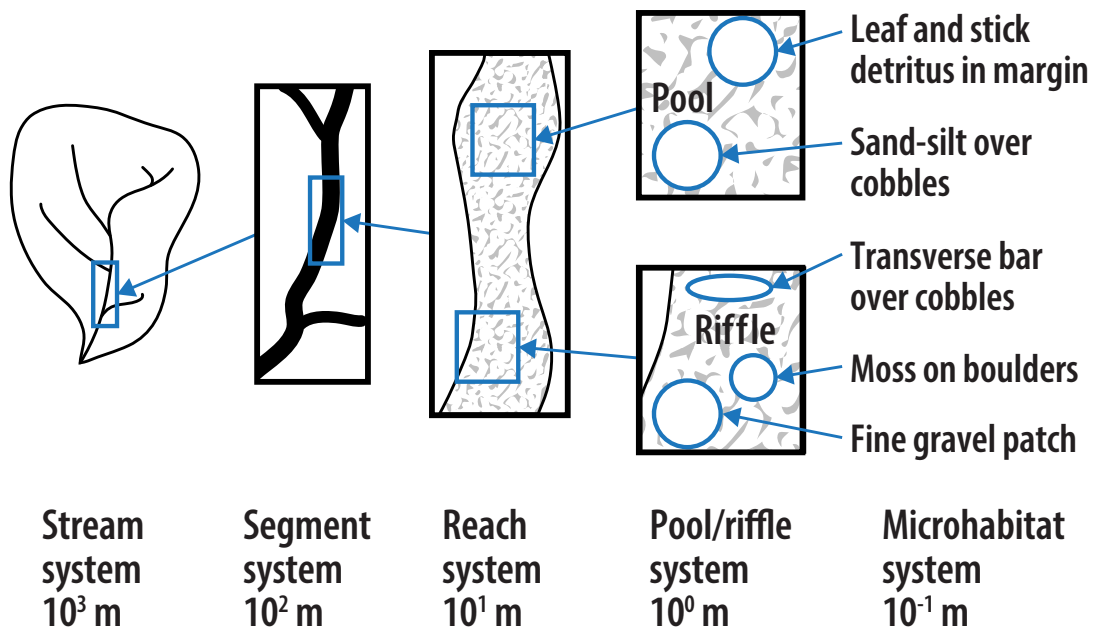


Figure 8.4. Hierarchical spatial organization of a watershed and its aquatic habitats. Approximate spatial scale, appropriate to second or third-order mountain stream (modified from Frissell et al. 1986).

On the other hand, riparian areas have experienced high levels of anthropogenic disturbance, both directly (e.g., harvest, road building) and indirectly (e.g., windthrow, landslides, and forest fire) due to forest management, which also compromises the dynamic equilibrium in riparian-aquatic ecosystems. In response, policy makers have reduced forest management-related disturbances in riparian areas, with the intent of passively reestablishing underrepresented late-seral classes (such as mature forest) which should improve riparian ecological functions, and conserve fish and wildlife species dependent on older forest. Such policies are all likely necessary parts of a successful riparian management strategy. However, because they do not address watershed-scale processes, these policies by themselves are almost surely insufficient to achieve desired riparian and aquatic ecosystem outcomes.

8.2.1. What are Watershed Processes?

Although the immediate goal of riparian management is the protection of species and their habitats, Frissell et al. (1986:199) suggested that “[w]e begin with the assumption that structure, operation, and other aspects of the organization and development of stream communities are largely determined by the organization, structure, and dynamics of the physical stream habitat.” (Using the terminology elsewhere in this document, these terms correspond to the structure, composition, and functions of physical habitat). If so, “the problem becomes one of understanding these physical patterns across time and space. This requires a broad, integrative framework that places streams, their habitats, and their

communities in wider geographic context" (Frissell et al. 1986:200). Frissell et al. (1986) developed this wider context by describing a spatial hierarchy that recognizes the influence of larger scale conditions and processes acting primarily (but not exclusively) unidirectionally on smaller scales (Figure 8.4). Factors that are best characterized over the largest extents, and that exert their influence over longest time frames, can be thought of as the ultimate "drivers" of the conditions and processes at lower levels in the hierarchy.

Three overarching process drivers—climate, geology, and topography—structure the suite of landscape-forming processes that are distributed over a landscape and that, in turn, govern watershed characteristics and processes (paraphrasing the framework of Montgomery 1999). At management time scales (i.e., years to decades), these process drivers are invariant and immutable—they are the "givens" under which a watershed evolves. The physical habitat features of any watershed do not simply arise from these process drivers directly, however; instead, they are created and continuously modified by the fluxes of materials (particularly water and sediment) and energy that arise from these process drivers and are widely termed watershed processes. Watershed processes are defined as "[t]he dynamic physical and chemical interactions that form and maintain the landscape and ecosystems on a geographic scale of watershed to basins (i.e., hundreds to thousands of square miles)" (Stanley et al. 2011:8).

To this simple, unidirectional, physical model of watershed influences must be added a few complications of lesser but still critical importance. First, the flow of influence is not always one-way: although topography exerts the dominant influence on the flow of water, over time the erosion by that flowing water will alter the topography to some degree (which, over geologic time scales, may be sufficient to change the very boundaries of the watershed). Second, biota are not always passive respondents to the

presence and changes of physical habitat, but instead can also influence that physical habitat in ways that are only slowly being recognized (see Moore 2006 for an overview of such effects). Robinson et al. (2002) emphasizes the role of fauna as ecosystem engineers of riverine landscapes, for which the modification of stream substrates by spawning salmon (Montgomery et al. 1996) or the rearrangement of floodplain dynamics by Beaver (Pollock et al. 2003) are two widely recognized examples. Biological conditions and processes are also of fundamental importance to the expression of some watershed processes: the flux of nutrients may not alter the physical habitat but is key to the health of the ecosystem; the character and extent of vegetative cover will greatly mediate the effects of topography, climate, and geology on the movement of runoff, the downslope transport of sediment, and the potential for dramatic, process-altering wildfire. Finally, the effects of people and human activities cannot be ignored in any useful conceptual framework applied to the modern landscape. Although direct modification of habitat and streams is an obvious impact with a long historical legacy in the Pacific Northwest (and beyond), the aggregate effects of human activities across whole watersheds can be even more consequential to instream resources, to the extent that land use, in many settings, becomes no less of a process driver (i.e., a determinant in a watershed) than is topography or climate.

These concepts are integrated into Figure 8.5, which emphasizes the unidirectional, hierarchical flow of influence from the large-scale process drivers onto the watershed processes that, in turn, give rise to the instream physical and ecological conditions and responses. This representation is not intended to deny the *upstream* influences that also occur (see Beechie et al. 2010, Figure 1 as an alternative representation), but it sacrifices completeness for clarity in acknowledging the overriding importance of this unidirectional perspective. This conceptual model also articulates the variety of processes that are embraced within each of the major watershed processes we

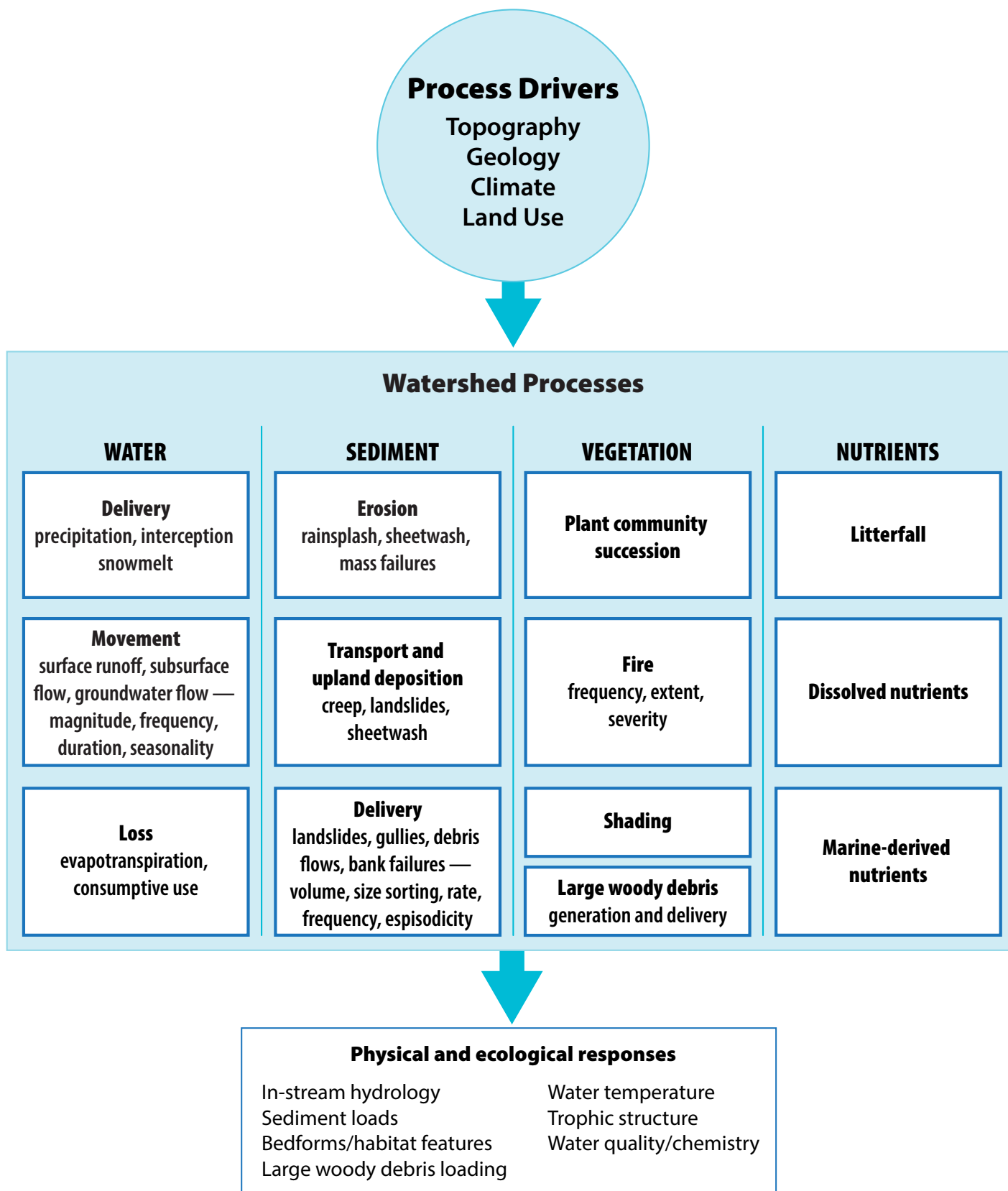


Figure 8.5. Conceptual framework for the hierarchical relationship of invariant, large-scale process drivers, the suite of watershed processes that are determined by these drivers, and the instream physical and biological responses to those processes. Multiple additional interactions between elements and levels are not shown on this diagram to emphasize the primary influences; but in any given setting, one or more of these secondary interactions may temporarily achieve equivalent importance. This framework embraces the definition of watershed processes from Stanley et al. (2011:8): “[t]he dynamic physical and chemical interactions that form and maintain the landscape and ecosystems.”

recognize (water, sediment, vegetation, and nutrients), and it reminds us of the major instream responses to these dynamic watershed processes.

8.2.2. How Does the Watershed Affect Instream Conditions?

The direct effects (both physical and biological) of watershed processes on the stream channel are most commonly understood as the delivery of material from the watershed, with or without some attenuation or other modifications as they pass through the riparian ecosystem: water, sediment, nutrients, pollutants, and large wood. These materials are delivered primarily by surface water flow, subsurface flow, landslides and debris flows (Figure 8.6). These fluxes of material and energy from the broader riverine landscape interact with those arising from the riparian corridor itself, to different degrees and over different time scales, with a resulting complexity that defies our current efforts to quantitatively predict their expression in the physical form or biological condition of a stream.

The complexity of these interactions is highlighted by relatively weak correlations reported between various instream features and landscape predictors, regardless of the spatial scale being evaluated (e.g., whole-watershed vs. riparian areas). For example, Anlauf et al. (2011) evaluated the correlation between eleven instream habitat features with landscape variables characterizing both process drivers (e.g., watershed gradient, rainfall) and management-influenced factors (e.g., forest cover, disturbance history, road density) across 121 coastal Oregon streams. The strongest relationships showed unexceptional correlations between particular habitat features and the suite of landscape variables (active channel width, $R^2 = 0.72$; percentage of fine sediments, $R^2 = 0.48$). Other habitat features expressed essentially no

relationship (percentage gravel, $R^2 = 0.05$; pools per 328 ft (100 m), $R^2 = 0.11$; percentage secondary channel area, $R^2 = 0.12$). Including management-influenced predictors increased adjusted R^2 values only modestly (by up to 16%). Many of the strongest relationships followed intuitive expectations, such as: "Wood volume was associated with several landscape predictors reflecting wood availability (% non-forest, % small trees, and % remnant forests), whereas pools per 328 ft (100 m) were associated with disturbances affecting pool retention (cow density, road density) and pool formation (% small trees)" (Anlauf et al. 2011:708). However, no relationship was sufficiently strong to suggest that either deterministic understanding or statistical correlations are sufficient to precisely characterize the influence of watershed-scale processes on a stream.

Our inability to predict instream conditions from watershed processes and riparian conditions with any useful degree of accuracy is widely recognized. In part, this inability is because the riparian corridor itself has significant, complex effects on the stream (see other chapters in this document). In addition, all of these influences—at every spatial scale—occur within a time-dependent framework mediated by rates of vegetation growth and decay, seasonal variations in flow, and episodic disturbances from floods, and even less frequent but potentially long-lasting channel impacts from fire or landslides (Lake 2000; Roper et al. 2007; Luce et al. 2012; Jellyman et al. 2013).

[E]mpirical associations between land use and stream response only varyingly succeed in implicating pathways of influence. This is the case for a number of reasons, including (a) covariation of anthropogenic and natural gradients in the landscape; (b) the existence of multiple, scale-dependent mechanisms; (c) nonlinear responses; and (d) the difficulties of separating present-day from historical influences. [From Allan 2004:257.]

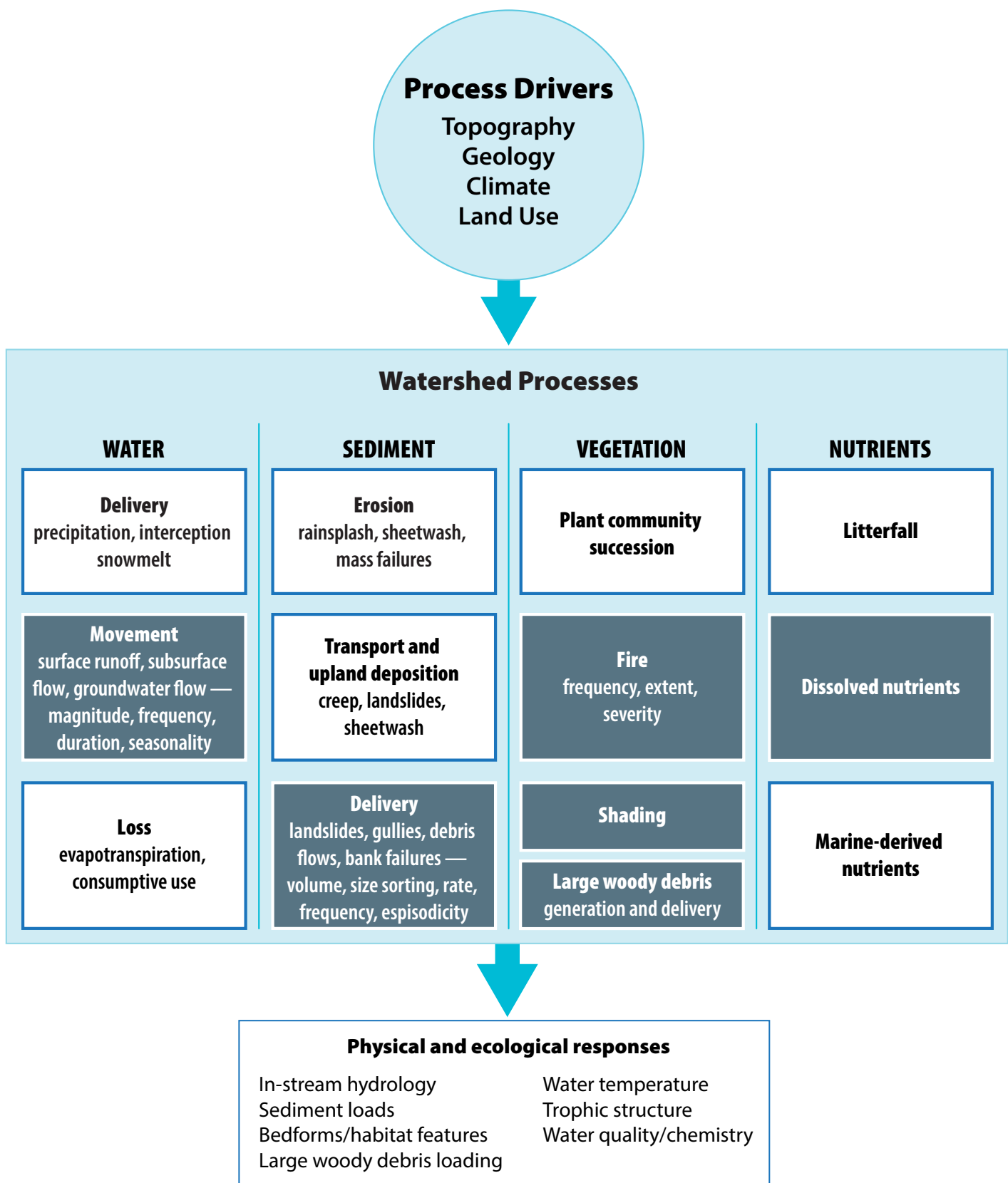


Figure 8.6. The conceptual framework of Figure 8.4, highlighting the subset of watershed processes (dark shaded boxes) that most directly affect instream conditions.



Clearcut harvest in a managed forest landscape/Jane Atha, WDFW

Regardless of our present inability to make reliable predictions of instream conditions from watershed processes, watershed processes do create and maintain instream habitat, and so the determinants of those processes are of indirect, but ultimately critical importance, to the understanding and the management of aquatic resources. Because the nature and intensity of these processes are strongly influenced by prevailing (and past) watershed land use(s), the effects of the dominant land use activities of the Pacific Northwest are discussed individually.

Forestry

The effects of watershed-scale forestry on instream conditions have been a primary focus of scientific research and forest practice regulations for many decades. Most of the attention has been paid to several discrete problems: increased stream temperature from loss of riparian vegetation, the degree to which large-scale loss of forest canopy alters the hydrologic regime,

whether the creation of new roads has a discernible impact on both hydrology and sediment delivery to the channel network, and whether forest practices increase the frequency and intensity of debris flows and other forms of mass failure that reach the stream.

The potential for hydrologic alteration in logged watersheds focuses on two major mechanisms: 1) the loss of forest canopy, which should increase total water yield by reducing interception and evapotranspiration, and increase accumulation of snow on canopy-less ground, which increases the total volume of water available during subsequent rain-on-snow events, and 2) more rapid drainage of surface runoff to stream channels from a newly created road network. The review article of Andréassian (2004:12) provides a convenient summary of much of the voluminous literature on this topic, concluding that “deforestation could definitely increase both flood volumes and flood peaks. However, this effect is much more variable than the effect on total flow and may even be inverted in some years or in some

seasons." The underlying causes for such increases are associated not only with the loss of forest canopy but also (and, perhaps, primarily) the consequences of soil compaction and development of the road network.

Increased sediment delivery to streams from watersheds is an anticipated outcome of both the direct and indirect effects of logging. Direct consequences result from the loss of canopy cover, increasing the potential for rainsplash and sheetwash erosion in areas of intrinsically low infiltration capacity, and the eventual loss of soil cohesion in areas of steep slopes. Indirect effects result from the construction of roads, for which inappropriate siting can result in sheetwash erosion and a greater incidence of landslides and debris flows from either concentrated road runoff or failure of the road prism itself. A variety of case studies making use of detailed field mapping, radionuclide tracers, and suspended sediment measurements have implicated various landscape features and erosive processes in post-logging watersheds, such as skid trails and landings, promoting surface runoff and erosion (Wallbrink et al. 2002), enhanced gully erosion (Reid et al. 2010), and road-initiated debris flows (May 2002).

Nutrient dynamics across the watershed are also affected by forest practices, with potential effects throughout the ecosystem (including the channel network and its riparian corridor). Richardson et al. (2005) offered a well-focused and detailed evaluation of the consequences of watershed disturbance, including logging, on the delivery and retention of organic matter in small streams of the Pacific Northwest. He noted that the replacement of coniferous with deciduous trees in recently logged areas can increase the delivery of nutrients, but that more rapid breakdown of delivered material and the accompanying reduction in both large wood and channel complexity, commonly expressed throughout the channel network of logged watersheds, "could produce a substantial reduction in stored organic matter." (Richardson et al. 2005:930).

Agriculture

Cultivated agriculture normally occupies a comparatively narrow range of low-gradient settings in a watershed. Thus, processes associated with steep slopes—particularly landslides and debris flows—found in logged watersheds are nearly absent here. However, the working of the agricultural land surface is far more intensive where it does occur, and a wider range of water-borne contaminants are potentially introduced. As with forestry, hydrology, sediment delivery, and nutrient dynamics are all affected by agricultural land use, but the nature and severity of its impacts on instream resources can be quite different. Runoff from agricultural watersheds, notably its load of nutrients and pesticides, were the historical impetus for the use of riparian buffers under an assumption of surface-runoff filtration (Osborne and Kovacic 1993). Brown et al. (2009) found that the legacy of prior agricultural land use, even in areas presently undergoing urbanization, is one of the strongest determinants of instream conditions in their nine study areas nationwide.

Grazing is a second, broad category of agricultural activities with significant impacts to streams, primarily as a result of direct encroachment into riparian areas and the channel itself. Belsky et al. (1999:2) reviewed dozens of mid- to late-20th century evaluations of grazing throughout arid lands of the American West that evaluated impacts to water quality and temperature, hydrology, channel geomorphology,

Watershed processes help create and maintain instream habitat. Thus the determinants of those processes are indirect but critically important to the understanding and the management of aquatic systems.

wildlife, and instream and riparian-zone vegetation. Their conclusion was that “[n]o positive environmental impacts were found” as a result of grazing, and they advocate complete cessation of grazing as the only sure course for recovery of riparian areas. More recent work (e.g., Agouridis et al. 2005; Raymond and Vondracek 2011) suggest that various strategies of rangeland management may have local success at reducing the magnitude of such impacts; but the large spatial extent over which grazing occurs in certain areas of the Pacific Northwest continues to make this a regionally significant impact to streams and riparian areas.

Urbanization

Urbanization is widely recognized to be the most intensive land use affecting watershed processes. It is also typically the most permanent, insofar as urban developments are rarely returned to anything approaching a natural state, a transition that is not precluded by agriculture and is quite practical in commercially managed forests. As a pervasive, near-total conversion of the land surface, urbanization has the ability to alter each of the dominant watershed processes wherever it occurs: hydrology (both surface and groundwater); the delivery of sediment, nutrients, pollutants, and sunlight; and the interaction of upland/terrestrial biota with the stream channel (Booth et al. 2004; Walsh et al. 2005). Nearly all of these alterations stem from the same fundamental change: the conversion of the land surface, with its vegetative cover and natural soils, to a variety of impervious and near-impervious surfaces. Undisturbed riparian corridors are widely recognized as useful protective measures for streams in urban areas, but all multi-scale evaluations of urban land cover and instream quality affirm the shared importance of not only riparian areas but also upland urbanization in ultimately determining instream conditions (e.g., Wang et al. 2001; Morley and Karr 2002). These watershed-level effects are significant at even low levels of urbanization (e.g., Vietz et al. 2014), and to date they have proven

virtually impossible to control under typical riparian-management policies, highlighting the continuing challenge of achieving meaningful aquatic-system protection in an urbanizing watershed.

8.2.3. How Does the Watershed Affect Riparian Areas?

Changes to an upland watershed and watershed processes can also affect the conditions and functions of riparian areas directly (Figure 8.7). Although a riparian area is commonly defined in terms of its relationship to the stream, it also has a relationship to the uplands that surround it. Water from the stream channel will commonly be the riparian area’s dominant source of both overland flow (during floods) and groundwater, but adjacent upland water sources can support riparian hydrology during periods of low flow. Much of the sediment that originates from the uplands is transported directly to the streams via channeled flow, but some fraction of that load will deposit before ever reaching the main channel, particularly if the riparian area includes a broad, low-gradient floodplain or if delivery occurs via episodic and channel-overtopping debris flows. Upland vegetation “buffers” riparian areas, providing

More important than simply protecting the habitat itself is protecting the processes that create and sustain that habitat. For this strategy to be successful, however, space in which that habitat can be expressed must also be protected.

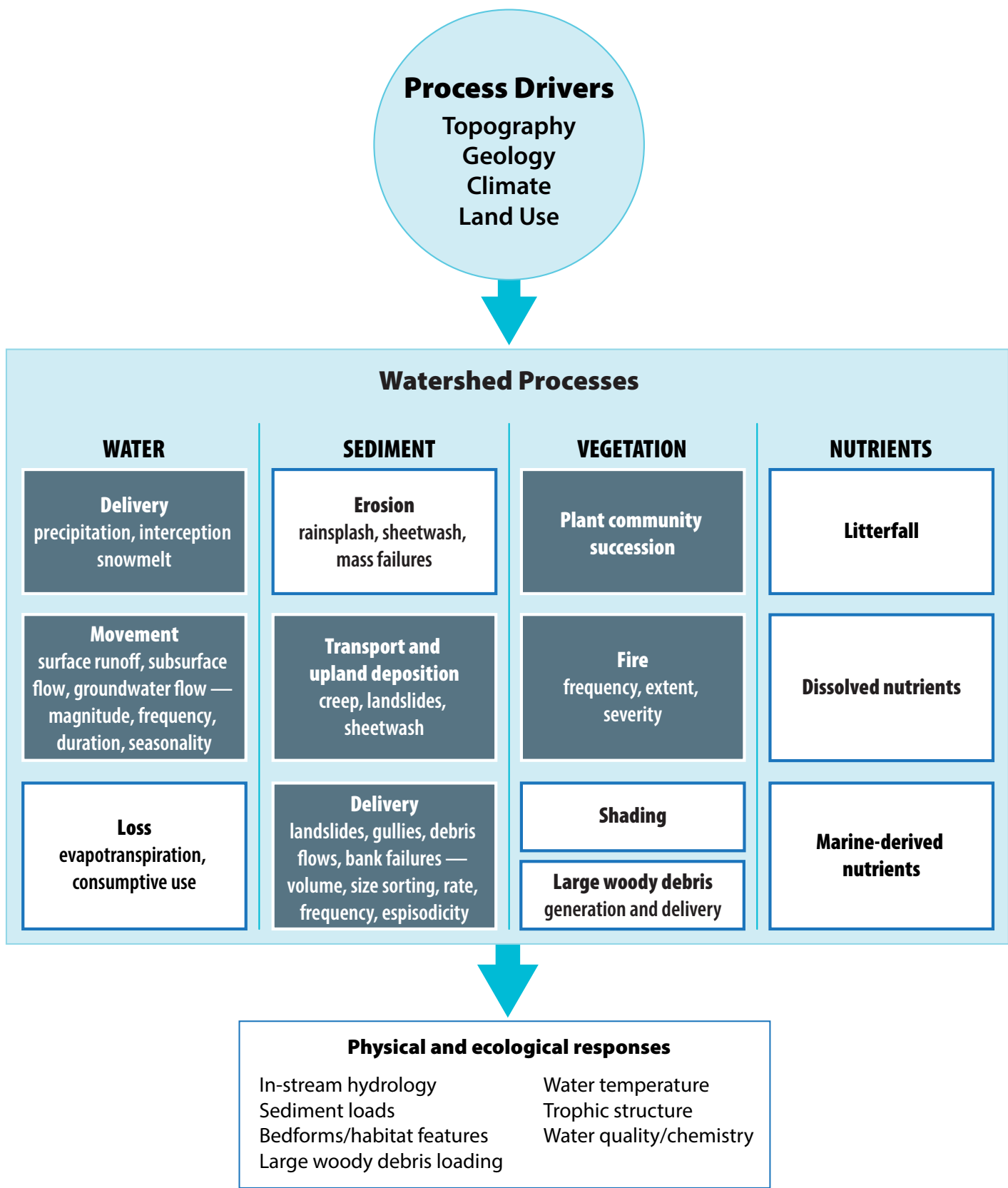


Figure 8.7. The conceptual framework of Figure 8.4, highlighting the subset of watershed processes (dark shaded boxes) that most directly affect conditions in riparian areas.

ecological connectivity between upland plant and animal communities with their riparian counterparts, and providing protection from mechanical disturbances, such as windthrow. Uplands also constitute a broader environment that either supports or suppresses wildfires that may freely cross the upland/riparian boundary.

Various land uses are relatively consistent with respect to their particular impacts to riparian ecosystems. That is, all three of the primary types (forestry, agriculture, urban) physically remove native vegetation, with differences only in the degree of impact. The loss of upland vegetation will consistently affect ecological connectivity and the risks of windthrow and fire regardless of the specific upland land use.

The interactions between uplands, riparian areas, and instream conditions are particularly complex with respect to wildfire. Arkle et al. (2010:299) found that “increasing riparian burn severity and extent were associated with greater year-to-year variation, rather than a perennial increase, in sediment loads, organic debris, large woody debris (LWD) and undercut

bank structure.” They emphasized a decrease in the stability of physical habitat and high variability in macroinvertebrate communities, which they attributed to annually fluctuating loadings of sediment, large wood and other organic material. They did not recognize any tendency for the macroinvertebrate community to become more like those of relatively undisturbed, reference streams over time, suggesting that changes to wildfire regime can result in permanent changes to stream ecosystems, and that these changes are a result not only of direct influence of burned areas on the stream but also of a permanently altered structure of the riparian corridor. With greater human disturbance, invasive species with high flammability (including those that have begun transforming riparian areas from fire breaks to fire-prone areas of a landscape; Coffman et al. 2010) become more common, as does the greater overall frequency of wildfire in modern human-dominated landscapes (Keeley et al. 2009). Thus this process driver, operating largely independent of typical considerations of riparian area management, can have a profound influence on instream resources (Pausas and Keeley 2014).



*Wildfire in Methow River valley, 2018/
Scott Fitkin, WDFW*

8.3. The Role and Limitations of Site-Scale Riparian Area Management

Whereas large-scale watershed processes govern the interactions and delivery of water, sediment, organic material, and nutrients to the stream over long distances, the effects of riparian vegetation on physical and ecological processes occur over much shorter distances with complex, direct, time-dependent interactions. These effects are expressed along river corridors “by influencing temperature and light regimes; producing organic detritus (leaf litter, woody debris); by routing water and sediment; by structuring the physical habitat at several scales; by providing a substrate for biological activity and habitat/cover for aquatic, amphibious and terrestrial animals” (Ward et al. 2002:524). For this reason, particular management attention to riparian areas is warranted, insofar as this part of a watershed has a unique, intimate interaction with the stream channel and its biota. Previous chapters explore these specific interactions in detail.

In addition to spatial relationships, temporal interactions are fundamental attributes of aquatic and riparian habitats. These habitats can be created by disturbances and also are episodically affected by them—streams are not static. Just as the influence of process drivers is not uniform across a watershed, so also is the influence of disturbances. In the case of floods, the most common and obvious of disturbances in rivers, this variability is primarily temporal and can be expressed through flood frequency, duration, seasonality (i.e., when in the year they occur), magnitude, and the predictability of occurrence (Lytle and Poff 2004).

The expression of these drivers, their interactions within a watershed and in individual streams, and their variability over time creates and maintains a dynamic mosaic of habitats. These interactions among drivers are complex and intertwined even in the absence of anthropogenic disturbances. Therefore, scientists have had difficulty separating the effects of the different drivers independently and in assessing how any species (even well studied salmon species) respond to this mosaic (Fausch et al. 2002). Adding to this complexity is the fact that habitats are species-specific; what constitutes habitat for one species may be mostly unrelated to what constitutes habitat for another aquatic species in the same river.

Thus, if riparian areas are managed with the objective of maintaining high-quality habitats for aquatic species, managers must ensure that riparian areas contribute what they can (i.e., separate from, but in combination with, watershed processes or drivers) to the long-term maintenance of the temporally variable spatial mosaic of habitat conditions. The mere presence of these habitats, however, is not sufficient: they must exist in configurations that are advantageous to aquatic species, with sufficient variety to support multiple life stages, adequate size and number to support a population, sufficiently proximate to be accessible from one to another, and yet sufficiently distal to not be subject to the same deleterious disturbances.

This, then, defines the fundamental challenge of watershed and riparian ecosystem management: given a system of great diversity and complexity, with attributes that can vary greatly and unpredictably in their influence over time, and biological communities that depend on both the diversity and interconnections between habitats, what fundamental principles should guide management to perpetuate fish and wildlife? We return to this question in the last section of this chapter.

8.4. Integrated Effects of Site-Scale Riparian Areas Management

"Connectivity" is the term most often used to describe whether organisms can move from one habitat to another (Taylor et al. 1993). It comprises two parts: structural connectivity, the physical relationships among habitat patches without regard for the behavior or organisms; and functional connectivity, the degree of movement of organisms through the landscape (Taylor et al. 2006; Kadoya 2009). The two are obviously related in all landscapes, but lotic systems impose some characteristic influences. First, there is a strong (though not universal) downstream bias on functional connectivity, insofar as most organisms and all inert constituents move in the direction of water flow. Second, impediments to flow can impose partial barriers to both structural and functional connectivity, but to very different degrees. For example, a culvert may allow most or all discharges to pass unimpeded but nevertheless present a barrier to migrating salmon (e.g., Davis and Davis 2011).

Concern over longitudinal barriers along a channel network typically focuses on the effects of instream physical barriers, particularly dams, culverts, and road crossings, rather than the consequences of longitudinal disturbances to riparian areas more broadly. Instream connectivity and riparian connectivity are related, however, even if they are not direct surrogates. Some types of discontinuity (e.g., a road running perpendicular to the stream) will affect the longitudinal connectivity (both structural and functional) of both; but others (e.g., an impassible migration barrier in the stream) will affect the movement of aquatic and terrestrial organisms quite differently. Most importantly from the perspective of riparian management, alterations that are limited to riparian areas can nonetheless affect instream

(functional) connectivity. For example, loss of shading from riparian area disturbance (Chapter 4) can create unfavorable instream temperatures that impact the movement or outright survival of migrating salmonids (e.g., Thorstad et al. 2008; Martins et al. 2012). Other direct and indirect actions, such as channelization, removal of large wood, or bank failures from vegetation loss can affect connectivity for migratory fish and among other aquatic species, and alter the flow of material and nutrients through the stream network.

These impacts have been explored in a variety of studies at multiple scales. Flitcroft et al. (2012:288) reported that "...[spatial] network variables perform better at explaining juvenile Coho Salmon *Oncorhynchus kisutch* density than instream habitat variables. Moreover, analysis of network distances among seasonal habitats indicates that juvenile Coho Salmon density may be higher where the distance between critical seasonal habitats is short." Perkin and Gido (2012:2183) found lower species richness in fish communities in stream networks fragmented by road crossings across multiple spatial scales. "Our findings support network connectivity as a mediator of ecological processes occurring within complex dendritic ecosystems and promote the need for improved connectivity to enhance conservation of metacommunity dynamics and biodiversity in dendritic ecological networks." Similarly, Favaro et al. (2014:1815) interpreted their findings on the influence of culverts in a channel network to demonstrate that "...fragmentation of habitats and populations acted on a whole stream scale rather than being restricted to within-stream differences that related to position."

These findings speak to the importance of recognizing the channel as part of the riparian ecosystem, that is, they form an interconnected system, both laterally and longitudinally. The degree to which seemingly isolated discontinuities affect either of these elements directly can ultimately impact the entire ecological network. Prescriptive management is challenging, however,

because the ecological functions of any given site or habitat patch along a channel network depend on its context and interconnection with other such sites. Furthermore, not all habitats have the same value for all species:

The relationship between species richness and connectivity is therefore determined by complex relationships among several interacting variables. In addition, species richness maxima for different faunal and floral elements occur at different positions along the connectivity gradient (Tockner et al. 1998). Fish diversity, for example, may peak in highly connected habitats, whereas amphibian diversity tends to be highest in habitats with low connectivity. Other groups attain maximum species richness between these two extremes. The resulting pattern is a series of overlapping species diversity peaks along the connectivity gradient, suggesting that habitats collectively traversing a broad range of connectivity will optimise community diversity in riverine landscapes. [From Ward et al. 2002:535.]

Although such studies emphasize the importance of connectivity along the channel corridor, they offer little guidance for managing these barriers and discontinuities beyond *less is better*. The impacts of road crossings, in particular, have been evaluated in several studies in Pacific Northwest lowland streams, comparing measures of biological conditions with the frequency of crossings that describe a negative, monotonic relationship (May et al. 1997; McBride and Booth 2005). Unfortunately, these studies do not suggest a consistent, discrete threshold of impacts that might serve as a management objective. For example, the study of McBride and Booth (2005) showed correlations between biological health (as characterized by a multi-metric index of benthic macroinvertebrates)



Chum Salmon *Oncorhynchus keta* need connected habitat to reach spawning grounds/Alex Biswas, WDFW

and road crossings with more than three crossings per km, whereas the biological differences reported by Perkin and Gido (2012) occurred on fragmented streams with as few as one road crossing over a stream segment length of one to many kilometers.

The overarching message from these studies is that any given implementation of site-scale riparian area management does not occur in a vacuum: “protecting a site” has ecological meaning only within the context of the entire channel network. Although existing computational tools can characterize the degree of fragmentation from discontinuities or the spatial coherence of a riparian corridor of varying width, the existing literature suggests that we lack clear deterministic linkages between alternative riparian management strategies and the resulting response of instream organisms, particularly the identification of thresholds of disturbance that impact fish mobility. However, any management action that results in frequent interruptions to riparian areas, or riparian corridors where blockage of terrestrial and aquatic organisms is not fully mitigated, is sure to have deleterious impacts to aquatic and terrestrial system health.

8.5. Managing Riparian Areas From a Watershed Perspective

The perspective of riparian area management developed in this chapter has been intentionally expanded, in both space and time, beyond that normally applied (and most feasibly implemented) in the Pacific Northwest. It relies heavily on the active research in the field of landscape ecology, which is organized around a few themes of particular relevance to riparian area management: 1) patches differ in quality, 2) patch boundaries affect flows, 3) patch context matters, 4) connectivity is critical, 5) organisms are important, and 6) scale is important (Wiens 2002:501). We will explore each of these in turn with an eye towards how management of riparian areas might be improved with respect to perpetuating fish and wildlife.

8.5.1. Patches Differ in Quality

Not every location along a stream is equally influential on the physical processes or ecological functions of the riparian-aquatic ecosystem. This generalization is complicated, however, by the fact that different perspectives may not assign the same level of “influence” to every location. For example, bedrock-bound channels have very limited capacity for response (Montgomery and Buffington 1997), despite the potential for highly variable, episodic inputs of water and sediment. Thus, from a geomorphological perspective they might be considered less sensitive and so “less critical” for riparian area protection. However, such

channels commonly occupy headwater, high-elevation positions in their watersheds that host potentially critical habitat(s) for a variety of non-fish species. A general treatment of the topic such as this cannot resolve the multiplicity of such complex phenomena across the diversity of landscapes in the Pacific Northwest, but this brief discussion suggests the importance of recognizing the range of riparian functions that must be served, and the improbability that they are all of equivalent importance throughout a channel network.

8.5.2. Patch Boundaries Affect Flows

In general, riparian regulations rarely consider the nature of the transition from riparian to upland (i.e., from regulated to unregulated) areas. This theme provides a reminder that the character of those transitions can affect each of the patches through the flux of material, energy, and organisms across their shared boundary. So, for example, when what was once a part of a forest interior becomes the exposed edge of a buffer strip, adjacent to recently cleared uplands, windthrow can greatly increase (and so compromise the riparian management area itself). Direct adjacency of a riparian area to urban development can invite substantial human intrusion (e.g., invasive species, excess nutrients, pesticides) into the riparian area, reaching all the way to the nominally protected stream because attention is not given to the relationship of upland development to the riparian area, nor to the “porosity” of the boundary between them.

8.5.3. Patch Context Matters

Riparian areas within separate watersheds containing different land uses (e.g., forestry, agricultural, urban) provide very different ecological functions depending on the adjacent land uses. The impacts to a stream from watershed urbanization, for example, span the range

from pervasive hydrologic changes (for which buffers are typically irrelevant) to pesticide-laden run-off (for which the pollutant removal that a buffer provides may be somewhat to highly effective). In a forestry dominated watershed, primary concerns may be the potential for unnaturally high delivery of sediment from increased rates of mass wasting; or potential losses of streambank integrity, habitat complexity, shading, large wood, and allochthonous inputs of organic matter.

According to Hansen et al. (2015:54):

Our review demonstrated that greater widths were required to achieve objectives when adjacent land use intensity was high, or when the objective of management was improving terrestrial biodiversity (particularly fauna). This becomes problematic when intense land use practices occur on small properties, reducing the amount of riparian land that can economically be protected or targeted for management...For example, if we apply the evidence summarized here to a streamside property used for dairying in the lower Hunter River, New South Wales, a riparian zone width of 40 m may achieve ≥75% reduction of nitrogen inputs to the river and reduce streambank erosion, contributing to improved downstream water quality. However, the same investment in riparian set-aside in the upper reaches of the Hunter catchment may provide additional improvements to stream nutrient processing (Lowe and Likens 2005), aquatic biodiversity (Chessman et al. 1997) and bird diversity (Bennett et al. 2014).

8.5.4. Connectivity is Critical

Connectivity in riparian areas occurs not only parallel to the stream (previous section), but also orthogonally to the channel in a lateral dimension – from the stream through the riparian area into uplands—and the vertical dimension in the hyporheic

zone. Typical riparian area regulations are generally successful at maintaining connectivity in the longitudinal dimension at some minimum width, although the consequences of limited interruptions to longitudinal connectivity (e.g., bridges, utility crossings) are commonly dismissed, a consequence of viewing riparian areas only from the perspective of lateral width rather than a recognition of the importance of stream network connectivity.

Longitudinal connectivity is especially important for the movement of sediment, large wood, and other organic matter. Fox (2003), for instance, found that the condition of riparian areas was a reasonable predictor for the quantity of large wood key pieces in adjacent stream channels; however, upstream basin characteristics and processes were likely responsible for most of the large wood in larger channels. Therefore, land managers should not base site-level objectives for in-stream large wood on the condition of adjacent riparian areas alone, but should also manage riparian areas at the watershed scale to provide adequate in-stream large wood throughout a watershed's stream network.



*Issaquah Creek is a tributary to Lake Sammamish in King County/
Derek Booth*



Figure 8.8. View of isolated wetlands (a) and riparian management zones (b) in a commercially logged portion of southwest Washington, providing some degree of local, structural connectivity within each buffer but no functional connectivity between them. Forested buffers in this image are approximately 50 feet (15 meters) wide.

Lateral connectivity, particularly between the riparian area and the adjacent uplands, is a more complex relationship, because improving this connectivity simultaneously enhances ecosystem protection but can also compromise the protection of a stream from upland activities. Continuity of a protected riparian area with uplands that are protected as well provides a range of key habitats for mobile species that depend on both upland and riparian environments for different needs or at different life stages. Separated patches with relatively porous boundaries may achieve only a modest fraction of these benefits, however, and truly isolated riparian-upland patches may be no better than an absence of

such habitats altogether (at least for many terrestrial species of concern) (Figure 8.8). Porous boundaries also run the risk of compromising some of the primary goals of a riparian management area, and so the nature of connectivity does not universally result in beneficial outcomes (see 8.5.2 above).

Vertical connectivity occurs at the ecotone between stream water and deeper groundwater. This ecotone, known as the hyporheic zone, is comprised of coarse sediments, and the vertical connectivity occurring there is more commonly referred to as hyporheic exchange (Boulton et al. 1998). Hyporheic exchange includes

water, dissolved solutes, fine sediments, fine organic matter, and small organisms. The size of the hyporheic zone is enlarged by structures such as large wood and boulders that store sediment. Hyporheic exchange is enhanced by structures such as large wood or boulders that redirect flow into the streambed and by undulations in channel morphology (e.g., meanders, pool-riffle beds) that intercept the flow of water.

In summary, the importance of connectivity is broadly recognized:

Restoration of important ecological processes often implies improving connectivity of the stream. For example, longitudinal and lateral connectivity can be enhanced by restoring fluvial dynamics on flood-suppressed rivers and by increasing water availability in rivers subject to water diversion or withdrawal, thereby increasing habitat and species diversity. Restoring links between surface and ground water flow enhances vertical connectivity and communities associated with the hyporheic zone. [From Jansson et al. 2007:589.]

However, tangible recommendations for how best to manage for this outcome in typical regulatory settings are more elusive.

8.5.5. Organisms are Important

Although not strictly an issue of spatial or temporal relationships between landscape elements, the recognition of organisms as key elements of riverine composition, structure, and functions is a valuable contribution of landscape ecology to watershed management. Some of these influences have been long-appreciated: the importance of large wood to stream structure and salmonid habitat, the role of root strength in mediating bank erosion, and indeed the entire construct of conserving riparian areas of native



Black Bear Ursus Americanus feeding on grass/Scott Fitkin, WDFW

vegetation to maintain ecosystem health. However, this perspective has broadened our appreciation of the multiple ways in which biota interact with the physical environment and each other to support the full range of watershed processes and thus the systems that depend on them (Beavers, bears, and marine nutrients, etc.). Management of riparian areas thus must include not only some awareness of the watershed in which that riparian area exists but also the biota that inhabit this environment (and, in some cases, move beyond its boundaries), and the ways in which those biota support the integrity of the aquatic ecosystem (Robinson et al. 2002).

8.5.6. Scale is Important

The goals and application of riparian management actions are generally limited in both space (i.e., the site) and time (i.e., the present). In a system as interconnected and disturbance-prone as a stream channel network, however, the site-scale management of a riparian area is *necessary*, but not *sufficient*, to ensure the desired composition, structure, and functions

of riparian and aquatic habitats. Of all locations on a natural or human-dominated landscape, river channels are probably the least stable in time, experiencing (and depending on) both gradual changes and episodic disturbance that structure their habitats and the organisms that utilize them. They also are subject to a spatial hierarchy of influences, not only those of the immediately adjacent riparian area itself (such as shade) but also those of the upstream watershed (delivering water and sediment to the channel) and the landscape even beyond its drainage boundaries. "Conditions far from stream banks affect the distribution of key instream habitat characteristics. Amount of instream wood, percentage of gravel, and pool frequency, which are essential to healthy salmon habitat, are particularly sensitive to land use" (O'Callaghan 2012:2). At even larger scales, the mobility of large terrestrial animals, the ability of salmon to return to headwater streams from the ocean, and the episodic disturbance from wildfire can exert equivalent (or greater) influences.

8.6. Conclusions

The perspective provided by landscape ecology emphasizes the temporally and spatially varying nature of habitats, and it suggests that achieving genuine habitat protection (and thus species conservation) is crippled by management that is limited to only narrow riparian corridors. To perpetuate fish and wildlife in the long term, three principles need to become integrated into the current paradigm for protecting aquatic ecosystems:

1. More important than simply protecting habitats is protecting the processes that create and sustain habitats. For this strategy to be successful, however, space in which that habitat can be expressed must also be protected. So, for example, instream and riparian area protection is indeed necessary, but it is not sufficient—the watershed and local-scale processes that create habitats within these areas must also be

maintained. Current paradigms that focus on site-level management of riparian areas will not successfully support the dynamic processes that maintain diverse, productive fluvial ecosystems.

2. Habitats have not only spatial but also temporal dimensions to their creation and maintenance, and they cannot retain their functions if they remain static. The historical frequencies, durations, and magnitudes of natural disturbances (flood and fire being the most common) need to be better understood and then emulated to the greatest extent that surrounding land uses can tolerate.

3. Spatial connectivity between habitats is critical, particularly for species (such as salmon) with a variety of habitat requirements at different life stages. Isolated key habitats for mobile species are scant improvement over no habitat at all.

Integration of these principles into the management of aquatic systems will be challenging under existing regulatory frameworks. However, even an awareness of their relevance to sustaining healthy ecosystems may reveal opportunities for their application in regulatory and non-regulatory settings alike. The following key points are offered in support of such opportunities:



Decaying salmon carcass/Ned Pitmann, WDFW

8.6.1. Manage the Riverine Landscape

The riverine landscape is the proper construct for understanding and managing aquatic systems. Although riparian areas are disproportionately important for fish and wildlife relative to their area on a landscape, they are not exclusively important. Although riparian areas affect many critical instream conditions, including temperature, nutrient input, bank stability, and large wood, while also filtering sediment and other pollutants from adjacent upland areas, the watershed outside of the riparian area is no less influential on the ultimate state of instream conditions, particularly with respect to its control of hydrology and sediment delivery. From even beyond a watershed's boundaries, influences on the stream can be carried by wind, mobile biota, and wildfire.

8.6.2. Manage at Multiple Scales

Effective and efficient conservation of fish and wildlife habitats requires management at multiple spatial and temporal scales. Just as the influences on streams arise from within and beyond the riparian area, management must find vehicles to embrace these multiple spatial scales as well. Treatments must also embrace the ever-changing temporal patterns of stability and disturbance, which not only result in constantly shifting physical habitats but also create the ecological template necessary for healthy, resilient biological communities (Ryan and Calhoun 2010). This will require approaches that allow sufficient space and for the expression of key habitat-forming processes (Beechie et al. 2010) rather than simply the creation or protection of static habitat features.

8.6.3. Connect Individual Actions

Particularly in rivers, longitudinal connectivity of individual locations is a defining feature of these systems and their biota, and so maintaining this connectivity is an essential consideration of aquatic ecosystem protection. We increase our chances of maintaining connectivity with coordinated actions across all riparian sites, and even more so by considering the entire riverine landscape as the focus of conservation efforts. However, connectivity is only as strong as its weakest link, and so even a single ill-executed action can preclude achieving this goal altogether.

8.6.4. Engage the Challenge of Implementing Effective Management

Adhering to these key points for achieving genuine riparian ecosystem protection, particularly in the face of continued human impacts, may not be presently attainable. Even if specific beneficial actions are neither everywhere known nor universally feasible to implement, our current understanding can support a positive trajectory. "Landscape conditions far from the river's edge may have strong impacts on instream conditions. Understanding the effects of natural processes and human activities across entire drainage basins is key to researching, monitoring, and restoring aquatic resources." (O'Callaghan 2012:5). Progress will require not only an appreciation of the most effective riparian management strategies but also a broadened perspective on the scope of necessary actions, actions that must extend far beyond the river itself and its adjacent riparian ecosystem.

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Chapter 9. Science Synthesis to Management Implications

By: Timothy Quinn, Kirk L. Krueger, and George F. Wilhere

9.1. Introduction

This chapter summarizes important scientific findings from chapters 1 through 8 and provides a brief discussion of scientific themes that can inform thoughtful approaches to protecting or restoring riparian ecosystems and associated aquatic habitats. The current state of the science, as reviewed in chapters 1 through 8, clearly demonstrates the importance of an intact riparian ecosystem to the proper functioning of aquatic habitats. It also introduces new studies on conservation of watershed-scale processes that directly affect aquatic habitats and that help maximize the ecological benefits of riparian ecosystems.

Riparian ecosystems are a priority habitat because their composition, structure, and functions dramatically affect a multitude of fish, amphibian, reptile, bird, mammal, and invertebrate species (Cummins 1974; Richardson et al. 2005). Although riparian ecosystems are a small portion of the landscape, approximately 85% of Washington's wildlife species use them (Thomas et al. 1979). Protecting or restoring high function to this relatively small portion of the landscape can disproportionately benefit many species and other important ecosystem goods and services (e.g., clean water, fisheries, and flood control) (NRC 2002).

Our definition of riparian ecosystem is integral to the development of management recommendations. Riparian ecosystems are transitional areas (ecotones) between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions,

ecological processes, and biota (NRC 2002). Riparian ecosystems include areas through which surface and subsurface hydrology connect waterbodies with uplands. They include those portions of terrestrial area that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Following Naiman and Bilby (1998), we include active floodplains and the terraces and adjacent uplands that contribute organic matter to active channels or active floodplains as part of the riparian ecosystem.

9.2. Summary of Chapters 2 Through 8

Chapters 2 through 8 discussed five key riparian ecosystem functions including bank stability, stream shading, wood recruitment, litter fall, and pollutant removal, as well as other topics related to the riparian ecosystems including stream channel morphology, nutrient dynamics, dryland riparian areas, and watershed-scale processes. Here we summarize the main points of each chapter.

9.2.1. Stream Channel Morphology (Chapter 2)

The stream morphology chapter explained how the composition, structure, and functions of riparian ecosystems and their associated aquatic habitats

depend on dynamic interactions of water, sediment, wood, and riparian vegetation. Important points from this chapter are:

- Erosion, transport, and deposition of sediment are part of a hierarchy of disturbance processes that continually create, maintain, destroy, and recreate the variety of aquatic habitats.
- Geomorphic processes related to the input of sediments to streams (from local stream bank erosion to mass wasting events) are integral to a watershed's natural disturbance regime and necessary for long-term ecological sustainability. For example, sediments delivered to streams from hillslope mass wasting events are often the predominant source of gravel, which is essential for salmon spawning habitat.
- Bank stability is one of five key ecological functions of riparian areas. Vegetation has mechanical and hydrologic effects on bank stability, and these effects can be stabilizing or destabilizing. However, in general, the net effect of vegetation is stabilizing.
- Simple models suggest that in an old-growth riparian forest, the full contribution of root strength to streambank stability is provided by trees within approximately 33 ft (10 m) of the streambank.
- Over a period of decades to centuries, a river or stream will travel across the entirety of its channel migration zone. Because the riparian ecosystem is defined by proximity to water, as the active channel moves back and forth across the channel migration zone, the riparian ecosystem moves with it.

9.2.2. Wood (Chapter 3)

Chapter 3 focused on the role of wood in aquatic ecosystems, and the recruitment of large wood to aquatic ecosystems. Wood plays a critical role in the composition, structure, and functions of riparian and aquatic ecosystems. In-stream large wood increases hydraulic complexity, i.e., creates a wider range of flow velocities, which causes pool formation, streambed scour, sediment deposition, and channel migration. The net result is a diversity of aquatic habitat types. Main points from the wood chapter include:

- The effects of wood on aquatic ecosystems in the Pacific Northwest are well-understood and ecologists are very confident about the critical role of wood in fish habitats.
- Ecologists are also confident about the role of riparian forests in supplying large wood to aquatic systems.
- Source distances for in-stream wood are a function of tree height in riparian ecosystems. Source distances are longer for riparian forests with taller trees.
- The main uncertainties for management are: the shape of the wood recruitment function, and in particular, the shape under different site-level and watershed conditions; and the potential contributions from recruitment mechanisms outside the riparian forest, such as landslides, debris flows, and extreme channel migration.
- In an unmanaged natural riparian area, 100% of a site's large wood recruitment potential comes from a distance of about 85 to 230 ft (26 to 70 m), depending on site productivity class. This does not account for additional wood recruitment through landslides, debris flows, or extreme channel migration.

9.2.3. Stream Temperature (Chapter 4)

The chapter on stream temperature presented a conceptual model for stream thermal regimes, discussed the effects of water temperature on fish, herpetofauna, and invertebrates; and reviewed the impacts of various land uses on stream thermal regimes. The chapter's key points include:

- Riparian vegetation can strongly affect stream thermal regimes (i.e., the spatial and temporal distribution of temperatures) which affects the survival and productivity of aquatic species. The importance of the thermal regime, not just summer peak temperatures, to aquatic species is increasingly acknowledged, but our ability to manage for suitable thermal regimes is limited.
- Fish and other aquatic organisms use different stream habitats, defined in part by specific water temperature ranges. However, the scientific literature is conclusive about the importance of cool stream temperatures ($\leq 60^{\circ}\text{F}$ [15.6°C]) for salmonid survival and productivity.
- Shade can substantially reduce the amount of direct solar radiation to the stream, which is one of the main sources of heating, especially in narrow low-order streams.
- Shade from riparian vegetation is affected by vegetation height, canopy density, and stem density. The width of a riparian area affects the amount of shading to the stream.

- A stream's thermal regime is also affected by latitude, elevation, aspect, topographic shading, channel bed shape, and water volume in addition to tributary, groundwater, and hyporheic flows.
- Structures such as large wood can reduce stream temperature by increasing pool depths, causing the development of undercut banks that provide shade, and by enhancing hyporheic exchange through redirecting surface flow to subsurface flow.

9.2.4. Pollution Removal (Chapter 5)

The pollutant removal function is unique in that it only exists in the presence of human activities that generate polluted water, and it is only necessary when nonpoint source runoff from upland activities threaten to degrade water quality. The pollution removal chapter covered the common sources, biological impacts, in situ chemistry, transport pathways, and results of removal efficacy studies for five types of pollutants—sediments, excess nutrients, metals, pesticides and other organic compounds, and pathogens. Key points from the pollution removal chapter include:

- There is overwhelming evidence in the scientific literature that riparian buffers¹ reduce nonpoint source water pollution for a variety of pollutants, and that riparian buffer width is the most important variable explaining removal efficacy.
- Research also indicates that the second most important variable in pollution removal is the vegetative composition and structure in riparian buffers.

¹ Riparian buffer refers to a strip of land adjacent to a stream that helps protect the stream from nonpoint source pollutants originating from upslope areas.

- Riparian buffer width recommendations depend on the particular pollutant to be removed and the desired removal efficacy. Policy makers must choose the desired removal efficacy.
- Models from four separate peer-reviewed meta-analyses show that riparian buffer widths for 95% removal efficacy of sediment range from 56 to 251 ft (17 to 76 m). Meta-analyses for other pollutants exhibit a similar degree of uncertainty with regard to riparian buffer width.
- Due to uncertainty regarding riparian buffer widths needed for a desired removal efficacy, management of riparian areas for the removal of pollutants should be monitored within an adaptive management program.

9.2.5. Nutrient Dynamics (Chapter 6)

The nutrient dynamics chapter explained the many effects of riparian areas on the three primary macro-nutrients: nitrogen, phosphorus, and carbon. Riparian areas can be nutrient sources or sinks, and riparian areas mediate the movements of nutrients between uplands and surface waters. Key points from the nutrient dynamics chapter include:

- Organic matter from riparian areas is an essential source of nutrients and chemical energy for aquatic ecosystems. Nutrients enter streams via plant litter fall or via surface and subsurface water flow.
- Streams in the Pacific Coastal Ecoregion of Washington (Naiman et al. 2000) are generally nutrient-poor and well shaded. Hence, additional nutrients (e.g., salmon carcasses) may enhance aquatic ecosystem productivity. However, aquatic

communities may be adversely impacted by excessive anthropogenic nutrients such as nitrogen and phosphorus.

- One study suggests that riparian area widths needed to deliver 95% of annual litter input from mature conifer forests to streams ranges from 39–54% of mean tree height depending on a site's slope and wind exposure.
- Empirical evidence suggests increasing salmon carcasses, and their marine-derived nutrients and energy, to riparian ecosystems could contribute significantly to the recovery of imperiled salmon populations.
- More research is needed on the effects of riparian litter fall on stream productivity and on the relationship between salmon harvest escapement and salmon population productivity.

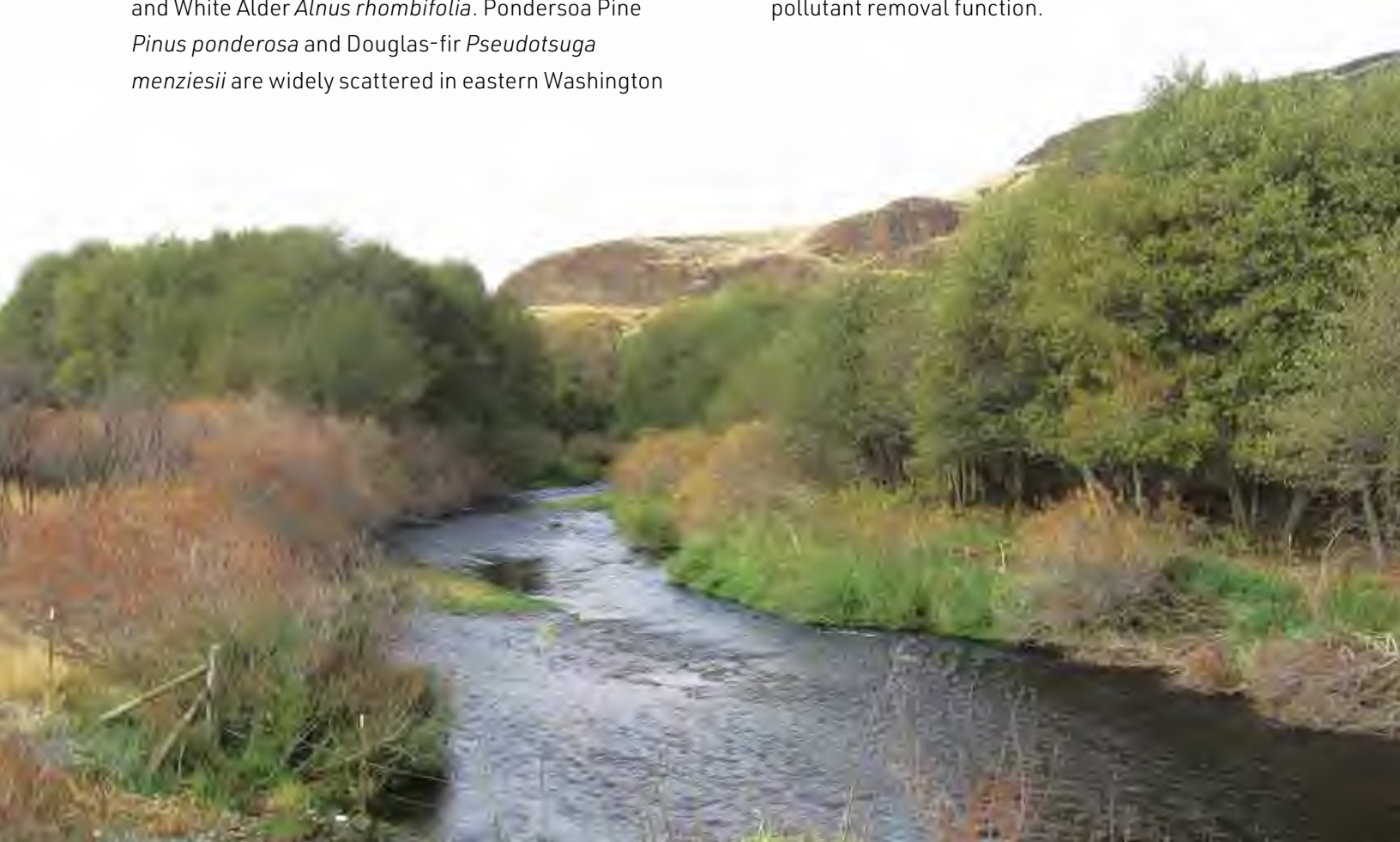
9.2.6. Riparian Areas of the Columbia Plateau (Chapter 7)

The chapter on riparian areas of the Columbia Plateau covered aspects of riparian ecology that are unique to this semi-arid to arid (i.e., dryland) ecoregion. The chapter clarified the definition of riparian ecosystem in dryland ecoregions, and reviewed the history of human impacts to riparian areas in the Columbia Plateau. It also reviewed the scientific literature on the five key riparian ecosystem functions – bank stability, stream shading, wood recruitment, litter fall, and pollutant removal – and it added a function of particular importance in the Columbia Plateau – alluvial water storage. Other important points include:

- Vegetation within riparian ecosystems of the Columbia Plateau often exhibits an abrupt demarcation between the riparian zone and the zone of influence. Phreatophytic trees and shrubs and hydrophytic herbaceous plants are confined to moist streamside areas, but the upland zone of influence may consist of sagebrush or bunchgrass communities.
- Nearly all riparian areas in the Columbia Plateau have been significantly impacted by human land use (grazing, intensive agriculture), resource exploitation (Beaver *Castor canadensis* trapping, timber harvest), water management (dams, diversions, reservoirs), or invasive plant species.
- Riparian areas in the Columbia Plateau are inhabited by a variety of deciduous woody plants, with the largest being Black Cottonwood *Populus trichocarpa* and White Alder *Alnus rhombifolia*. Ponderosa Pine *Pinus ponderosa* and Douglas-fir *Pseudotsuga menziesii* are widely scattered in eastern Washington

riparian areas and were likely more common historically than at present. Compared to forested ecoregions, large woody debris play a much smaller role in fluvial processes.

- A rudimentary classification system based on overstory conveys obvious differences in stream shading provided by riparian areas: tall tree, short tree, tall shrub, shrub, grass-like, grass, and forb. The obvious implication of these vegetation types is that some stream channels in the Columbia Plateau receive little or no shade from vegetation, even historically. However, the actual historical condition of many riparian areas is unknown.
- Where the riparian zone is narrow (<100 ft [<30 m]) or the zone of influence lacks tall trees (<100 ft), the width of the riparian ecosystem is based on the pollutant removal function.



The Tucannon River flows generally northwest from headwaters in the Blue Mountains of southeastern Washington to the Snake River/Terra Hegy, WDFW

9.2.7. Watersheds (Chapter 8)

The chapter on watershed-scale processes looked beyond the site-level perspective at which riparian ecosystems are normally studied and managed.

The chapter presented a conceptual framework that identified the key watershed processes and their primary influences on riparian ecosystems. The key points from the watersheds chapter are:

- Riparian ecosystems occupy perhaps the most dynamic and disturbance-prone area in a watershed. Nevertheless, the relative abundances of various aquatic habitat types in unmanaged, natural watersheds tends to remain constant over long periods (decades to centuries). In other words, at the watershed scale, habitat types appear to be in dynamic equilibrium.
- Riparian areas and surrounding watersheds are complex and dynamic systems comprised of many interacting components. These interactions across the watershed and through time create a mosaic of stream conditions necessary for self-sustaining populations of fish and other aquatic organisms.
- Some animal species have major impacts on the composition and structure of stream networks. Salmon, for example, restructure channel bed substrates during spawning and Beaver restructure the morphology and hydrology of floodplains. These “ecosystem engineers” are vital components of riparian ecosystems.
- Longitudinal, lateral, and vertical connectivity are critical for maintaining or restoring riparian ecological composition, structure, and functions. Studies have shown the importance of connectivity along the riparian corridor, but are often lacking specific guidance for management beyond “more is better.”

- The composition, structure, and functions of riparian areas are affected by surrounding land uses (e.g., forestry, agriculture, residential).
- The effectiveness of riparian ecosystems to protect aquatic habitats can be circumvented by anthropogenic changes at the watershed scale. The routing of water from human development to streams via channelized flow, for example, can result in changes to the stream hydrograph, changes in channel morphology, reduced efficacy of the riparian pollutant removal function, and increases in fine sediment inputs to streams.
- More research is needed on practical ways to maintain or emulate natural disturbances in watersheds dominated by human land uses (e.g., agriculture, residential). This includes disturbances such as flooding and landslides that are essential for maintaining aquatic habitats.

9.3. Key Management Implications from Chapters 1 through 8

- Protection and restoration of riparian ecosystems continues to be critically important because: a) they are disproportionately important, relative to area, for aquatic species, e.g., salmon, and terrestrial wildlife, b) they provide ecosystem services such as water purification and fisheries (Naiman and Bilby 2001; NRC 2002; Richardson et al. 2012), and c) by interacting with watershed-scale processes, they contribute to the creation and maintenance of aquatic habitats.
- Stream riparian ecosystems encompass the riparian zone, the active floodplain including riverine wetlands, and the terraces and adjacent uplands that contribute matter and energy to the active channel or active floodplain (Gregory et al. 1991; Naiman and Bilby 1998).



Engineered large wood structure in the north fork of the Lewis River/ Chuck Stambaugh, WDFW

Such terraces and adjacent uplands are called the zone of influence.

- The width of the riparian ecosystem is estimated by one 200-year site-potential tree height (SPTH) measured from the edge of the active channel or active floodplain. Protecting functions within at least one 200-year SPTH is a scientifically supported approach if the goal is to protect and maintain full function of the riparian ecosystem.
- Where the riparian zone is narrow (<100 ft [30 m]) and the zone of influence lacks tall trees (<100 ft), (e.g., in parts of the Columbia Plateau Ecoregion) the pollution removal function may determine the width of the zone of influence.
- The riparian ecosystem begins at the edge of the active channel or active floodplain, whichever is

wider. As the active channel moves back and forth across the channel migration zone (CMZ), the riparian ecosystem moves with it. Consequently, there are times when the riparian ecosystem lies adjacent to and immediately outside the CMZ. Hence, to maintain riparian ecosystem functions, management must anticipate and protect future locations of the riparian ecosystems.

- A near consensus of scientific opinion holds that the most effective and reliable means of maintaining viable self-sustaining fish, especially salmon, is to maintain/restore ecosystems to conditions that resemble or emulate their historical range of natural variability (Swanson et al. 1994; Reeves et al. 1995; Bisson et al. 2009). This opinion is based in part on the complexity of processes that affect the expression of habitats over time and space.

- The protection and restoration of watershed-scale processes, especially related to hydrology, water quality, connectivity, and inputs of wood, shade, and sediment are important for aquatic system function, and help maximize the ecological benefits of riparian ecosystem protections.

- Riparian areas and surrounding watersheds are complex and dynamic systems comprised of many interacting components. Natural disturbances (floods, fire, and landslides) across the watershed and through time create the mosaic of conditions necessary for self-sustaining populations of fish, especially salmon, and other aquatic organisms.

- Impending changes to aquatic systems as a result of climate change increase risk to species already threatened by human activities. The effects of climate change on rivers and streams threaten to reduce fish distribution and viability throughout the Pacific Northwest (Beechie et al. 2013).

- The use of the precautionary principle and adaptive management are particularly appropriate when dealing with complex and dynamic systems, and when we have uncertainty related to exactly how management activities affect functioning of watersheds and riparian ecosystems.

9.4. Width of Riparian Ecosystems

The width of the riparian ecosystem is based on the zone of influence, and the zone of influence is based on riparian ecosystem functions (or processes) that affect aquatic habitats. FEMAT's (1993) curves are conceptual models describing how four key riparian ecosystem functions change with distance from the stream channel (Figure 9.1). The four functions are root strength (i.e., streambank stability), stream shading, litter fall (i.e., input of detrital nutrients), and coarse wood debris to stream

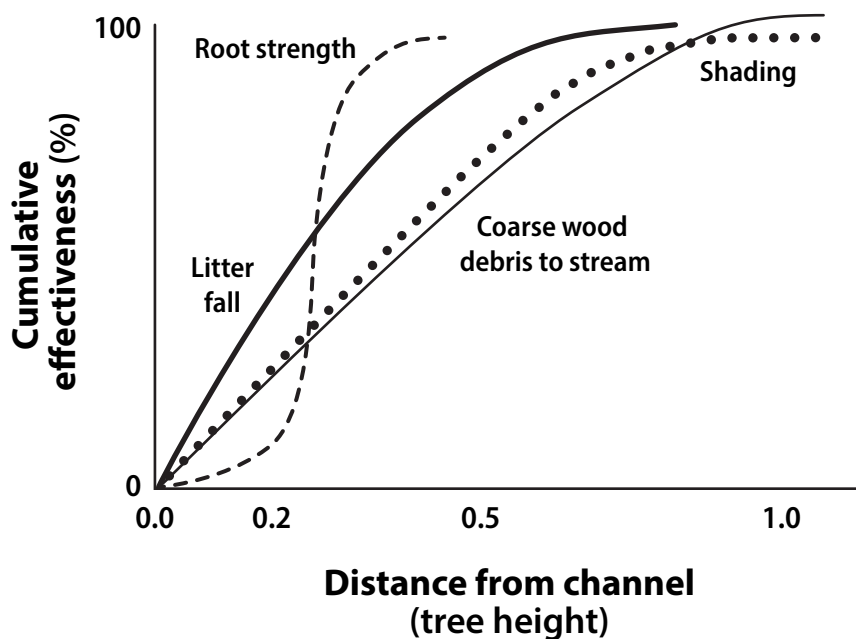


Figure 9.1. The “FEMAT Curves” (FEMAT 1993) are generalized conceptual models describing some riparian ecosystem functions and processes as the distance from a stream channel increases. “Tree height” in this figure is based on the average maximum height of the tallest dominant trees (200 years old or greater) and is referred to as site-potential tree height (SPTH).

stream (i.e., recruitment of large wood). FEMAT (1993) also included the pollution removal function (i.e., water quality) but did not create a curve for it. Originally, the curves were meant to convey two important points:

1) these four riparian ecosystem functions occur within one SPTH, and 2) the marginal return for each function decreases as distance from the stream channel increases. In other words, the FEMAT curves show that areas closer to the stream provide more of each function per unit width than areas farther from the stream.

The FEMAT curves are generalizations that ignore site-specific variability in riparian function among stream reaches. Nevertheless, FEMAT's conceptual models have influenced the width of riparian management zones (RMZs) in a number of important conservation plans such as the Forests and Fish Habitat Conservation Plan (DNR 2005).² Protecting natural vegetation within at least one SPTH is a scientifically supported approach if the goal is to protect and maintain ecological functions of riparian areas for the benefit of aquatic species. All else being equal, protecting areas narrower than one SPTH will result in lower levels of ecological function, and generally increase risk to fish and aquatic wildlife.

Although not all riparian functions are strongly associated with tree height (e.g., pollution removal), several key functions are, e.g., large wood recruitment, stream shading, and litter fall. Hence, the FEMAT curves use tree height of the dominant tree species to help estimate the amount of function provided by riparian areas of different widths. Consequently, the area within a site-potential tree height has often been used to define the extent of the "riparian ecosystem." However, FEMAT curves dealt strictly with functions strongly associated with vegetation and thus did not attempt to represent all aspects of the riparian ecosystem, such as other riparian functions or habitats for terrestrial species. For example, FEMAT curves did not explicitly address floodplains

and riverine wetlands, sub-surface water movements, nutrient dynamics, pollutant removal, or groundwater recharge.

Given its utility, the height of site-potential trees has been described for a wide variety of tree species and can be readily found in the silvicultural literature. Fox (2003) found that mean heights of dominant trees in riparian old-growth forest of Washington range from 100 to 240 ft (30 to 70 m). The wide range of heights reflects differences in site productivity, i.e., local differences in soil nutrients and moisture, light and temperature regimes, and topography (Avery and Burkhart 1994: 278). Site productivity is described quantitatively through a site index, which is the average height that dominant trees of a particular species are expected to attain at a specified tree age. Tables (e.g., King 1966) have been developed to predict the future average height of dominant trees on a site.

FEMAT (1993:V-34) defined site-potential tree height as "the average maximum height of the tallest dominant trees (200 years or more) for a given site class." The key phrase in this definition is "200 years or more" which refers to the approximate minimum age of old-growth forests (Franklin and Spies 1991). This reflects FEMAT's underlying assumption that old-growth forest conditions are needed for full riparian ecosystem functions. Because Douglas-fir can continue height growth for more than 200 years (Herman and Lavender 1990), site-potential height based on age 200 years is the minimum width for full riparian ecosystem functions according to FEMAT. Moreover, in addition to changes in SPTH with increasing forest age, other riparian forest components (e.g., basal area of live trees, species composition, volume of dead woody material) continue to change after 200 years of age (Fox 2003) resulting in what may be important but relatively unstudied implications for riparian ecosystem functions and values.

² However, we note that the Forests and Fish Habitat Conservation Plan (FFHCP) did not adopt the FEMAT (1993) definition of site-potential tree height. The FFHCP defined SPTH as the height of dominant trees at age 100 years.



Quinault River/Wendy Cole, WDFW

9.5. The Condition of Riparian Ecosystems

Many scientific experts (Swanson et al. 1994; Reeves et al. 1995; Bisson et al. 2009) believe that the most likely way to realize viable self-sustaining fish, especially salmon, populations is to maintain/restore ecosystems to conditions that resemble their historical range of natural variability³ (hereafter historical conditions). The scientific rationale for this opinion is that fish species have over many millennia adapted to particular disturbance regimes and consequent habitat conditions. Therefore, many scientists believe that dramatic deviation from historical conditions reduces the average survival and fecundity of animal populations, and thus puts species at risk of extinction (Swanson et al. 1994).

We define the historical conditions as the dynamic range of ecosystem composition, structure, and functions prior to significant impacts by Euro-American settlement (Swanson et al. 1994). Landres et al. (1999) suggest that the historical conditions provides guidance, context, and benchmarks for management. Understanding changes to historical conditions imposed by past

management action (e.g., clearcutting riparian areas) can inform decisions on future management and realistic future objectives, such as desired future condition (DFC). Articulating riparian DFC with awareness of historical conditions provides a meaningful benchmark for assessing potential loss of riparian function and potential risks to fish and wildlife populations (Landres et al. 1999; Morgan et al. 1994). Because historical composition and structure were driven by disturbances, Landres et al. (1999) also suggest that managers should maintain, or at least emulate, the disturbance processes that created historical conditions. In other words, historical conditions describe relationships between species and habitats and thus provide context and guidance for managing ecological systems in the future. Emulating historical conditions could include the appropriate use of engineered solutions (e.g., stormwater basins to reduce peak flows, placing large wood in streams) to protect or restore habitats. Bisson et al. (2009) promote this same concept for conserving freshwater habitats of anadromous salmonids.

Managing a site, reach, or watershed to more closely resemble historical conditions may also effectively serve as a coarse-filter conservation strategy. Coarse filter strategies are based on the idea that managing for a habitat type, perhaps by emulating historical

³Also referred to as "historical natural variability," "natural variability," "range of natural variability," "natural range of variability," "historical range of variability," or "reference variability" (Landres et al. 1999).



Riparian ecosystem near Naches/Mary Huff, WDFW

conditions, will more efficiently conserve many species rather than managing for each species separately (Hunter et al. 1988; Swanson et al. 1994). Consistent with Landres et al. (1999), managing riparian areas with a goal of emulating historical conditions may be more cost effective in the long run than other approaches as it should require fewer investments in mitigation for degraded riparian ecosystem functions. In other words, managing for historical conditions is consistent with the idea that avoiding impacts to habitat is less expensive and more scientifically defensible than restoring habitat for each species after impacts.

Emulating an ecosystem's historical conditions poses both empirical and conceptual challenges. Empirical data needed to estimate the historical conditions are seldom available, and when available, the data are usually inadequate for the task of reliably estimating historical variation over time and space (Keane et al. 2009). The biggest conceptual challenge is posed by the ever-changing environment, much of it wrought by humans. While the historical conditions provides

the best description of habitats that supported fish and wildlife species in the past, we recognize the challenge of applying that knowledge to watersheds that have been drastically altered by exotic species, fire suppression, intensive land uses, and climate change. Despite these challenges, Keane et al. (2009) still believe that the historical conditions provides an essential perspective for managers.

Historical conditions are the result of natural processes such as frequent floods, landslides, and wildfire – some of catastrophic magnitude – occurring throughout a watershed. Hence, for obvious reasons, managing riparian areas so that they roughly match their historical conditions may be unrealistic, especially in residential or agricultural settings. Furthermore, WDFW acknowledges that other uses of riparian areas as legitimate and worthwhile. Such uses and a wide variety of societal values must also be considered when developing strategies, plans, or rules for riparian areas. Therefore, rather than a goal, the historical conditions may better serve as a guide.

Dynamic mosaics of riparian and aquatic habitats are created, maintained, and altered in predictable (e.g., seasonally) and unpredictable ways (e.g., due to random events like storms, fires, and landslides).

9.6. Other Important Issues

We highlight three important issues that deserve more in-depth discussion: complexity, connectivity, and climate change. We also consider management implications of each issue for riparian areas and watersheds.

9.6.1 Complexity

The ecologist Frank Egler stated, "Ecosystems are not only more complex than we think, but more complex than we can think" (Egler 1977). Riparian ecosystems fit that description – they are dynamic, nonstationary, nonlinear systems comprised of many interacting components. In dynamic systems, conditions continually change over time. Dynamic equilibrium, for instance, means that conditions continually fluctuate about an

average state, and the long-term statistics describing that process – mean, variance, fluctuation frequency – remain virtually constant. Nonstationary means that a system's functional relationships are changing over time, and consequently, the long-term statistics describing the process are changing. Some scientists believe that future climate change will lead to more pronounced nonstationarity in aquatic ecosystems (Milly et al. 2008). Nonlinear implies that functional relationships between ecosystem components are complicated. Under certain conditions, some types of nonlinear relationships may exhibit chaotic behavior. Not surprisingly, predicting the effects of management actions on dynamic, nonstationary, nonlinear systems is challenging.

Frissell et al. (1986) helped conceptualize watersheds as hierarchical systems where larger scale components, structures, and processes act primarily in the downstream direction on smaller scale components, structures, and processes. Factors that affect processes



The Nooksack River is located in the northwest part of Washington. It drains an area of the Cascade Range around Mount Baker, and flows through a fertile agricultural area before emptying into Bellingham Bay./Department of Natural Resources

over the longest duration can be considered “drivers” of the conditions and processes at lower levels in the hierarchy. Climate, geology, topography (and land cover) largely determine watershed characteristics and processes (paraphrasing the framework of Montgomery 1999). However, the composition, structure, and functions of streams and riparian ecosystems do not simply arise from these drivers. They are created and modified by continuous and episodic fluxes of materials (particularly water, sediment, and wood) and energy, which are broadly termed watershed processes. Dynamic mosaics of riparian and aquatic habitats are created, maintained, and altered in predictable (e.g., seasonally) and unpredictable ways (e.g., due to random events like storms, fires, and landslides).

These types of nonlinear dynamics are intrinsic properties of all ecosystems and important for the creation and maintenance of habitats that fish and wildlife populations depend on (Fausch et al. 2002; Ward et al. 2002; Wiens 2002), including salmon (Merz et al. 2015). The availability of multiple types of habitat (i.e., habitat heterogeneity) within and among streams may be essential for the persistence of multiple life history strategies in salmon species (Hilborn et al. 2003; Bisson et al. 2009; Waples et al. 2009; Merz et al. 2015) and the coexistence of other aquatic and riparian-dependent species (Bellmore et al. 2015).

The availability of multiple types of habitat within and among streams may be essential for the persistence of multiple life history strategies in salmon species and the coexistence of other aquatic and riparian-dependent species.

How should we approach the management of ecosystem complexity? Because ecosystems are wickedly complex (Ludwig 2001) and exhibit irreducible natural variability at multiple spatial and temporal scales, managers should adopt an attitude of humility. Over-confident managers who approach decisions with resolute certainty may fail to anticipate problems or recognize potential risks. Humility should instill in managers a desire to understand more before acting and a further desire to continually improve one’s understanding of the system. The former is a quality of the precautionary principle, and the latter is a philosophical underpinning of adaptive management. Adaptive management is discussed later in this chapter.

9.6.2. Connectivity

Several chapters in this volume introduce the idea of watershed connectivity, in particular, longitudinal, lateral, and vertical connectivity. Connectivity is vital to aquatic ecosystem function and especially important at conferring resiliency to the negative effects of climate change (see section 9.6.3). Streams and their associated riparian ecosystems transport water, wood, sediment, nutrients, and organisms predominantly, but not exclusively in the downstream direction. Longitudinal (upstream to downstream) fragmentation of streams, for example by road crossings that block passage of fish, can reduce habitat capacity for individual species and change aquatic community composition by impeding movements of fish and other animals. Dams and undersized culverts also reduce the transport of large wood and sediment from upstream areas, which can adversely impact habitat composition and structure. Loss of lateral connectivity between streams and their floodplains due to levees, dams, or channel incision can reduce development of off-channel aquatic habitats, alter riparian plant communities, and impact processes such as water storage and nutrient cycling. Reduction of vertical connectivity, i.e., exchanges between stream water and deeper groundwater in the

hyporheic zone, can increase stream water temperatures, alter stream chemistry, and impact macroinvertebrate populations.

The importance of connectivity is also supported by our understanding of the extents at which aquatic species, especially fish, use stream habitat (Fausch et al. 2002). Movement of individuals among reaches and watersheds to locate specific habitat conditions (e.g., suitable water temperatures) is increasingly acknowledged as important to fish population persistence, particularly in light of climate change.

Maintaining connectivity in aquatic ecosystems likely requires management at site and watershed-scales. Management to protect or restore salmon and other aquatic species should ensure that all parts of a stream network that could be accessible to fish are in fact accessible to fish. That is, artificial structures should not impede fish movement. This requires watershed-scale stream network inventories and site-scale correction of artificial barriers. Additionally, barriers to the longitudinal or lateral transport of sediment and wood should be corrected, and hyporheic exchange should be enhanced by restoring the processes that supply in-stream large wood and coarse sediments. Where practical, management should ensure that the flows of water, sediment, and wood continue to flow as they did historically.

9.6.3. Climate Change

Climate change is expected to directly affect aquatic ecosystems by increasing air and water temperatures, altering stream hydrology, and impacting sediment yields throughout Washington. Indirect effects are too



Bull trout in Deep Creek, Yakima County/Eric Anderson, WDFW

numerous to mention here but are likely to include changes to riparian plant communities, changes in fire regime, introduction of new diseases, exotic pests, and competitors with salmon. Because water temperature is widely recognized as one of the most important environmental factors influencing the geographic distribution, growth, and survival of fish (Regier et al. 1990; Armour 1991; McCullough 1999), the warming effects of climate change on rivers and streams threaten to reduce fish distribution and population viability (Beechie et al. 2013). The Pacific Northwest experienced a significant warming trend in summer stream temperatures of approximately 0.40°F/decade (0.22°C/decade) between 1980 and 2009 (Isaak et al. 2012). In the future, August stream temperatures are expected to increase an average of 5.1°F (2.8°C) by the 2080s (Isaak et al. 2015), and stream temperatures are expected to increase in all seasons of the year. The effects of climate change on surface water temperatures are compounded by other anthropogenic increases of water temperature caused by removal of riparian vegetation, water withdrawals, and channelization of streams (Poole and Berman 2001; Moore et al. 2005).

Climate change is projected to cause major changes in hydrology across Washington. Scientists have already detected negative trends in glacier volume and snowpack (Granshaw and Fountain 2006, Sitts et al. 2010, Stoelinga et al. 2010) and earlier peak streamflow in many rivers (Stewart et al. 2005). These trends are expected to continue in the future, along with increasing flood magnitudes, declining summer minimum flows, and rising stream temperatures (Elsner et al. 2010, Mantua et al. 2010). In Washington State, projected changes in future annual total precipitation are generally small compared to year-to-year fluctuations in seasonal and annual rainfall. Nonetheless, hydrological projections for the mid to late 21st century show a shift in flood frequencies that results in larger peak flows at all recurrence intervals, e.g., 2-year, 5-year, 10 year, etc. in some watersheds (Salathè et al. 2014). Changes are projected to be most pronounced in middle elevation basins, where a substantial proportion of the basin is located near the snowline (i.e., the "mixed rain and snow" zone). In these watersheds, warming will cause more precipitation to fall as rain instead of snow, which will decrease snow accumulation, hasten melt, and increase runoff (Hamlet et al. 2007).

Changes in stream flow are expected to alter sediment transport and channel morphology, however, published research analyzing the potential impact of future climate change on fluvial processes is limited. Praskievicz (2015) modeled the effects of future climate on geomorphic responses in three snow-dominated river basins of Idaho and eastern Washington. The results from the first site on the Tucannon River indicate that net sediment deposition is likely to occur, with increasing mid-channel bars. The second study site on the Coeur d'Alene River projects net erosion, and results for the third site forecast minimal changes on the Red River. These varying results indicate that the impacts of climate on sediment movement also depend on local context, i.e., how reach traits, such as substrate size or riparian vegetation, affect a stream channel's morphological stability or lateral mobility.

Management to minimize direct detrimental effects of climate change on aquatic habitat includes: 1) increasing shade to streams by protecting or restoring riparian forests, 2) decreasing thermal sensitivity of surface waters by increasing summer low flows, 3) maintaining longitudinal, lateral, and vertical connectivity within watersheds, 4) monitoring and mitigating stream temperatures, especially when management actions are known to cause stream temperature increases, and 5) developing contingency plans for responding to climate related changes to water temperature, hydrology, or channel morphology. Because riparian areas can provide longitudinal habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife, climate change makes the restoration of riparian areas especially important (Seavy et al. 2009).

9.7. Uncertainty and Management

Chapters 2 through 8 demonstrate that management of riparian ecosystems often involves substantial and unavoidable uncertainty, despite the fact that many riparian ecosystem functions are well understood. We include a discussion on uncertainty in management because effective use of scientific knowledge requires an understanding of its uncertainty (Fischhoff and Davis 2014) and because addressing uncertainty can lead to better long-term outcomes (Steel et al. 2009) for all stakeholders.

Some uncertainty is due to limited knowledge. For instance, the historical composition and structure of native riparian vegetation in the Columbia Plateau remains relatively unknown (see Chapter 7). Research can improve knowledge and reduce this type of uncertainty. A less well-appreciated type of uncertainty is associated with stochastic environmental variability, which introduces irreducible uncertainty or "unavoidable unpredictability" (sensu Spielgelhalter and

Riesch 2011) into the expected effects of management decisions. In other words, the longer one's time horizon for management decisions, the more likely that less expected, or even unexpected effects are going to occur. This type of uncertainty can be quantified through research, but never reduced. For example, large floods may unexpectedly alter channel form (e.g., widen a channel) and as a result change a stream's thermal regime. This in turn can decrease the effectiveness of management aimed at maintaining stream temperature based on pre-flood riparian conditions (see Chapter 4). This concept is important because conditions created by some land management actions are ubiquitous and long-lived (e.g., young forests after timber harvest), thus creating a situation where less expected effects due to environmental variability are virtually guaranteed.

Using stream temperatures to discuss uncertainty is instructive because our understanding of riparian effects on stream temperatures is arguably the best developed of any riparian function (see Chapter 4). We know for instance how certain ecosystem composition, structures, and functions (predictor variables) affect stream temperatures, so we could accurately predict the effects of common management actions with high certainty. Unfortunately, logistical or economic constraints of collecting predictor variable data usually preclude the development and use of such models. Instead, we often employ simpler, statistical models or correlations to inform management. For instance, we can generally predict changes to water temperatures based on changes to shade from riparian vegetation because changes in shade are often strongly correlated with changes in water temperatures (Cristea and Janisch 2007).

Figure 9.2 shows the results of several studies relating changes in summer stream temperatures to changes in riparian buffer width. Stream temperatures were measured before and after reducing the widths of forested riparian buffers, which decreased shading of streams. The results of such studies are often assumed

to predict the effects of shade reduction on stream temperatures in other locations. However, because each stream is unique (e.g., differences in stream widths, topographic shade, groundwater flows, etc.), changes in water temperature based solely on shade are relatively uncertain. For example, Jackson et al. (2001) found that 30-ft wide forested buffers caused summer stream temperatures to increase by an average of 4.2°F (2.4°C), but the 95% confidence interval for the average was -0.1° to 8.6°F (0.0 to 4.8°C). At one site, temperatures decreased, likely due to unmeasured effects on groundwater flow (Janisch et al. 2012). Such uncertainty is common. Additional studies of this type might narrow confidence intervals and more accurately estimate the average response, but predictions of stream temperature based on buffer width alone will remain highly uncertain despite our knowledge that shade can strongly affect water temperature.

Similarly, empirical data describe wood recruitment from riparian areas as increasing with distance from the channel (i.e., riparian area width), but this relation varies widely among streams (Figure 9.3). Other potential predictor variables might include the wood recruitment mechanism, topography, fire regime, and forest age. However, we are unaware of other recruitment models that include variables that would allow us to predict the effects of management actions on wood recruitment with high certainty.

Currently, most riparian ecosystem functions described in this volume are best described with statistical models or correlations that often reliably predict the direction or sign (+ or -) of the correlation and some of the variability around the central tendency. Many such models rely on data from few sites that poorly describe the average or range of relations. For example, sample sizes for studies in Figure 9.2 are small, i.e., $N = 6, 3, 5$, and 5. Additional studies with larger sample sizes could better describe responses to shade reduction but are unlikely to substantially reduce uncertainty if they do not consider other important predictors in addition to buffer width.

Even as we conduct studies that reduce uncertainty associated with a lack of knowledge, we are continually challenged to make sound decisions into the future by irreducible uncertainty due to stochastic events, such as natural disturbances, and non-stationary processes like climate change. As riparian ecosystems change through time, whether due to future wildfire, floods, or climate change, we must ensure that our management strategies meet their intended goals. Uncertainty about the future effects of current management actions is perhaps the biggest challenge faced by managers because those effects of management often persist over long periods or may be practically irreversible (e.g., loss of riparian areas due to residential development). With this uncertainty comes the risk that the unpredictable may convert current and successful regulatory policies

or management practices into future failures. We can never eliminate uncertainty, but we can make management decisions that are appropriate given our current level of uncertainty. We recommend reducing risk to riparian ecosystems by: 1) reducing uncertainty through new research, 2) explicitly acknowledging and directly addressing uncertainty in policy and management decisions that affect fish and wildlife habitats, 3) considering the application of the precautionary principle to reduce unacceptable risk (O’Riordan and Jordan 1995; Gullet 1997). That is, erring on the side of caution, particularly when dealing with environmental impacts that are difficult to undo (irreversible damage or long recovery times), and 4) practicing adaptive management.

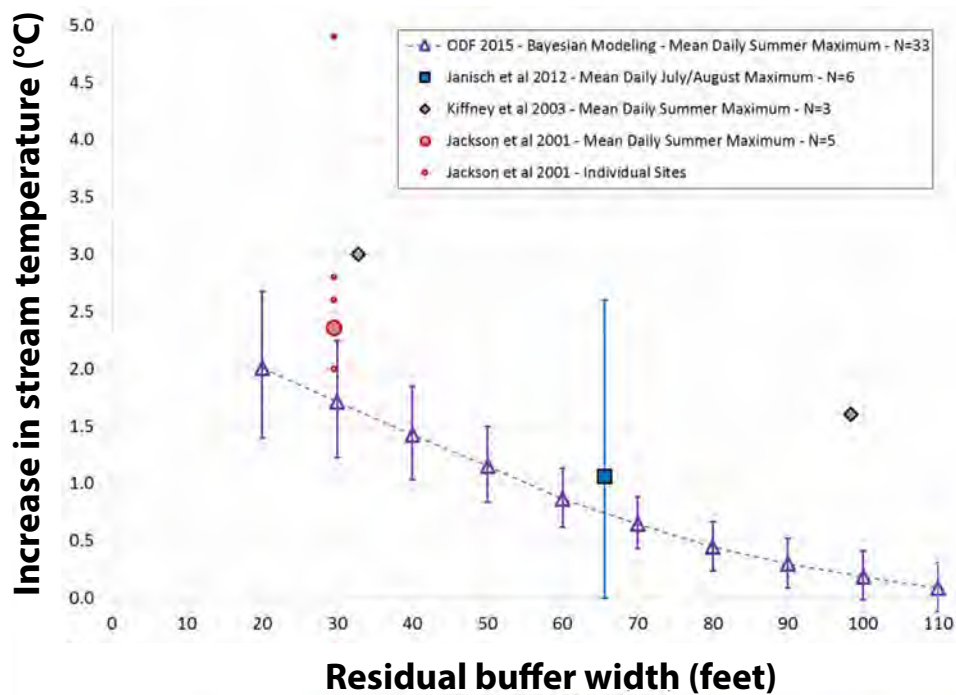


Figure 9.2. Observed temperature response associated with “no-cut” riparian buffers with adjacent clearcut harvest. Only studies that employed a Before-After-Control-Impact design and conducted in Pacific Northwest forests are included. Bayesian modeling results (and 90% credible intervals) were derived from data collected as part of Groom et al. (2011). A change of 1°C is equivalent to a 1.8°F change. Analyses provided by P. Leinenbach, USEPA Region 10 (See Chapter 4 for a more complete description of this figure).

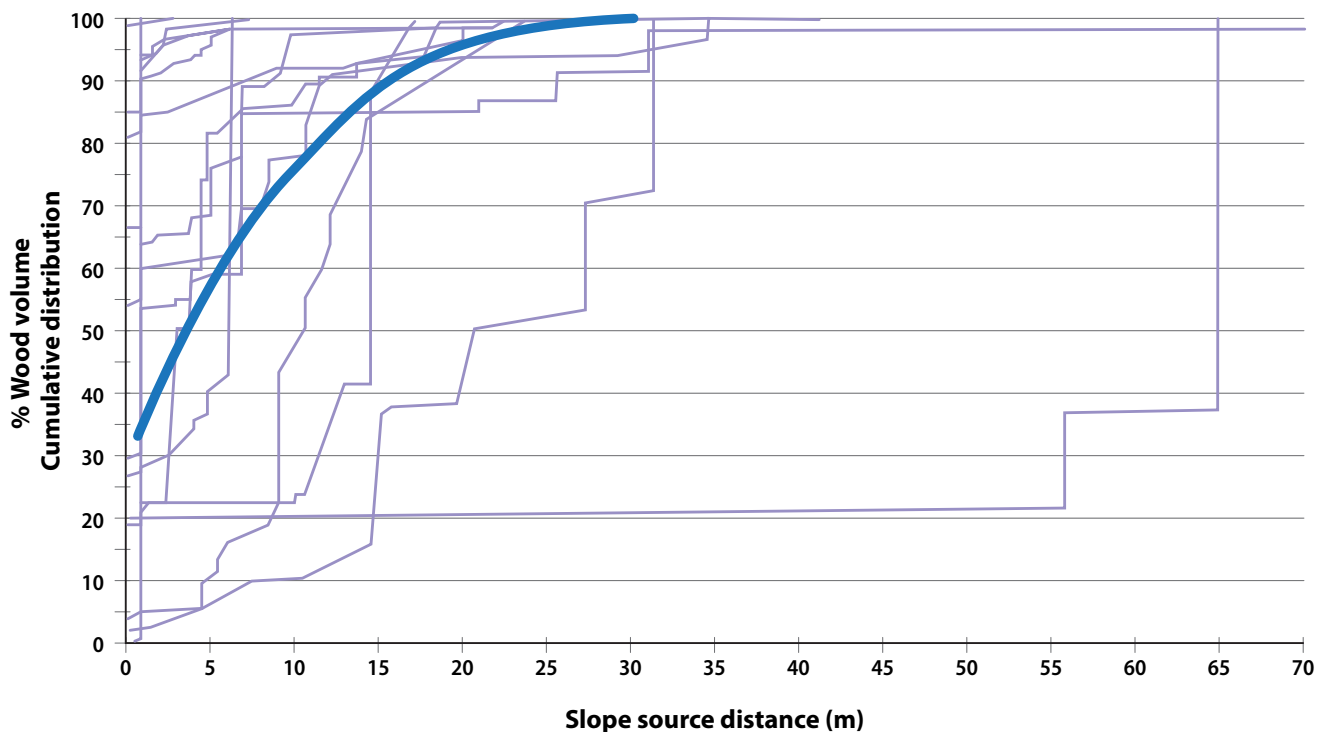


Figure 9.3. Sixteen large wood recruitment curves for second-growth redwood forest on 16 sites in northern California (from Benda et al. 2002). The theoretical prediction curve (thick line) is based on mortality recruitment only using random 360° fall trajectories. Curves to the left of the theoretical curve are sites where bank erosion is a major recruitment mechanism. Curves to the right of the theoretical curve are sites where landsliding is a major recruitment mechanism. (See Chapter 3 for a more complete description of this figure).

9.8. Adaptive Management

Despite new insights into ecosystems dynamics and better understanding of the effects of management actions on species and their habitats, natural resource management decisions will always struggle with some level of uncertainty. Adaptive management is widely recognized as a sensible, if not essential, approach to the management of natural resources under uncertainty. As originally conceived, adaptive management can be defined as the systematic acquisition and application of reliable information to improve management over time (Wilhere 2002). Reliable information is acquired through statistically-valid research and monitoring. Furthermore, adaptive management can facilitate a way

forward when levels of uncertainty become high enough to threaten stakeholder agreement about environmental policies (Wilhere and Quinn 2018).

The adaptive management process is a continual cycle consisting of planning, action, monitoring, evaluation, and adjustment (Bormann et al. 1994, Wilhere 2002) (Figure 9.4). Monitoring and evaluation form a feedback loop that provides information for management decisions. However, feedback alone cannot fulfill the goal of adaptive management, that is, the continual improvement of management. Ideally, an “adaptive management plan” integrates every phase of management with monitoring, and considers how information collected through monitoring will lead to future changes in management. Developing an adaptive management plan should be a collective endeavor of policy makers, managers, field staff, and scientists.

Successful adaptive management requires an understanding of all stakeholder perspectives. Hence, developing an adaptive management plan should begin with discussions amongst stakeholders about their concerns regarding uncertainty and risk. The plan should be developed through a negotiated process, and it should explain how specific risks will be addressed through a program of systematic learning (e.g., management experiments, focused monitoring, targeted literature reviews, etc.). Importantly, the best adaptive management plans have agreements about the specific information necessary to change policy or management and what those changes might be.

Adaptive management programs can fall victim to the widespread confusion between the roles of values

and science in management decisions (Wilhere and Quinn 2018). Maintaining a clear distinction between values (cultural, social, and economic) and science, and between the roles of policy makers and scientists, is critical to success. That said, WDFW recognizes that natural resource management or land use policies must often balance competing ecological, economic, and social values. In fact, one of WDFW's conservation principles is that management decisions should integrate ecological, economic, and social perspectives. This volume addresses only the ecology of riparian area management; it does not cover economic and social aspects. Determining an acceptable balance requires a political process involving stakeholders, local governments, tribes, and state agencies. We hope this volume can help to inform that process.

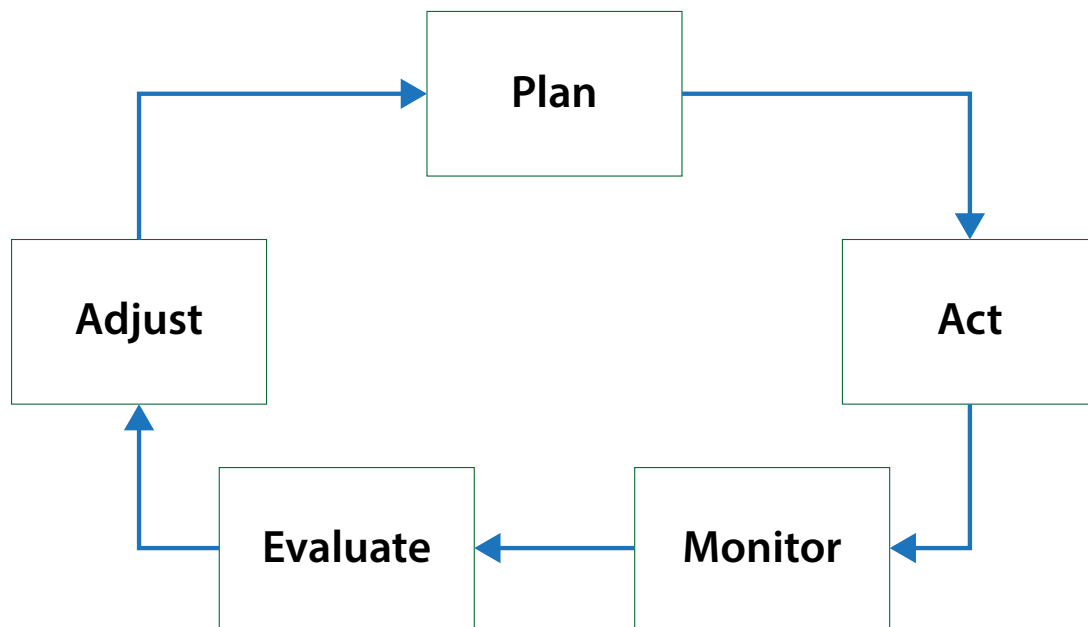


Figure 9.4. The adaptive management cycle (modified from Bormann et al. 1994).

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⁴ References are classified according to RCW 34.05.271 (see Appendix 1) denoted by a lower case roman numeral (i - viii) in parentheses at the end of the citation.

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Grande Ronde River/Alan Bauer

Appendix 1: Glossary



Riparian areas along streams (blue lines) in north King County/Terry Johnson, WDFW

Active channel

The portion of a stream channel defined by the lower limit of continuous riparian vegetation, and it may be delineated by absence of both moss on rocks and rooted vegetation. The upper most elevation of the active channel is sometimes equated with the ordinary high water mark.

Active floodplain

A portion of floodplain that is located between the active channel and adjacent terrace or hillslopes. Depending on the watershed, the flood return interval of the active floodplain varies between 1 and 10 years.

Adaptive management

The systematic acquisition and application of reliable information to improve management over time. Ideally, adaptive management treats management decisions as

experiments in order to address critical uncertainties and learn more quickly from experience. It involves setting targets, monitoring outcomes, and adjusting management decisions based on results. Hallmarks of a well conceived adaptive management program include: 1) adequate funding for research, 2) a willingness to change course when pre-established triggers are reached, and 3) a commitment to monitor and evaluate conditions at appropriate spatial and temporal scales. See Ecosystem-based management.

Anthropogenic

Caused by human activity.

Channel confinement

A description of how much a channel can laterally move within its valley determined by the ratio of valley width (distance between toe of hillslopes on both sides of a

valley) to active channel width. Typically, a segment is considered confined when the ratio is less than two and unconfined when greater than four.

Channel migration zone

The area within which a river channel is likely to move laterally over a specified period (e.g., 100 years).

Channel morphology

A stream channel's shape, which changes over time due to the interplay of water, sediments, vegetation, and certain animals, e.g., Beaver *Castor canadensis* and salmon.

Channel reach (stream)

A continuous segment of a channel that has similar physical features, such as gradient and confinement.

Channel slope or gradient

The average steepness of a stream segment measured as its change in elevation divided by its length. Typically, a segment's gradient is considered low if less than 2%, moderate between 2% and 4%, and high if greater than 4%.

Composition: See *Ecological composition*.

Disturbance regime

The frequency, magnitude, and duration of disturbance events.

Disturbance

A disturbance is any relatively discrete event in time that disrupts the composition, structure, or functions of ecosystems, communities, or populations.

Dynamic equilibrium

An ecological system's long-term state of relative stability that is maintained through opposing processes. Understanding an ecosystem's equilibrium, is a goal of ecosystem-based management.

Ecological (biological) integrity

Capacity of an ecological system to maintain a community of organisms that has species composition, diversity, and functional organization comparable to those of natural habitats within a region. An ecological system has integrity when its dominant ecological characteristics (e.g., composition, structure, function) occur within their historical ranges of natural variation.

Ecological composition

A term encompassing all parts of an ecosystem that include both living (biotic) and nonliving (abiotic) parts. Ecosystem composition is an important consideration in conservation.

Ecological function(ing)

1) The process or cause-effect relationships between two or more interacting ecosystem components; 2) the sum of processes that sustain the system; or 3) the capacity of natural processes to provide goods and services that satisfy human needs, either directly or indirectly.

Ecological process

Interactions among components of an ecosystem, both biotic (living organisms) and abiotic (chemical and physical) components. Many processes involve the transfer, conversion, or storage of matter and energy. This term is synonymous with the first definition of *ecological function*.

Ecological structure

The arrangement of and relations among the parts or components of an ecosystem.

Ecosystem

A spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment. Ecosystems have *composition*, *structure*, and *functions*.

Ecosystem-based management (EBM)

An integrated management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation. EBM often involves balancing ecological, economic, and social trade-offs within the context of existing laws and policies.

Erosion

The loosening and transport of soil particles and other sediment by water. Terrestrial erosion includes raindrop splash erosion, overland flow sheet erosion, surface flow rill (shallow) and gully (deeper) erosion. Channel erosion includes streambank erosion and channel incision. Rill and gully erosion diminishes the capacity of riparian areas to trap sediment and pollutants and often can be avoided with intact riparian vegetation.

FEMAT curve

A conceptual model that describes the relationship between various riparian *ecosystem functions* and distance from channel. The model consists of generalized curves that show the cumulative effectiveness of litter fall, root strength, shading, and coarse wood debris recruitment to stream as a function of distance from channel.

Flow regime

The distribution of stream discharges through space and time. Flow regimes can be described by their magnitude (e.g., mean annual, hourly maximum), timing, frequency or return periodicity, duration, spatial distribution, and rate of change. The pathways that water takes to reach a stream (e.g., surface runoff) exert a strong influence on the flow regime.

Function

Physical, chemical, or biological processes that occur within an ecosystem. See *ecological function(ing)* and *ecological process*.

Historical conditions: See *Range of natural variability*.

Hot moments

Periods of elevated denitrification rates. Hot moments can occur during a rainfall event. Also see *hot spots*.

Hot spots

Areas that exhibit high denitrification rates. Hot spots often occur in floodplains and other riparian areas with oscillating groundwater levels and/or higher hyporheic flows. Locations of hot spots can vary through time.

Hydrology

Study of the occurrence, distribution, movement, and properties of the water and their relationship with land.

Hyporheic zone

The area beneath the bed of a river or stream that is saturated with water.

Impervious surface

Ground surfaces that resist or prevent water infiltration, e.g., roofs of houses and roadways.

Incision

The process of downcutting into a stream channel leading to a decrease in the channel bed elevation. Incision is often caused by a decrease in sediment supply or an increase in stream flows capable of transporting (scouring) sediment.

Infiltration

The rate or process by which water on the ground surface enters the soil.

Macroinvertebrates

Animals, including insects, mollusks, crustaceans, and worms, that do not have a backbone, and are large enough to be seen without a microscope. Aquatic macroinvertebrates are commonly used as an indicator of habitat and water quality.

Mass wasting

The down slope movement of soil, sediments, and rock due to gravity (rather than water, wind, or ice, for example).

Nutrient cycling

The movement, uptake, transformation, storage, and release of nutrients, especially carbon, nitrogen, and phosphorus. Riparian characteristics that affect nutrient cycling include flow path, vegetation composition and structure, topography, groundwater level, and soil type.

Nutrient spiraling length

The distance nutrients move downstream during a complete cycle; a measure of nutrient utilization to nutrient supply. Long spiraling lengths indicate that the system is saturated with nutrients and organisms can no longer use the incoming nutrient loads. Streams in Washington forests typically have relatively short nutrient spiraling lengths.

Ordinary high water mark

This mark occurs along stream channels where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland.

Precautionary principle

Erring on the side of causing no negative impact to natural resources when faced with uncertainty, especially for harm that is essentially irreversible. The precautionary approach involves: 1) taking preventive action (avoiding impacts), 2) shifting the burden of proof to the project proponents, 3) exploring a wide range of potential alternatives, and/or, 4) including multiple stakeholders and disciplines in decision making.

Process: See *Ecological process*.

Range of natural variability (or historical range of natural variability)

Refers to the range of ecological conditions (composition, structure, and functions) in a time period before widespread anthropogenic changes.

Riparian

An adjective meaning adjacent to a water body: stream, river, lake, pond, bay, sea, ocean. Riparian areas are sometimes referred to by different names: riparian ecosystems, riparian habitats, riparian corridors, or riparian zones. Depending on the context, these different terms may have somewhat different meanings.

Riparian buffer

Buffer refers to its purpose, which is to reduce or prevent adverse impacts to water quality, fisheries, and aquatic biodiversity from human activities occurring upslope of the buffer. Riparian buffers may also be called a riparian management zone. Riparian buffers managed specifically for pollutant removal may also be called a vegetated filter strip.

Riparian ecosystem

Riparian ecosystems are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Our definition of riparian ecosystem does not include adjacent waters (i.e., river or streams, but does include riverine wetlands) and recognizes the riparian zone as a distinctive area within riparian ecosystems.

Riparian management zone

Riparian management zone is often synonymous with riparian buffer. See *Riparian buffer*.

Riparian zone

A distinctive area within riparian ecosystems. The riparian zone contains wet or moist soils and plants adapted to growing conditions associated with periodically saturated soils.

Riverscape

A landscape organized around a river system that includes the river network and contributing watershed along with other components that are not organized by watershed boundaries such as wildfire, mobile organisms, and wind-borne seeds. Distinct from uplands, it is primarily organized in a downstream direction (e.g., movement of water, sediment, and wood) but also contains lateral elements (e.g., floodplain interaction), vertical elements (e.g., interaction of surface and hyporheic flow), and upstream elements (e.g., migrating salmon).

Salmonid

A family of fish comprised of salmon, trout, and whitefish. Native salmonid species in Washington State include: Chinook Salmon *Oncorhynchus tshawytscha*, Chum Salmon *O. keta*, Coho Salmon *O. kisutch*, Pink Salmon *O. gorbuscha*, Sockeye Salmon/Kokanee *O. nerka*, Steelhead/Rainbow Trout *O. mykiss*, Cutthroat Trout *O. clarki*, Bull Trout *Salvelinus confluentus*, Dolly Varden *Salvelinus malma*, Pygmy Whitefish *Prosopium coulteri*, and Mountain Whitefish *P. williamsoni*. This list does not include names of subspecies.

Site class

The classification of a site's productivity based on the growth of the dominant tree species. Site classes vary based on local differences in soil nutrients and moisture, light and temperature regimes, and topography. Site classes are typically described as most productive (I) through least productive (V).

Site-potential tree height

The average maximum height of the tallest dominant trees for a given age and site class.

Stochastic process

An event involving chance or probability (e.g., landslide, flood). Stochastic processes may have patterns that can be analyzed statistically but cannot be precisely predicted.

Stream order

A hierarchical stream classification system in which headwater tributaries are classified as first order; when two first order tributaries meet they form a second order tributary, when two second order tributaries meet they form a third order tributary, and so on. Low order (1st-3rd) streams make up ~88% of the state's stream miles. Below its confluence with the Snake and Yakima rivers, the Columbia River is a 10th order river.

Structure: See *Ecological structure*.

Thermal loading potential

The potential amount of solar radiation (sunlight) available at a given location. Primary factors include shading (topographic and vegetative), latitude, elevation, and date.

Thermal regime (stream)

The distribution of stream temperatures through space and time. Thermal regimes can be described by their magnitude (e.g., monthly mean, hourly maximum), timing, frequency, duration, spatial distribution, and rate of change.

Thermal sensitivity (stream reach)

The susceptibility of a stream reach to changes in temperature. Thermal sensitivity typically increases with less stream flow, less groundwater input, and a wider channel to depth ratio.

Uncertainty (scientific)

The absence of information about something. Sources of uncertainty include, but are not limited to: natural variation (i.e., because ecosystems vary in unpredictable ways through time and space), model

uncertainty (e.g., we do not understand a process), systematic error (e.g., poorly designed experiments), or measurement error.

Vegetative filter strips

A riparian buffer designed to capture nutrients, contaminant compounds, and sediment transported by run-off. Filter strips are sometimes synonymous with riparian buffers.

Water quality

Physical, chemical, and biological characteristics of water that describe its suitability to meet human needs or habitat requirements for fish and wildlife.

Watershed processes

The fluxes of energy (e.g., chemical, sunlight, wildfire) and materials (particularly water and sediment) that interact with biota (e.g., vegetation, salmon, Beavers, soil microbes) to form a watershed's physical features and characteristics, which give rise to its instream physical and ecological conditions. These processes occur within a context that reflects the watershed's climate, geology, topography, and existing human land use. Also see *Ecosystem process*.

Watershed

An area of land that drains to a common waterbody.

Wood recruitment

The process of wood moving from a riparian area to the stream channel. Sources of recruitment include bank erosion, windthrow, landslides, debris flows, snow avalanches, ice storms, Beaver, and tree mortality due to fire, insects, or disease.



Northwestern salamander/WDFW

Appendix 2: Categorization of Information Sources

Legal Requirement: RCW 34.05.271

The Revised Code of Washington (RCW) 34.05.271 requires the Washington Department of Fish and Wildlife (WDFW) to categorize sources of information used to inform technical documents that directly support implementation of a state rule or statute. Because WDFW Priority Habitat and Species documents—such as this one—are referenced in regulations for the Growth Management Act [e.g., WAC 365-190-130(4)] and Shoreline Management Act [e.g., WAC 173-26-221(5)(b)], we classify all references in the literature cited sections of Volume 1 into the following RCW 34.05.271 categories:

- (i) Independent peer review: Review is overseen by an independent third party;*
- (ii) Internal peer review: Review by staff internal to the department of fish and wildlife;*
- (iii) External peer review: Review by persons that are external to and selected by the department of fish and wildlife;*
- (iv) Open review: Documented open public review process that is not limited to invited organizations or individuals;*
- (v) Legal and policy document: Documents related to the legal framework for the significant agency action including but not limited to:*
 - (A) Federal and state statutes;*
 - (B) Court and hearings board decisions;*
 - (C) Federal and state administrative rules and regulations; and*

- (D) Policy and regulatory documents adopted by local governments;*
- (vi) Data from primary research, monitoring activities, or other sources, but that has not been incorporated as part of documents reviewed under the processes described in (i), (ii), (iii), and (iv) of this subsection;*
- (vii) Records of the best professional judgment of department of fish and wildlife employees or other individuals; or*
- (viii) Other: Sources of information that do not fit into categories i - vii.*

Meeting the Intent of RCW 34.05.271

Assigning references to categories requires judgement where methods of peer-review are not clearly defined. We assigned all scientific journal articles, science related books by independent science book publishers, universities, the National Research Council (NRC), and the National Academy of Engineering; symposia volumes sponsored by professional organizations (e.g., American Fisheries Society); and graduate theses and dissertations to category i – *independent peer review*. Government agency documents including those published by the Fish and Wildlife Service (USFWS), Environmental Protection Agency (EPA), Geologic Survey (USGS), Forest Service (USFS), and the Canadian Wildlife Service were assigned to category viii. Others references were assigned as described above.



Headwater wetland that flows north to Stavis Creek and south to Tahuya River/Keith Folkerts, WDFW



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EXHIBIT H

Wetlands in Washington State

Volume 1: A Synthesis of the Science



Final





Funding for this project was funded in part through a grant from the United States Environmental Protection Agency (EPA Region 10 and EPA Headquarters Grant #'s CD-970018-01 and CD-970585-01, Ralph Rogers, grant officer). The views herein are those of the authors and do not necessarily reflect the views of EPA.

If you have special accommodation needs or require this publication in an alternate format, please contact Tim Schlender at 360-407-6096 (Voice) or TTY (for the speech or hearing impaired) at 711 or 800-833-6388.

Published by the Department of Ecology's Shorelands and Environmental Assistance Program, P.O. Box 47600, Olympia, WA 98504-7600. For more information contact Teri Granger at 360-407-6857, e-mail: tgra461@ecy.wa.gov

Wetlands in Washington State

Volume 1: A Synthesis of the Science

FINAL

March 2005

Ecology Publication #05-06-006

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Refer to Publication #05-06-006

For the *Responses to Comments* on the draft of this volume refer to Publication #05-06-007.

For the Draft *Freshwater Wetlands in Washington State – Volume 1: A Synthesis of the Science* refer to Publication #03-06-016.

For Volume 2 of this two-volume series, *Wetlands in Washington State – Volume 2: Guidance for Protecting and Managing Wetlands*, refer to Publication #05-06-008.

Preferred citation:

Sheldon, D., T. Hraby, P. Johnson, K. Harper, A. McMillan, T. Granger, S. Stanley, and E. Stockdale. March 2005. *Wetlands in Washington State - Volume 1: A Synthesis of the Science*. Washington State Department of Ecology. Publication #05-06-006. Olympia, WA.

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Acknowledgements

Many hours of painstaking work by dedicated experts went into the production of this document. The Core Team (listed in Appendix 1-A) persistently guided us through numerous challenges and did the bulk of the work by gathering and reading articles, dealing with problems with the database, and crafting and re-crafting the framework for the document. Katherine March, from state Fish and Wildlife (WDFW) also searched the public databases, generating long lists of articles to be considered for the synthesis, as well as provided valuable review. Kim Harper, while working as a staff member at Sheldon and Associates, accepted the difficult challenge of managing the database.

The authors and other members of the Core Team spent countless hours reading and summarizing articles and writing and re-writing text. Of special note is Tom Hruby whose knowledge of the literature and ability to translate scientific concepts into lay terms results in his valuable technical writing skills and contribution to many chapters.

Also of special note is the dedication and time spent by Dyanne Sheldon of Sheldon and Associates in the production of this document. She donated many hours of her own time toward the project, often burning the midnight oil to make sure articles were read and text written. Patricia Johnson deserves kudos for her work sifting through the voluminous information on compensatory mitigation and presenting it in a thorough yet easy to read manner.

Staff at the Washington Department of Fish and Wildlife provided review of internal drafts. Special thanks go to Steve Penland and Bob Ziegler for their valuable input and critique.

Sara Noland, 2N Publishing, is to be complimented for her excellent skills editing the draft document. Editing the draft was a real challenge given the numerous authors involved, each with a different writing style, and the changes that were initiated relatively late in the production process. We thank her sincerely for her patience and flexibility. Tom Noland, the other N in 2N Publishing, provided invaluable assistance in scanning and converting graphics into a format suitable for publication, as well as patiently trouble-shooting computer problems.

Thanks also to Mary Lynum for her role as Ecology support staff during completion of the review draft; Yolanda Holder and Paige Boule` from Ecology provided valuable assistance with finalizing and proofing the document. Keren Marzi of Sheldon and Associates is acknowledged for her effort designing several covers for the document, the final cover design being chosen by the Core Team. Thank you to Tim Schlender of Ecology for developing the web site and posting the draft and final versions of the document on the site.

Considerable acknowledgement is due to Dana L. Mock. The final production of Volume 1 would not have been possible without her diligence, hard work, attention to detail, and patience. Dana also took the lead on communications during the production of the final draft.

The document and this effort as a whole were the vision of Andy McMillan, who also obtained the funding from several sources. In addition, Andy wrote portions of the document and provided wise leadership and guidance, as well as contributing his unique ability to the resolution of complex problems.

Finally, of great importance is the acknowledgement of Teri Granger, the project manager. Teri coordinated every aspect of the project, facilitated meetings, provided encouragement to the authors and support staff, wrote and edited portions of the text, and provided overall management while working part time. Her oversight, management and attention to detail kept everyone on track and were greatly valued by all of her colleagues.

This document would never have been produced had it not been for the financial backing provided by the U.S. Environmental Protection Agency. The Washington State Departments of Ecology and Fish and Wildlife also contributed to the funding for this project. We thank the agencies for their support in undertaking such an ambitious endeavor.

Chapter 1

Introduction to the Document

This is the first volume of a two-volume series. This volume contains a summary and synthesis of the recent literature relevant to the science and management of wetlands in the state of Washington. Volume 1 describes what the scientific literature says directly about the topics described below. In some cases where scientific information is lacking, the authors present their own hypotheses or conclusions based on a process of deductive reasoning or their own observations. Hypotheses and conclusions based only on the authors' reasoning or observations are clearly labeled as such.

The focus of Volume 1 is freshwater wetlands in Washington. Estuarine and marine wetlands are discussed in this document only in regard to the wetland rating systems covered in the second volume.

The topics covered in Volume 1 are:

- How environmental factors control the functions of wetlands across the landscape and at individual sites, how freshwater wetlands are classified according to these controls, and what functions are performed by different classes of freshwater wetlands in the state
- How human activities and land uses affect the environmental factors that control the functions of freshwater wetlands
- How disturbances caused by human activities and land uses impact the performance of functions by freshwater wetlands
- How wetlands are protected and managed using common tools such as buffers and compensatory mitigation, including what the literature says about the relative effectiveness of these tools
- How cumulative impacts can result from current approaches to managing and regulating wetlands

Volume 2 of this series translates these scientific findings into guidance to local governments and others regarding programs they can or currently do use to protect and manage wetlands.

This work was collectively prepared by the Washington State Department of Ecology (Ecology), the Washington State Department of Fish and Wildlife (WDFW), and a private consulting firm. The U.S. Environmental Protection Agency (EPA) provided funding and assisted in its production. Representatives from these agencies, as well as staff from the private consulting firm, made up a team (the Core Team) that guided the project. See Appendix 1-A for a list of members of the Core Team.

Both volumes will be of use to all those interested in protecting and managing wetlands. The authors hope they will find these documents useful in gaining a greater understanding of the current science regarding wetlands in the state, their ecology and functions, as well as their protection and management. Examples of groups who might use these documents include federal, state, and tribal staff; planners; resource managers; wetland scientists; builders; farmers; environmentalists; and other concerned citizens.

Local governments, however, are the primary audience for this document. They are a key group involved in wetland protection in the state. Through the Growth Management Act (GMA) (Revised Code of Washington (RCW) 36.70A), every county and city in Washington must designate critical areas (including wetlands) within their boundaries and protect them. In 1995, an amendment to GMA (RCW 36.70A.172 [1]) required that all city and county governments must include best available science (BAS) when developing their critical areas policies and regulations.

This synthesis, therefore, may be of special interest to local governments that do not have the resources to complete their own review of the scientific literature. All local governments, however, should also consider locally and regionally specific information not included in this synthesis if it meets the criteria of a valid scientific process, as described below.

1.1 Best Available Science (BAS)

The Washington Administrative Code (WAC 365-195-905) provides assessment criteria to assist in determining whether information constitutes the best available science, i.e., by having been developed through a valid scientific process. A valid scientific process is one that produces reliable information that is useful in understanding the consequences of regulatory decisions and in developing policies and regulations that will be effective in protecting the functions and values of wetlands and other critical areas.

Appropriate sources of scientific information as defined in WAC 365-195-905 include:

- Research
- Monitoring
- Inventory
- Survey
- Modeling
- Assessment
- Synthesis
- Expert opinion

Information derived from any one of these sources can be considered scientific information if it possesses the required characteristics in WAC 365-195-905 (see Table 1B-1 in Appendix 1-B). For example, a synthesis such as Volume 1 is considered best available science when it has undergone peer review, describes the methods used to obtain the information, presents conclusions based on reasonable assumptions that are logically derived, places the information in proper context, and is well referenced. See Appendix 1-B for a list of all the characteristics of a valid scientific process and their definitions, as well as a table displaying the characteristics needed for each of the sources listed above to be considered BAS.

Methods for preparing and reviewing Volume 1

The primary steps taken to arrive at publication of this document include:

- Searching the literature
- Reviewing, sorting, and prioritizing the reference lists
- Obtaining the reference documents
- Reading and entering information from the documents in a database
- Writing and revising the text
- Obtaining peer and public review
- Responding to comments, revising the text, and completing the document

The processes used for these steps, including the scientific databases and the key words used to search them, are described in Appendix 1-C.

1.1.1 Volume 1 as BAS

Volume 1 meets the definition and characteristics required for a synthesis in the WAC. Findings from scientific journal articles, government publications, technical books, and other sources that meet the definition and characteristics of BAS in WAC 365-195-905 were used and referenced in the synthesis. Conference proceedings and personal communications were occasionally used when no other information was available. In some cases, we were unable to ascertain to what level these additional sources were peer reviewed.

In a few instances, we have cited data collected during the calibration of the *Methods for Assessing Wetland Functions* (Hruby et. al. 1999, 2000) (also known as the Washington State wetland function assessment methods or WFAM) and the Washington State wetland rating systems (Hruby 2004a, b). These data have not been published in scientific journals. However, these observations reported as “unpublished data” in Volume 1, were collected in the field by interdisciplinary teams of wetland experts and used to support and calibrate the function assessment methods and the wetland rating systems. The methods and rating systems have been extensively reviewed and field tested by peer experts as well as the public. The data themselves were offered for review on request during public review and continue to be available on request.

A peer review of documents concerning wetlands, specifically the function assessment methods, wetland rating systems, and these two volumes, means that comments were solicited from a broad range of people on a mailing list of hundreds. This included experts from various disciplines, not just a select few that were in house or close associates. All comments received were addressed. For these volumes, a response to each comment, including rationales for those not used to modify the drafts, has been prepared. To read the comments on Volume 1 and the authors responses go to <http://www.ecy.wa.gov/biblio/0506007.html>.

1.1.2 Making Hypotheses and Assumptions

As mentioned previously, in some places in the document we offer our conclusions based on the literature when the references searched do not provide specific information on a topic important for wetland management. In such instances, the authors clearly state that a hypothesis, assumption, or conclusion is being made. For example, we use statements such as “in the absence of research to the contrary, it can be assumed....,” “it is possible to hypothesize....,” or “it can be inferred that...”

In these cases, a description of the logic being used is provided which meets the criteria in WAC 365-195-905 for expert opinion, one of the sources of valid scientific information. The criteria include logical conclusions and reasonable inferences, context, and the use of references (see Appendix 1-B for definitions of these criteria). These hypotheses can be considered expert opinion according to WAC 365-195-905 in which expert opinion is defined as a “Statement of a qualified scientific expert based on his or her best professional judgment and experience in the pertinent scientific discipline. The opinion may or may not be based on site-specific information.” To be considered best available science according to the WAC, an expert opinion must meet three of the six characteristics listed in the table in Appendix 1-B: logical conclusions and reasonable inferences, context, and references.

Logical conclusions and reasonable inferences are defined as “The conclusions presented are based on reasonable assumptions supported by other studies and consistent with the general theory underlying the assumptions. The conclusions are logically and reasonably derived from the assumptions and supported by the data presented. Any gaps in information and inconsistencies with other pertinent scientific information are adequately explained.”

Context is defined as “The information is placed in proper context. The assumptions, analytical techniques, data, and conclusions are appropriately framed with respect to the prevailing body of pertinent scientific knowledge.”

References are defined as “The assumptions, analytical techniques, and conclusions are well referenced with citations to relevant, credible literature and other pertinent existing information.”

The statements that are hypotheses in this document meet these criteria because they are presented with a clear and logical train of thought and the conclusions are based on reasonable assumptions supported by other credible studies that are relevant. They are placed in context and referenced.

In addition, the definition of *synthesis* in Webster's 7th Collegiate Dictionary is "deductive reasoning" and "the combining of often diverse conceptions into a coherent whole." The statements that present hypotheses and assumptions are based on deductive reasoning.

There are a few instances in the document where the authors of Volume 1 offer their observations based on their own professional experience. These are usually limited to statements relating to protection measures used to manage wetlands. Such statements are clearly labeled as those of the authors only.

1.2 Scope of Volume 1

The focus of this document is freshwater wetlands of Washington State. We have included information on wetlands in other regions and countries and on aquatic systems in general when more local information is lacking and the data are applicable to the wetlands in Washington. See the following section (1.3) for more discussion on this topic. Volume 1 does not address streams or riparian areas that are not wetlands. We do, however, summarize some of the literature related to buffers on streams where the information can be transferred to wetlands.

Marine and estuarine systems are discussed only in regard to wetland rating systems and wetland types for which specific management is needed. Marine and estuarine wetlands were excluded primarily to keep the scope of the project in the range of the available funding. Some recent scientific information on coastal and estuarine wetlands has been summarized by WDFW, Ecology, and other agencies through the Aquatic Habitat Guidelines Project, which is available on the internet (www.wa.gov/wdfw/hab/ahg).

There are several types of freshwater wetlands that are highlighted in the wetland rating systems (described in Volume 2) that are not specifically reviewed in this synthesis (e.g., bogs, interdunal wetlands, and vernal pools). These wetlands are subsets of wetlands in the different hydrogeomorphic (HGM) classes described in Chapter 2. At the level of detail provided in this document, general information summarized about wetlands also applies to these types of wetlands in whatever HGM class and region of the state is appropriate.

The effects of growing cranberries in wetlands are also not covered in this volume because of the time and funding constraints of the project. The limited area of the state that is affected by cranberry production was also a factor. In addition, information related to the effects of silviculture and forest practices on forested wetlands is not included because this subject is being addressed in another document currently being developed (Cooke in press).

In addition, the synthesis in Volume 1 is limited to information that has a practical application to the management and protection of wetlands. For the most part, available documents from the past ten years were used as the primary sources for this synthesis. It was assumed that this most recent literature would incorporate relevant science from the preceding years. Older documents were used in instances where they had not been superseded by more recent studies.

This volume DOES NOT contain agency recommendations or suggestions for implementation of any program to protect or manage wetlands. Any recommendations provided in Volume 1 (for instance, in the section of Chapters 5 and 6 addressing buffers and compensatory mitigation) are those that have been described in the literature. They are included here only as part of the synthesis of existing scientific information. Agency recommendations are provided in Volume 2.

1.3 Relevance of Scientific Information to Conditions in Washington

One of the tasks in reviewing scientific information was to determine what is relevant to wetlands found in the state of Washington. Determining the relevance of scientific information encompasses two aspects. The first is the degree to which general conclusions and principles developed from existing information can be used to predict what will happen in new or different situations. The conclusions of a scientific study done at one time in one wetland with specific characteristics may not be directly transferable to circumstances that develop in the future or at sites that have different characteristics or situations.

The first aspect also encompasses the concept that science doesn't often provide a "bright line." In other words, science rarely supplies us with precise solutions for protecting and managing natural resources. Very few experiments demonstrate true cause-and-effect relationships. For example, in reviewing the literature for this volume, we found few studies that actually documented the effectiveness of different ways for managing the wetland resource (such as the effectiveness of buffers of a specific width at protecting a specific wetland function). Rather, most studies, for example, discuss the impacts of human activities on wetlands. As a result, guidance on protection and management based on scientific information (as presented in Volume 2) is, to a large degree, extrapolation and synthesis of all the information collected.

The second aspect is the relevance of information collected in one region to the conditions found in another region. We have relied, whenever possible, on literature that was derived in the Pacific Northwest. However, in some cases, scientific information generated in other regions of the United States, and to a lesser extent from other countries, was used. Authors of this volume judged whether each "out-of-region" reference was applicable to Washington by extrapolating, interpreting, and synthesizing the information to determine how it pertains specifically to Washington.

We understand establishing what is relevant to Washington is a subjective decision; however, two criteria were used in the decision. First, an “out-of-region” reference was incorporated in the synthesis if the basic ecological principles on which it was based are relevant to most landscapes. Second, it was incorporated if the geomorphic setting of the wetland in a scientific report was similar to those found in the Pacific Northwest and no information specific to the region (that meets the criteria of BAS) was found in our search of the literature.

One of the basic assumptions in ecological and biological research is that environmental processes operate in a similar way if the basic conditions are similar. For example, water is expected to flow downhill whether it occurs in Minnesota or in Washington. Denitrifying bacteria are assumed to transform nitrate to nitrogen gas wherever they are found as long as the soils are anaerobic. The particular wildlife species that are closely associated with wetlands may differ regionally, but frequently fill the same habitat niches in Ohio or California as they do in Washington. Thus, much of the information on functions developed outside the region is transferable to Washington. Regional differences in functions occur when the basic conditions differ, and we have tried to point this out where possible.

As mentioned previously, the definition of *synthesis* in Webster’s 7th Collegiate Dictionary is “deductive reasoning” and “the combining of often diverse conceptions into a coherent whole.” This is the goal we have set for Volume 1. Part of the role of a synthesis, thus, is to summarize many studies and scientific articles; glean the general principles that apply in most areas as well as those that relate specifically to the state of Washington; and try to determine if they will apply to future conditions based on best professional judgment of the authors and the reviewers of the document.

1.4 Overview of Volume 1

Volume 1 is organized into seven chapters. The chapters share a common organization, beginning with a reader’s guide that describes the topics covered in the chapter and how the chapter is organized. An introduction then provides general background information, definitions, and clarifications. Each chapter describes the sources of information used and how well the subject is documented in the literature, particularly for the Pacific Northwest. The chapters also note gaps where information on an issue could not be found. Key points are summarized at the end of major sections and conclusions provided at the end of each chapter.

A brief summary of the contents of each chapter that follows and the appendices is provided below. In this document, page numbers are assigned to each chapter individually and are not sequential. The first number represents the chapter and the second the page number in that chapter (e.g., [3-2] represents page 2 in Chapter 3).

Chapter 2 – Wetlands in Washington and How They Function

Chapter 2 summarizes the information on how wetlands are categorized and how wetlands function in Washington State. It describes how functions are defined and introduces the concept that the performance of functions is controlled by a number of environmental factors within the wetland boundary (site scale) as well as in the broader landscape (landscape scale). The chapter then describes how some of the key factors that control functions are used to classify wetlands into groups that perform functions in similar ways.

The chapter goes on to describe functions of freshwater wetlands in Washington. Where applicable, the chapter discusses the differences in functions among wetland classes and in various areas of the state. The major functions described are those that were defined for the Washington State wetland function assessment methods (Hruby et al. 1999, 2000).

Chapter 3 – Environmental Disturbances Caused by Different Human Activities and Uses of the Land

In Chapter 3 the discussion shifts from wetland functions and the environmental factors that control the performance of functions to the major disturbances caused by human activities that affect wetlands and their functions. In this context, a *disturbance* is an event that changes an environmental factor that controls wetland functions. Ten disturbances (listed below) are discussed.

- Changing the physical structure within a wetland (e.g., filling, removing vegetation, tilling soils, compacting soils)
- Changing the amount and velocity of water in wetlands (increasing or decreasing the amount)
- Changing the fluctuation of water levels (frequency, duration, amplitude, direction of flow)
- Changing the amount of sediment (increasing or decreasing the amount)
- Increasing the amount of nutrients
- Increasing the amount of toxic contaminants
- Changing the acidity (acidification)
- Increasing the concentration of salt (salinization)
- Fragmentation (decreasing area of habitat and its spatial configuration)
- Other disturbances (noise, etc.)

The chapter continues with separate sections for four of the major types of human land uses in Washington State (agriculture, urbanization, forest practices, and mining) and the types of disturbances they cause. For each of these four land uses, the ten types of disturbances that change the factors controlling wetland functions (listed above) are discussed where applicable.

Chapter 4 – Negative Impacts of Human Disturbances on the Functions of Wetlands

Chapter 4 integrates the concepts discussed in Chapter 2 and Chapter 3. In Chapter 4, ten sections, one for each of the disturbances listed above, summarize how these disturbances ultimately leads to impacts on hydrologic functions, functions that improve water quality, and habitat functions.

Chapter 5 – The Effectiveness of Wetland Management Tools

Chapter 5 presents a synthesis of what the current literature reports on four tools currently used to protect and manage wetlands and their functions: the definition of wetlands, wetland delineation methods, wetland ratings, and regulatory buffers. In the section on definitions, the issues of biological versus regulated wetlands, small wetlands, isolated wetlands, and Prior Converted Croplands that are wetlands are discussed. This chapter does not provide language or recommendations for regulations or policy—those are provided in the second, separate volume containing guidance for protecting and managing wetlands in Washington (Volume 2).

Chapter 6 – The Effectiveness of Wetland Mitigation

Chapter 6 discusses another commonly used tool for managing and protecting wetlands, compensatory wetland mitigation. This topic is discussed in its own chapter because of the large volume of information available on this subject. Topics covered in this chapter include:

- Evaluation of the success of compensatory mitigation
- Compliance of mitigation projects with permit requirements
- Types of compensatory mitigation
- Replacement ratios and replacement of wetland acreage
- Functions provided by compensatory mitigation projects
- Reproducibility of particular types of wetlands (bogs, fens, vernal pools, alkali wetlands, and mature forested wetlands)
- Suggestions from the literature for improving compensatory mitigation

Chapter 7 - Cumulative Impacts on Wetlands

Chapter 7 discusses different types of cumulative impacts, and the loss of wetland area as the most easily assessed indicator of cumulative impacts. It goes on to present some of the causes of cumulative impacts in Washington. These include:

- Case-by-case permitting as a cause of cumulative impacts
- Lack of consistent plans and regulations between jurisdictions as a possible cause of cumulative impacts
- Implementation of regulatory programs at the local level as a possible cause of cumulative impacts

The chapter ends with a discussion in which the types of cumulative impacts are compared to the protection measures commonly taken by local governments.

Glossary

The glossary provides definitions for some of the technical terms used throughout Volume 1. Other terms are defined in the context of the sentence in which they appear and may not be included in the glossary.

References

The references cited in the text are listed separately at the end of Volume 1. Some of these references represent reviews or syntheses in which a researcher describes trends observed from numerous studies conducted in previous years. In these cases, we cite only the review document and not all the citations in the review.

Citations from the review by Adamus et al. (2001), however, are an exception. Portions of Adamus et al. (2001), a review of current scientific literature on the impacts of human activities on wetlands and their functions, were adapted and included in Chapter 4 with permission from Dr. Adamus. The list of cited references at the end of the document does include the literature sources from those portions of Adamus et al. (2001) that were adapted.

Appendices

The appendices of Volume 1 are as follows:

- Appendix 1-A identifies the team guiding the production of Volume 1 (the Core Team)
- Appendix 1-B describes the characteristics of a valid scientific process and types of scientific information defined by the Washington Administrative Code (WAC 365-195-905)
- Appendix 1-C details the methods used in the literature review and production of Volume 1
- Appendix 1-D lists the reviewers who commented on the draft of Volume 1
- Appendix 2-A provides information about various terms and methods that have been used to organize and group information about wetlands, such as classification, characterization, and rating
- Appendix 2-B lists the species of wildlife associated with wetlands in Washington and Oregon from Johnson and O'Neil (2001)

1.5 Public Involvement and Review of Volume 1

1.5.1 The Process of Public Involvement

The process for public involvement of Volume 1 included meetings of two focus groups, numerous mailings and extensive peer and public review. Ecology compiled a mailing list of scientists with wetlands expertise, local government planners, and other groups and individuals from various existing mailing lists used for other wetland-related projects.

In October 2001, Ecology sent out a focus sheet describing the project and a cover sheet that solicited the recipient's participation in the project. This sheet included a tear-off card that could be used to request that the sender be retained on the mailing list. The mailing list was then edited based on the returned cards.

Meetings of focus groups were held in January 2002 in Moses Lake and Olympia to begin the process of gathering input from the public on the project. These meetings were attended by various members of the Core Team, local planners, other staff from local government, and other interested parties. The purpose of these meetings was to help focus the project so that the synthesis would meet the needs of our primary audience, local governments. The meetings gave opportunities to the Core Team to present information on the project and to listen to questions and concerns from the attendees. Lists of keywords to use for the search of the literature were revised based on input from the focus groups.

In June 2002, Ecology sent out a mailer with an update on the project to the entire mailing list. It discussed the status of the project, timelines, and other issues.

In November 2002, Ecology staff contacted selected experts in various disciplines to solicit their review. The list of peer reviewers was not intended to be inclusive of all experts. The purpose was to make sure that each of the major topics in Volume 1 was reviewed by one or more recognized experts in that discipline. These expert reviewers were selected from academia, public agencies and private consultants.

In February 2003, Ecology sent another mailing to all those on the list to determine who wanted to comment on the draft of Volume 1. In June 2003, Ecology distributed a notice by email to update the public on revised target dates for distribution of the draft document for peer and public review.

The draft was distributed for general review in September 2003. Over 170 paper copies as well as CDs were sent to reviewers. An undetermined number of reviewers downloaded the draft from the project's web site. The experts asked to review the document were provided the draft at the same time as the general public. Instructions for providing comments and a questionnaire were also distributed with the draft document.

Several mailings were distributed since the fall of 2003 informing those listed about the status of revisions to Volume 1 as well as progress on the completion of the draft of Volume 2. The Core Team decided that a draft of Volume 2, containing guidance on

protecting and managing, should be completed before Volume 1 was completed. The draft of Volume 2 was distributed for comment in August 2004, during which time the authors began writing responses to comments and revising Volume 1. The review process for Volume 2 is described in Chapter 1 of that document.

1.5.2 Responding to Comments and Reviewing Suggested Literature

Twenty-nine reviewers provided comments on the draft of Volume 1. The reviewer's comments varied from cursory to very detailed, approximately 900 comments were submitted.

Initially, the Core Team organized and reviewed the comments and developed responses to the most substantive comments as individual or synthesized comments. The responses were posted on the project's web site in the spring of 2004. In addition, Ecology posted a list of all the comments that were submitted, organized by chapter, section and page. After the draft of Volume 2 was completed, each of the original comments was addressed by the authors. Each comment and a response to it have now been posted on the project's web site at the address below. Comments are organized by chapter, except for the beginning section that contains answers to questions in a questionnaire distributed to reviewers with the draft document.

As a part of the questionnaire, the reviewers were asked to provide any additional references they felt were pertinent to the subjects discussed. In addition, those who suggested changes or additions to the text were asked to provide citations. As a result, reviewers submitted several hundred new references. The authors reviewed this list and rated each as high, medium, or low importance using the same criteria used in the original search (see Appendix 1-C). Attempts were made to obtain and review all citations rated as high or medium. The results of this process, whether the reference was or was not obtained and why, are documented in a table at the end of the document containing the responses to comments.

Volume 1 and the responses to comments are available online

Ecology has developed a web site for this project on the Shorelands and Environmental Assistance Program web site. The web site includes a project description, contact information, current status of the project, and copies of the updates that were sent. The web site also includes a copy of the final version of Volume 1, as well as Volume 2, along with two documents containing the comments received and the authors' responses, one for each document. http://www.ecy.wa.gov/programs/sea/bas_wetlands/index.html

1.6 Conclusions

Volume 1 provides a summary of relevant scientific information related to wetlands in the Pacific Northwest and their management. The document should be useful to all those who have an interest in the protection and management of wetlands including agency staff, consultants, interested organizations, and citizens. It should be particularly helpful to local governments that are required under the Growth Management Act, to include best available science when developing and revising regulations protecting critical areas including wetlands. Volume 1 has been reviewed by technical experts (peer reviewed) and other interested parties. The intention of the project and the review process was to produce a synthesis of the current science on wetlands in the state of Washington that is easily understood, yet thorough and scientifically rigorous.

Chapter 2

Wetlands in Washington and How They Function

2.1 Reader's Guide to This Chapter

Chapter 2 presents information on wetlands in Washington and how they function. It introduces the ecological principles that help us understand the impacts of decisions we make about wetlands. It then expands on the newer ecological concept that the performance of functions is controlled by a number of environmental factors within the wetland boundary (site scale) as well as in the broader landscape (landscape scale). The chapter then describes these controls relative to regions and wetland types (classification of wetlands) in Washington before turning to detailed descriptions of the functions performed by the wetlands east and west of the Cascade Mountains and in different wetland classes.

To protect and manage wetlands, an understanding of wetland functions must be supplemented by knowledge of how these functions are affected by human activities. Chapter 3, therefore, goes on to describe how various land uses and activities disturb the environment, for example by causing excess nutrients, increased runoff and fluctuating water levels, and reduction in habitat. These disturbances in turn affect the environmental factors that control wetland functions. Chapter 3 describes what the literature says about the disturbances created by different land uses, while Chapter 4 goes into detail regarding how each disturbance affects particular wetland functions, including the organisms that use wetlands.

2.1.1 Chapter Contents

Major sections of this chapter and the topics they cover include:

Section 2.2, Basic Ecological Principles Useful in Managing Wetlands and in Understanding the Impacts of Human Activities describes five basic ecological principles that are useful in managing wetlands as identified by the Ecological Society of America. The principles include time, place, species, disturbance, and landscape.

Section 2.3, Introduction and Background on Wetland Functions describes the evolution of our understanding of wetland functions over the last few decades. It also defines the term *wetland functions*. The section describes how environmental processes at many geographic scales control the functions provided by wetlands. The section includes a diagram summarizing the environmental factors that control functions and how they interact with human disturbances. The difference between *functions* and *values* is also explained.

Section 2.4, Classification of Wetlands in Washington as a Key to Understanding their Functions begins by describing the common classification systems used to categorize wetlands. It discusses ecological regions (ecoregions) in Washington State and how wetlands across the

state are classified within the ecoregions into groups (classes and subclasses) that function in similar ways. The classes and subclasses of wetlands found in the state are described.

Section 2.5, Overview of Wetland Functions in Washington State introduces the functions of wetlands that are currently the focus of management efforts. These functions fall into three main categories: improving water quality, hydrologic functions, and providing habitat. Each category is described and the functions related to each are listed.

Section 2.6, How Wetlands Perform Functions in Washington State describes each of the wetland functions listed in Section 2.5. For each function, the text provides a general description of how the function is performed, and then goes into detail about how that function is performed by wetlands of various classes and in different areas of Washington.

Section 2.7, Chapter Summary and Conclusions summarizes the major concepts presented in the chapter.

2.1.2 Where to Find Summary Information and Conclusions

Each major section of this chapter concludes with a brief summary of the major points resulting from the literature review on that topic in a bullet list format. The reader is encouraged to remember that a review of the entire section preceding the summary is necessary for an in-depth understanding of the topic.

For summaries of the information presented in this chapter, see the following sections:

- Section 2.3.4
- Section 2.4.6
- Section 2.5.4
- Section 2.6.4

In addition, Section 2.7 provides a summary and conclusions about the overarching themes gleaned from the literature and presented in this chapter.

2.1.3 Sources and Gaps in Information

Our understanding of how wetlands function and the factors that control these functions has increased in the last two decades and much of this information has been published in the journal *Wetlands* (the journal of the Society of Wetland Scientists). Other journals that often carry papers on wetland functions include *Environmental Management*, *Restoration Ecology*, and the *Journal of the American Water Resources Association*.

Much of what we know about wetlands in Washington, their functions, and how functions are defined, is based on the collective expertise and judgment of teams of experts who developed the *Methods for Assessing Wetland Functions* (also known as the Washington State wetland function assessment methods of WFAM) (Hruby et al. 1999, Hruby et al. 2000) and who revised the

Washington State wetland rating systems (Hruby 2004a,b). These tools are methods that analyze the functions of wetlands in the state. This expert, regional information is critical because much of the knowledge in the scientific literature about wetland functions was developed outside the Pacific Northwest.

These tools can be considered a synthesis of the best available science for defining and understanding the functions performed by Washington's wetlands. The wetland scientists who developed these documents analyzed existing scientific information and extracted material that is relevant for Washington State. They also added their best professional experience, expertise, judgment, and field observations during development of these products. Existing scientific information is cited in these tools where it was judged relevant to Washington State.

The tools were developed using a formal process that was based on using consensus among wetland scientists in the region. The process included peer review and public comment. The documents resulting from the function assessment project and the rating system effort are cited in this synthesis as Hruby et al. (1999), Hruby et al. (2000), and Hruby (2004a,b). Information about these projects is also available at <http://www.ecy.wa.gov/programs/sea/wetlan.html>.

Major gaps in our knowledge of how wetlands in Washington function, however, still exist for the types of wetlands for which function assessment methods have not yet been developed. For example, there is little published information about the functions of "slope" wetlands and "flats" wetlands (see section 2.4.4 for a description of these wetland classes). There is also less published information on the wetlands in the arid region of the state.

2.2 Basic Ecological Principles Useful in Managing Wetlands and in Understanding the Impacts of Human Activities

Many decisions about the management and use of land are made with little attention to any of their ecological impacts. Thus, a better knowledge of the functioning of "ecosystems" is needed to broaden the scientific basis of decisions on using the land and managing it (Dale et al. 2000). In response to this need, the Ecological Society of America established a committee to examine the ways that land-use decisions are made and the ways that ecologists could help inform those decisions. The following discussion on the basic ecological principles that are useful in managing how we use the land (including wetlands) is derived from the report of the committee that was published in *Ecological Applications* (Dale, et al. 2000).

The committee identified five ecological principles that have implications for managing wetlands. The principles deal with time, place, species, disturbance, and landscape. Each is described briefly below and represents a summary of the information in Dale et al. (2000). (Note: the citations used by Dale et al. (2000) in developing these principles are not included in the summary.)

Time Principle - Ecological processes function at many time scales; some long, some short; and ecosystems change through time. For example, activities in cells occur on the scale of microseconds to minutes, decomposition occurs over hours to decades, and soil formation occurs over decades and centuries. In addition, ecosystems can change from season to season, year to year, and decade to decade. Human activities that alter the species found in ecosystems or alter the biological, chemical, or geological cycles can change the pace or direction of these “natural” changes. Human activities have effects that can last decades or centuries.

Species Principle – Particular species and networks of interacting species have key, broad-scale effects on ecosystems. Such “focal” species affect ecological systems in many ways. *Indicator species*, such as amphibians, help us understand the current condition of ecosystems. The status of indicator species helps us understand the status of larger groups of species, the status of key habitats, or as an indication of the action of some environmental stressor (disturbance). *Keystone species*, such as elephants, are those that have a greater effect on ecological processes than would be predicted from their abundance alone. *Ecological engineers*, such as beaver, alter habitat, and in doing so modify the survival and opportunities of many other species. *Umbrella species*, such as cougar, deer, or elk, either require large areas or use multiple habitats and thus overlap the habitat requirements of many other species. *Link species*, such as salmon, exert critical roles in the transfer of matter and energy across trophic levels or provide critical links in the transfer of energy in complex food webs.

Place Principle – Local climatic, hydrologic, edaphic (resulting from soils), and geomorphological factors as well as biotic interactions strongly affect ecological processes and the abundance and distribution of species at any one place. Conditions in any one place reflect the variations that occur along gradients of elevation, longitude, latitude, and the many physical, chemical, and edaphic factors at a micro-scale. These factors provide the ecosystem with a particular appearance (e.g., a wetland formed in a glacial “kettlehole” is quite different from a wetland that formed in the “pothole” left behind in the basaltic surface of the Columbia Basin after the ice-age floods).

Disturbance Principle – The type, intensity, and duration of disturbances shape the characteristics of populations, communities, and ecosystems. Disturbances are events that disrupt ecological systems. They may occur naturally (e.g., wildfires, storms, floods) or be caused by human actions (e.g., clearing land, building roads, altering stream channels). The effects of disturbances on ecological systems are controlled in large part by their intensity, duration, frequency, timing, and size and shape of area affected. Many ecosystems, such as Ponderosa pine forests, are maintained by a certain level and type of disturbance, such as fire. Changes in land use that alter the regime of natural disturbances or initiate new disturbances are likely to cause changes in species distributions, abundances, the composition of ecological communities and the functioning of the ecosystem.

Landscape Principle – The size, shape, and spatial relationships of land-cover types influence the dynamics of populations, communities, and ecosystems. The spatial array of habitats and ecosystems make up the “landscape,” and all ecological processes respond, at least in part, to this “landscape template.” The kinds of organisms that exist and their interaction with ecosystem processes (e.g., decomposition, nutrient fluxes) are constrained by the sizes, shapes, and patterns of interspersions of habitat across a landscape. Human activities that decrease the size of habitat

patches or increase the distance between similar habitat patches can greatly reduce or eliminate populations of organisms.

These ecological principles underlie our understanding of how wetlands function and how they should be managed to protect their functions. They form the basis of the following discussion of how wetlands function, how human disturbances can impact those functions (Chapter 4), and how we should develop ways to protect and manage this resource (Volume 2).

2.3 Introduction and Background on Wetland Functions

2.3.1 An Evolving Understanding of Wetland Functions

The concept of wetland functions is relatively new in both the regulatory and scientific arenas. For many years wetlands were considered nuisances and wastelands (Washington State Department of Natural Resources 1998). The functions found within a wetland were not considered important enough to study and understand. Today, however, we know that the functions performed by wetlands are important and interacts with other aspects of the landscape around it. We have found that the structural components of a wetland and its surrounding landscape (such as plants, soils, rocks, water, and animals) interact with a variety of physical, chemical, and biological processes both within the wetland itself and the surrounding landscape. These interactions are called *functions*.

The concept of wetland functions has evolved since it was first introduced about four decades ago. Wetlands were first considered primarily to function as habitat for important species such as waterfowl. The factors that were thought to control how a wetland functions in this respect were the structural elements in a wetland. For example, how much open water did the wetland contain? What types of vegetation were found there? This interest in wetland structure led to the development of a classification system for wetlands in 1979 based on the vegetation and water regime (Cowardin et al. 1979). This system is still in use today. See Section 2.4.1 for more on this classification system.

It soon became apparent, however, that wetlands contribute more to the landscape than just habitat. During the 1980s much research was done on how wetlands filter pollutants and improve water quality. As a result, wetland engineers started to design and create wetlands specifically to treat wastewater (Hammer 1989). During the 80s wetlands were also recognized for their contribution to flood protection (Adamus et al. 1987).

The ongoing research in the 1980s also led to a realization that the functions performed within a wetland are controlled by a number of environmental factors both within and outside of the wetland. Climate was recognized as the major factor that affects how wetlands function at the largest geographic scale (Bailey 1995, Benda et al. 1998). Differences in temperature, rainfall, and seasonal and annual changes impact all aspects of interactions among organisms and their environment, including wetlands.

During the 1990's Brinson (1993b) and the National Academy of Sciences (National Research Council 1995) described and defined three other factors at a smaller geographic scale that can be considered primary controls of functions within a wetland:

- Geomorphic or topographic setting of the wetland
- Direct source of water to the wetland
- Hydrodynamics, or the direction of flow and strength of water movement within the wetland

More recently, however, scientists have become increasingly aware that functions performed by wetlands are also controlled by processes that occur at the scale of the watershed. There is currently an emphasis on trying to understand wetland functions in the context of how water, sediments, and nutrients move in a watershed (Bedford 1999). The surface geology and soils, the routing of water through the watershed, and the movement of sediments, large wood, nutrients, and other chemicals are all considered important factors in controlling how individual wetlands function (see Section 2.3.3).

2.3.2 How Wetland Functions Are Defined

The interactions that occur within a wetland occur at many scales as well, from the microscopic (such as bacterial decomposition of organic matter) to the continental (such as providing refuge and feeding for migrating waterfowl along the continental flyways). If every interaction that occurs within a wetland were identified as a separate function, the number of functions would be almost infinite. For example, the decomposition of organic matter by bacteria is a combination of many types of decomposition, one for each individual species of bacteria found in the wetland. Each bacterial species decomposes organic matter at a different rate and under different environmental conditions. Each of these could be considered a separate wetland function.

In contrast, a function can be a broad lumping of many environmental processes. For example, the “removal of imported elements and compounds” is a function identified in one method for assessing wetland functions (Brinson et al. 1995). At least a dozen nutrients and several hundred known contaminants can be found in surface waters. Therefore this function combines several hundred different processes of removal, one for each imported nutrient, contaminant, and other compound.

Wetland functions – The physical, biological, chemical, and geologic interactions among different components of the environment that occur within a wetland. There are many valuable functions that wetlands perform but these can be grouped into three categories – functions that improve water quality, functions that change the water regime in a watershed such as flood storage, and functions that provide habitat for plants and animals.

Furthermore, wetlands perform many types of functions, but not all wetlands perform the same functions, nor do similar wetlands provide the same functions to the same level of performance (Clairain 2002).

One of the initial tasks in defining functions, therefore, is to identify and group the processes and interactions that occur in wetlands into some manageable number of “functions.” Most functions are generally grouped in terms of three broad categories (Adamus et al. 1991):

- Biogeochemical functions, which are related to trapping and transforming chemicals and include functions that improve water quality in the watershed
- Hydrologic functions, which are related to maintaining the water regime in a watershed and include such functions as reducing flooding
- Food web and habitat functions

Functions are subdivided into more specific groups by the environmental processes or interactions within the wetland that are related and are on a similar temporal and spatial scale. They are also grouped based on the needs for managing wetlands (Hruby 1999). For example, managers may need to know how well a wetland removes specific constituents that contribute to poor water quality such as sediment, nutrients, and toxic compounds, rather than having only a general assessment of the removal of elements and compounds that cause problems with water quality.

Table 2-1 gives examples of how the many different processes and interactions that occur in wetlands have been grouped under different names for various policy and regulatory purposes. They are organized into the three broad categories above (water quality improvement, hydrologic functions, and food webs and habitat).

The names of the categories to some degree reflect how broadly the function is defined. “The removal of all imported elements and compounds” is a broadly defined function, whereas “removing sediment” is a more narrowly defined function. Section 2.5 describes in more detail the functions that have been chosen for the Washington State wetland function assessment project and the Washington State wetland rating systems.

Relationship of functions to values

The scientific literature has in the past confused the terms wetland *functions* and wetland *values*. In fact, the term *functional values* was in common usage during the 1980s and early 1990s (e.g., Amman et al. 1986). The correct interpretation of the term *functional values* suggests that wetland values were functioning, which was not the intent of the phrase. As mentioned previously, wetland functions are the environmental processes that take place in a wetland. Society, however, does not necessarily attach the same value to all functions. Value is usually associated with goods and services that society recognizes, and not all environmental processes are recognized or valued. The National Research Council (1995) says the following about the differences between values and functions.

Because value is a societal perception, it often changes over time, even if wetland functions are constant. Value can change over time as economic development changes a region. The value of a wetland in maintaining water quality near a source of drinking water can be great even if the wetland is small (Kusler 1994). Some values can be mutually exclusive if they involve direct or indirect manipulation, exploitation, or management of wetlands. For example, production of fish for human consumption could conflict with the use of a wetland to improve water quality of water that contains toxins.

There are three reasons for maintaining a clear distinction between functions and the services that wetlands provide (King et al. 2000). First, people can attach values to services, but usually cannot attach values to the underlying environmental functions and processes on which they depend. Second, the factors that affect the level of services a wetland provides are different from those that determine the levels of function. Third, different questions need to be addressed when considering values and functions. When assigning a relative value to a wetland, questions involving the importance and scarcity of the services need to be answered. Depending on the landscape context of the wetland, these may, or may not, be related to the levels of function in the wetland.

Generally, the important values of wetlands cannot be assessed or rated using the same methods as those used to assess functions (Hruby 1999). Analyzing values requires understanding a different set of factors than those used for functions (King et al. 2000).

2.3.3 Environmental Factors that Control Wetland Functions

"Ecosystems are not defined so much by the objects they contain as by the processes that regulate them" (Christiansen et al. 1989)

Functions of wetlands, as defined previously, represent interactions among the different components of the ecosystem and the landscape. Thus, functions can be influenced or controlled by changes to any one of these components. For example, a wetland may perform the function of providing overwintering habitat for coho, for which the presence of seasonal or permanent surface water is critical. This function will, therefore, change if the wetland is drained so no surface

water remains at any time. Changes in functions, however, can also be a result of alterations to the watershed outside the wetland boundary. For example, surface water in the wetland may also be eliminated if its water supply is diverted. Also if the gravel beds in which the coho spawn farther up in the watershed are disturbed, or if the flow in the stream is reduced to such an extent that the young can no longer swim to the wetland from the spawning areas, the wetland's support of coho overwintering habitat will be altered.

Likewise, the expression of one function in a wetland (such as habitat) can result in a change to the larger-scale environmental processes and the landscape. For example, if the conditions are right for beavers to settle in a wetland along a stream or river (i.e., the wetland functions as good habitat), the beavers will build a dam and create a ponded wetland. This will change the vegetation in the wetland and possibly alter other wetland functions such as improving water quality and storing flood waters. These changes may be important enough to change the water quality and the movement of water through that part of the watershed (a change in one of the primary controls of function).

Any factor that changes how well, or how much, a function is performed by a wetland can be considered a “control” of that function. Another term often used in the scientific literature is *driver*. The drivers of functions in wetlands determine how well the functions are performed. An action or occurrence that affects a control or driver is called a *disturbance* by ecologists (Dale et al. 2000). The type, intensity, and duration of disturbances can change the physical structure of the ecosystems and how they behave (ecosystem dynamics) (Dale et al. 2000).

Human activities create a disturbance that causes a “stress” on the ecosystem to which it responds. Scientists often use the term *stressor* to distinguish those disturbances that have a significant impact on an ecosystem from those that have little impact (see for example Adamus et al. 2001, Laursen et al. 2002).

In this document, however, we are not using the term *stressor*. All the disturbances discussed and reviewed here have documented negative impacts on wetlands and their functions. To avoid confusion, the term *disturbance* is used throughout this document.

Human uses of the land create a different set of disturbances than were present before human activities modified the land (Dale et al. 2000). The disturbances that are caused by human activities are discussed in Chapter 3, and the impacts these disturbances have on wetlands and their functions are described in Chapter 4.

The focus of research and management has been on functions and controls of functions that occur within the wetland itself and less on those that are a part of the landscape of the entire watershed. This has resulted from the fact that the need to define wetland functions has actually been driven by regulatory requirements and policy (Brinson et al. 1995, Clarain 2002). The policy has been to have a “no net loss of wetland area and function” at both the state and the national levels. However, this focus on functions confined to the wetland itself is changing. We are learning that managing wetlands requires an understanding of the “relationship of the individual wetlands to the landscape” (Bedford 1996) as well as the wetland itself.

A summary of the literature addressing the environmental factors that control wetland functions is presented below. First reviewed is the literature that addresses controls that occur at the scale of the wetland's contributing basin (that part of the landscape that contributes surface water to the wetland). The controls that are found within the boundary of the wetland (the site scale) are then described. The discussion includes a number of conceptual models that have been developed to help visualize and understand the complex interactions between wetland functions and environmental factors at different scales.

Terms used in this document to refer to environmental factors

Surface and subsurface water flows through the landscape within drainage systems. These drainage systems are often called basins, sub-basins, watersheds, or river basins depending on the size of the area. In this document, drainage systems are generally referred to using one of two terms:

- **Watershed** - A geographic area of land bounded by topographic high points in which water drains to a common destination.
- **Contributing basin** - The geographic area from which surface water drains to a particular wetland.

Environmental factors that affect wetland functions can occur at different geographic scales. In this document two scales are used.

- **Landscape processes** - Environmental factors that occur at larger geographic scales, such as basins, sub-basins, and watersheds. Processes are dynamic and usually represent the movement of a basic environmental characteristic, such as water, sediment, nutrients and chemicals, energy, or animals and plants. The interaction of landscape processes with the physical environment creates specific geographic locations where groundwater is recharged, flood waters are stored, stream water is oxygenated, pollutants are removed, and even wetlands are created.
- **Site processes** - Environmental factors that occur within the wetland itself or within its buffer. The interactions of site processes with landscape processes define how a wetland functions.

2.3.3.1 Environmental Controls of Functions at the Landscape Scale

Hydrogeologic Controls of Functions in Wetlands

Climate, geology, and the hydrologic characteristics in a watershed control how water, sediment, and nutrients move (Bedford 1999). Together, along with factors within the boundary of a wetland, these factors control the functions performed. Scientists call these large-scale, environmental factors the *hydrogeologic setting* of a wetland (Winter 1983, 1986, 1988, 1989, 1992, LaBaugh et al. 1987, Winter and Woo 1990). The following describes some models that have been developed to better understand these controls of wetland functions.

A hydrogeologic model created by Bedford (1996, 1999) concludes that wetlands develop and persist over time through the interaction of the hydrologic cycle with the landscape (Figure 2-1). This model views wetlands as part of an ecological system that is continuous with large-scale surface and groundwater systems. In this model, several geologic characteristics control the flow and chemistry of water, including the surface relief and slope of the land, the thickness and permeability of the soils, and the composition and hydraulic properties of the underlying geologic materials (Bedford 1999).

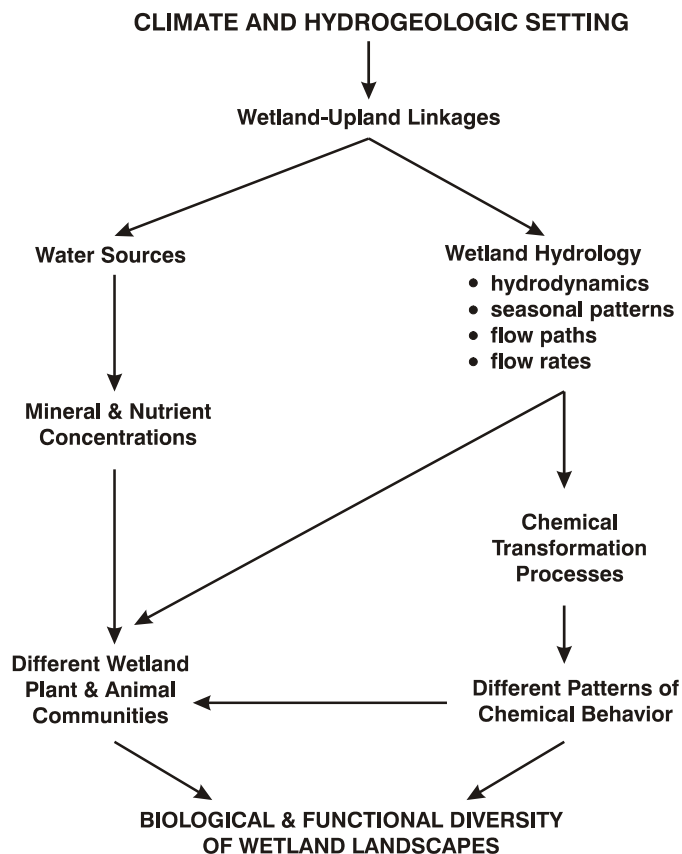


Figure 2-1. A model of the environmental factors that control wetland functions. (Bedford 1999; reprinted with permission)

In Bedford’s hydrogeologic model, as in all the models discussed here, climate drives the large-scale water regime. Climate determines the precipitation and patterns of evapotranspiration that ultimately move surface and groundwater into and out of wetlands (see Figure 2-1). It also determines how sediments and chemicals (e.g., salts and nutrients) are eroded from bedrock and transported throughout the system.

A similar model to that of Bedford considers the contributing basin of a wetland in describing the factors that affect functions. This model, known as the “process-structure-function” model (Figure 2-2), was developed in conjunction with restoration plans for Northwest riverine systems. It is described in more detail in Beechie and Bolton (1999), Gersib (2001), and Stanley and Grigsby (2003). The model assumes that the biological, physical, and chemical characteristics (structure and functions) of aquatic systems including wetlands are determined by the interaction

of many processes operating at the larger scale of the landscape (Kaufman et al. 1997, Beechie and Bolton 1999). These processes include the movement of (Naiman et al. 1992):

- Water (surface and subsurface)
- Sediment
- Nutrients and other chemicals (salts, toxic contaminants)
- Large woody debris
- Energy (in the form of sunlight)

According to the “process-structure-function” model, the interactions of these processes with climate and geomorphology determine the structure within wetlands (e.g., substrate, plant communities). The wetland structure, in turn, is one factor that influences the type and performance of wetland functions.

For example, a wetland may produce large quantities of plant material and support the function of a rich food web. In order to provide this function, the wetland needs to have waters rich in nutrients coming into it, good exposure to sunlight, and a way for the production of plant material to leave the wetland into surrounding aquatic resources. The major controls for this function are the movement of water to and from the wetland, the movement of nutrients into and within the wetland, and an adequate source of energy.

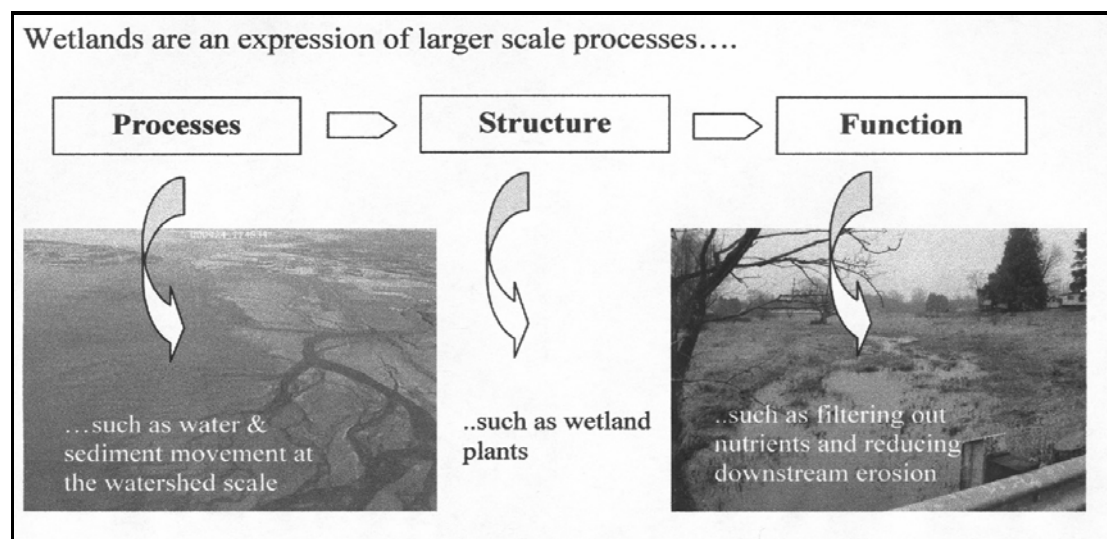


Figure 2-2. “Process-structure-function” model.

The “process-structure-function” model, like Bedford’s, assumes that changes in land use affect processes such as the delivery of water, nutrients, sediment, and toxics to aquatic systems (Poiani et al. 1996, Mallin et al. 2000). These in turn affect structure and function within those aquatic systems.

Controls of the Habitat Provided by Wetlands

The abundance and richness of species within a wetland may be explained by the attributes of the surrounding landscape as well as by the characteristics found within the site itself (review in Dale et al. 2000). This is the landscape principle in ecology that was described in Section 2.2. The kinds of organisms that exist in a wetland and their interaction with landscape processes are constrained by the sizes, shapes, and patterns of interspersions of habitat across a landscape.

Understanding how animals and plants move between different habitats, and how the distribution of habitat “patches” affect the abundance of species, are the goals of a relatively new science called *landscape ecology*. The major result of recent research has been to highlight the fact that the distribution and abundance of species at an individual site, or “patch” is affected by the location, size, and shape of other patches of similar or different habitat in the surrounding landscape (Haila 2002, Manning et al. 2004). Some of the questions being asked in this research have been summarized by Bissonette and Storch (2002) and include:

- What is the relationship between species richness and the size of the patch of habitat?
- What is the relationship of species abundance to size of the patch of habitat?
- Are the interactions between different species modified as habitat is fragmented?
- Do the changes in the amount and quality of habitat along the edges of patches (edge habitat) change how an area functions as habitat?
- What are the relationships between relatively undisturbed corridors and the movement of species between habitat patches that have been separated by human activities?
- Do such connections increase species richness?

The research to date has highlighted the fact that there are no easy answers to these questions. The response of animals and plants to changes in patches, corridors, and distance between patches of the same habitat is very specific to the species involved (Haila 2002, Bissonette and Storch 2002, Haddad et al. 2003, Manning et al. 2004). For example, Haddad et al. (2003) studied ten different species living in the forests of South Carolina. Although the species were chosen because the authors thought they were likely to respond to the presence of corridors connecting patches of forest habitat, the abundance of only five of the ten species was positively correlated with presence of corridors. The abundance of the other five species was not correlated with the presence of corridors.

The study of patches and interaction between patches and species richness and abundance has taken on an increasing importance as human activities on the land have changed the distribution of habitats. The changes in habitat at the scale of the landscape caused by human activities are called *fragmentation*. The fragmentation of habitat consists of both reductions in the area of the original habitat and changes in the spatial configuration of what remains (Haila 2002). The results of current research on fragmentation have been difficult to interpret because much of it does not adequately separate the environmental factors that might cause differences in biodiversity (Haila 2002, Fahrig 2003, Manning et al. 2004). There is, however, one general conclusion that can be made from the current research. In reviewing over one hundred articles on

habitat fragmentation, Fahrig (2003) found that the loss of area available as habitat that results from human uses of the land has a large, consistently negative effect on the abundance and richness of species.

2.3.3.2 Environmental Controls of Functions at the Site Scale

The environmental factors at the large scale ultimately affect the environmental factors within the wetland itself (the site scale). As introduced earlier, Brinson (1993b) has developed a model that defines three factors that can be considered as primary controls of wetland functions at the site scale. Brinson's (1993b) model also uses characteristics of the landscape as factors that control functions in a wetland, but his model focuses primarily on the wetland itself relative to the two models discussed earlier (Bedford 1999). For example, Brinson's model emphasizes the shape and location of the wetland in the landscape and the type of water movement in the wetland that is dominant. The three factors defined by Brinson (1993b) are:

- The **geomorphic setting** (landscape position) of the wetland. Geomorphic setting is the topographic location of the wetland within the surrounding landscape and the geology that underlies it. In other words, is the wetland in a depression, on a slope, in a floodplain, or on the shores of a lake? The underlying geology also determines the soils present in the wetland, and this for example has an effect on the type and abundance of the plants found there.
- The **source of water** to the wetland. The sources of water can be simplified to precipitation, surface flow, shallow subsurface flow, and groundwater.
- The **hydrodynamics** of the wetland (the direction of flow and strength of water movement within the wetland). Hydrodynamics refers to the movement of water in the wetland and its capacity to do work. There are three qualitative categories of hydrodynamics: (1) vertical fluctuations of the water levels or water table, (2) unidirectional surface or near-surface flows that range from strong currents contained in channels to slow sheet flow down a slope, and (3) bidirectional flows resulting from tides or wind-driven currents in lakes.

In contrast, the “hydrogeologic” and “process-structure-function” models describe the surface and subsurface conditions across the landscape that control water processes within the wetland's contributing basin. The Brinson model (1993b) is the basis of the hydrogeomorphic (HGM) classification system which groups wetlands into similarly functioning groups. The classification system and an earlier classification, used for habitat mapping, are described in Section 2.4.1.

2.3.3.3 Summary of the Controls of Wetland Functions

To summarize the literature on the environmental factors that control functions, the authors of this synthesis have combined the terms and information used by several different authors to arrive at the list of factors in Table 2-2. These terms will be used in the following chapters because no standardized terms have been defined to describe all that happens at the different geographic, temporal, or spatial scales. In fact, the many articles that have been written on the subject of wetland functions and how they are controlled by environmental factors have engendered some

confusion in the terms used. For example, the term *process* has been used by different authors to describe a wide range of happenings that include the routing of water at a landscape scale as well as the chemical reactions by which bacteria change nitrate to nitrogen gas at the microscopic scale. Both of these factors are considered controls of functions.

The relationship between the environmental factors in Table 2-2 that control wetland functions and how they interact with human-caused disturbances is shown conceptually in Figure 2-3.

Table 2-2. Environmental factors that have been identified as controls of functions in wetlands. Most of the controls can occur at both the landscape scale and the site scale.

Environmental Factors that Control Functions in Wetlands	Scale at which the Control Occurs
Physical structure of wetlands (e.g., soils, vegetation, rocks)	Site
Biological structure of wetlands (e.g., physical structure of plants)	Site
Input of water (amount of water; maximum and minimum water levels)	Landscape and site
Fluctuations of water levels (frequency, amplitude, direction of flows)	Landscape and site
Input of sediment	Landscape and site
Input of nutrients	Landscape and site
Input of toxic contaminants	Landscape and site
Temperature	Landscape and site
Level of acid (pH)	Landscape and site
Concentration of salts	Mostly site
Size, connections, and distances of habitat patches in the surrounding landscape	Landscape
This table is a synthesis of the information presented by Winter (1983, 1986), LaBaugh et al. (1987), Winter and Woo (1990), Naiman et al. (1992), Brinson (1993a), Brinson et al. (1995), Bedford (1999), Beechie and Bolton (1999), Gersib (2001), Adamus et al. (2001), Stanley and Grigsby (2003).	

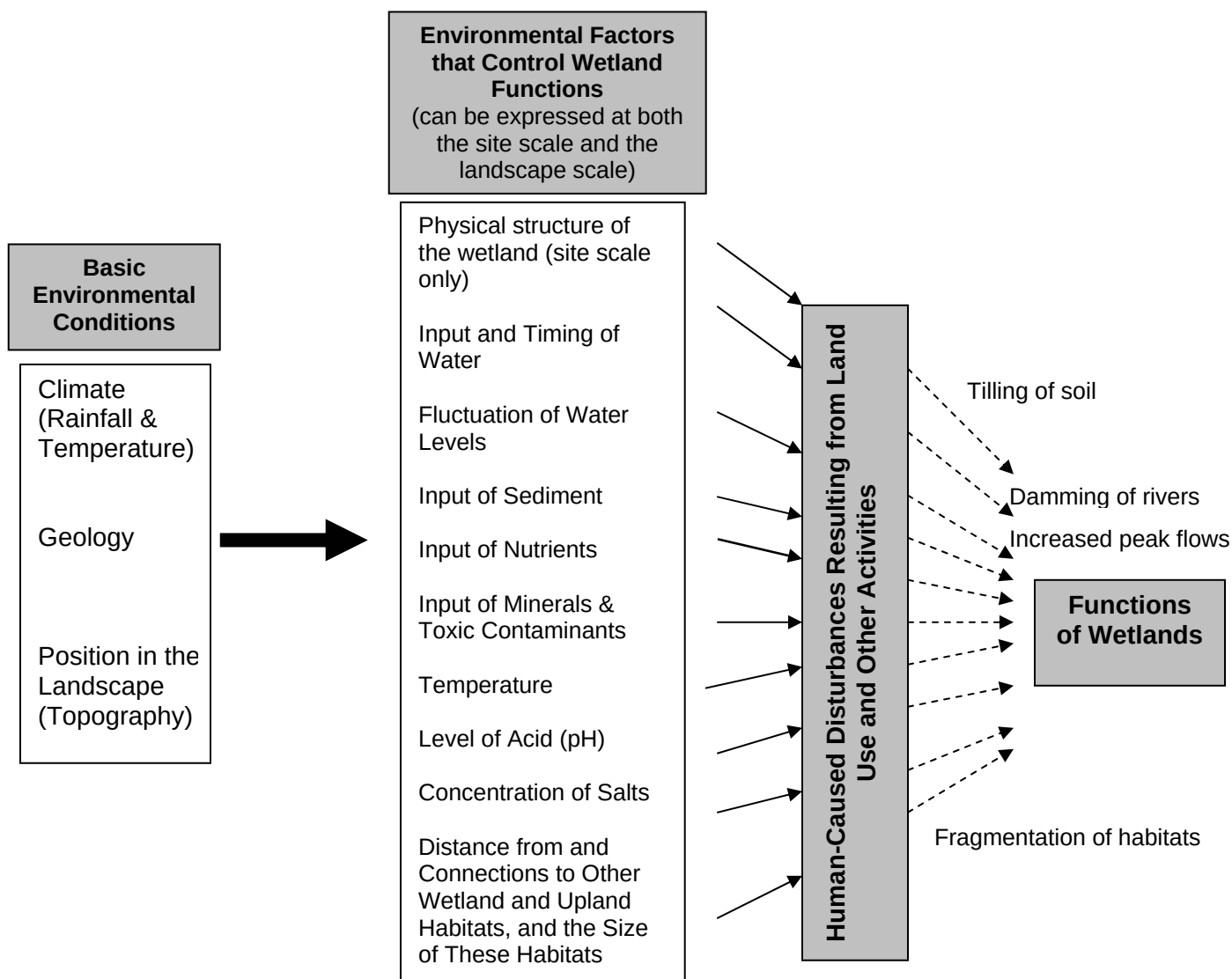


Figure 2-3. Diagram summarizing some major environmental factors that control functions of wetlands and how they interact with human-caused disturbances.

The basic environmental conditions establish and determine the factors that control the functions of wetlands. The controls can occur at both the landscape and site scales. Human activities cause disturbances that affect these controls in many different ways and thereby alter the performance of wetland functions. The figure gives some examples of the disturbances. This figure is a synthesis of the information presented by the same authors as listed in Table 2-2. The different models and information described above are the basis for Chapters 3 and 4 that describe the impacts of human activities on wetlands and their functions.

2.3.4 Summary of Key Points

- There are five basic ecological principles that are useful in managing wetlands. The principles deal with time, place, species, disturbance, and landscape.
- Wetland functions are the physical, biological, chemical, and geologic interactions among different components of the environment that occur within a wetland. There are many ways to define functions depending on specific needs for managing wetlands.
- Functions fall into three broad categories: biogeochemical, hydrologic, and maintenance of food webs and habitat.
- Society does not necessarily attach value, or equal value, to all functions.
- The functions that wetlands perform are controlled by environmental factors that occur in the broader landscape as well as within the wetland. The major controls of function are climate; geomorphology and soils; the source and quantity of water; the movement of water, nutrients, other chemicals, and sediments; energy in the form of sunlight; and biological interactions.
- The factors that control wetland functions interact with each other and there are many feedback loops. Environmental processes create the physical structure of the ecosystem and this in turn controls functions. Functions, in turn, can then modify the processes and structure as well.
- In order to gain a basic understanding of the ecological importance of functions provided by wetlands, they must be evaluated within the context of the landscape in which they exist.

2.4 Classification of Wetlands in Washington as a Key to Understanding Their Functions

This section presents a brief discussion of systems that scientists have developed to group or classify wetlands nationally and in Washington State in order to better assess how they function. It begins with an overview of two classification systems—the Cowardin classification, commonly used to inventory wetlands across the country, and the hydrogeomorphic or HGM classification, which is used to characterize how wetlands function. Understanding how wetlands are grouped and classified is a key to fully understanding how different types of wetlands in different areas provide different functions.

2.4.1 Commonly Used Classification Systems in Washington

2.4.1.1 The Cowardin Classification

The first commonly used classification system for wetlands was developed in 1979 by the U.S. Fish and Wildlife Service (Cowardin et al. 1979). The Cowardin classification system is hierarchical and includes several layers of detail for wetland classification that are based on:

- Water flow
- Substrate types
- Vegetation types
- Dominant plant species

The Cowardin classification system was developed to aid a national inventory of wetlands using aerial photographs (the U.S. Fish and Wildlife Service National Wetland Inventory or NWI). The wetlands in the state that can be identified from aerial photographs have been mapped using this classification system. The maps are available from the U.S. Fish and Wildlife Service in a digital form for GIS (<http://www.nwi.fws.gov/>). This information is a useful starting point for developing inventories of wetlands at the local level and looking at wetlands at the scale of watersheds and river basins.

Methods for organizing our knowledge about wetlands have been called *classifications*, *categorizations*, *characterizations*, *ratings*, *assessments*, and *evaluations*. These groupings are meant to indicate the type of information a method provides. Unfortunately, the scientific community has been inconsistent in the use of these terms. Users of methods developed for analyzing wetlands should be aware of some of these problems with terminology. See Appendix 2-A for further discussion.

2.4.1.2 The Hydrogeomorphic Classification

Although the Cowardin classification is useful in developing wetland inventories from aerial photographs and incorporates some landscape factors, it was not designed to help understand how functions differ among wetlands. A more recent system of classification, called the *hydrogeomorphic (HGM) classification* (Brinson 1993b), was developed to specifically address differences in how various wetlands function. This classification method was chosen by the statewide wetland technical committee that guided the development of the Washington State wetland function assessment methods (Hruby et al. 1999).

As previously described in Section 2.3.3, the HGM classification is based on (Brinson 1993b):

- The position of the wetland in the landscape (geomorphic setting)
- The source of water for the wetland

- The flow and fluctuation of the water once in the wetland (hydrodynamics)

Classifying wetlands based on how they function narrows the focus of attention to a specific type of wetland. It also focuses on the functions that wetlands within that type are most likely to perform and the environmental factors that most likely control how wetlands of that type function.

The HGM classification also uses the concept of grouping wetlands by geographic units (domains and regions) in which some of the controls of functions that occur at the landscape scale are similar. The assumption is that many of the functions performed by wetlands are also similar.

The highest category in the HGM classification (called *class*) is defined nationally (Table 2-3) and is based on the geomorphic setting of the wetland (Brinson 1993b, Smith et al. 1995). Not all geographic units (domains and regions) contain all the wetland classes possible.

Within a region, wetland classes can be further divided by local experts into wetland subclasses and sub-subclasses (sometimes called *families* of wetlands) based on other geomorphic or hydrologic characteristics. The wetland experts in each region can, therefore, tailor the classification to address differences in the performance of functions by different wetland types in their region (Smith et al. 1995).

Geographic areas to which this classification system is applied in Washington and a description of the HGM classes in the state are described in Section 2.4.4.

Table 2-3. Characteristics of wetland classes in the hydrogeomorphic classification (from Brinson 1993a).

Hydrogeomorphic Class (Geomorphic Setting)	Dominant Source of Water	Dominant Hydrodynamics (Movement of Water)
Riverine	Overbank flow from a channel, or hyporheic (underground) flow in floodplain	One direction, horizontal
Depressional	Surface runoff, or the “daylighting” of groundwater	Vertical
Slope	“Daylighting” of groundwater on slopes	One direction, horizontal
Lacustrine (Lake) Fringe	Lake water	Two directions, horizontal
Flats	Precipitation	Vertical
Tidal Fringe	Overbank flow from estuary	Two directions, horizontal

2.4.1.3 Other Classifications Used in Washington

There have been several other classifications developed in Washington to group wetlands for the purpose of inventories and identifying different types of habitats. Kunze (1994) developed a classification of native, low elevation, freshwater wetlands in western Washington that is based on the dominant plant species found in the wetland. The purpose of this classification was to distinguish “natural heritage resources,” whose identification was mandated by state law.

In eastern Washington, Kovalchik and Clausnitzer (2004) developed a classification of Aquatic, Riparian, and Wetland sites in the national forests that is also based on the dominant vegetation. The purpose of this classification was to describe the general geographic, topographic, edaphic (resulting from soils), functional, and floristic features of aquatic, riparian and wetland ecosystems. In addition, they developed it to describe successional trends in these ecosystems. Lastly it provides information on the values of the resources and opportunities for management (Kovalchik and Clausnitzer 2004).

2.4.2 Geographical Differences in Wetland Functions

Because hydrogeologic settings and the controls of functions vary across the landscape, it is important to identify the geographic areas in which these factors are similar. This allows the grouping of wetlands that function similarly.

For example, two conferences on wetland functions in the mid-1980s highlighted some of the differences between wetlands on the West Coast and those in the rest of the country (Horner 1986). Specifically, wetlands on the West Coast are different for the following reasons (Zedler 1985 as cited in Horner 1986):

- Drainage areas to West Coast wetlands are often smaller than those on the East Coast
- The coastal plain, with some exceptions, is not as large on the West Coast
- Soils in the West Coast region are often high in clay
- Conditions in a watershed are often highly erosive on the West Coast because of the steep topography
- Precipitation varies more seasonally on the West Coast than east of the Rocky Mountains

Even within Washington, the diverse areas of the state support many kinds of wetlands that vary in functions. For example, vernal pools on the scablands differ greatly from the floodplain marshes along the Snoqualmie River, and wetlands that formed in the potholes created by glaciers have different functions from those found along the shores of salt lakes in the Grand Coulee (Hruby et al. 2000).

Through the Washington State wetland function assessment project, there has been a major effort over the last eight years to build on previous work and to develop methods for assessing how wetlands function in different regions of the state. The methods are based on a formal process of quantifying the collective judgment of a group of local experts. This approach provides a

scientific basis for rapid methods in the absence of rigorous, site-specific scientific studies (Hruby 1999).

A statewide technical committee was formed in 1994 to guide the technical components of the function assessment project. In addition, several assessment teams, composed of experts in different disciplines, developed methods for specific wetland types and areas of the state (Hruby et al. 1999, 2000). At present, methods for four wetland types in the lowlands of western Washington and three types in the Columbia Basin of eastern Washington have been completed. These documents are available on the project's web site (<http://www.ecy.wa.gov/programs/sea/wfap/index.html>).

Another major effort has just been completed to incorporate differences among geographic areas and wetland functions into the Washington State wetland rating systems for eastern and western Washington. The Washington State Department of Ecology has been coordinating this effort, and teams of regional wetland experts and local government staff have provided technical expertise in writing the documents.

The geographic regions where wetlands function in different ways that have been identified by these teams of regional experts are described in the next section.

2.4.3 Wetland Regions in Washington

Wetlands in Washington are grouped first into “domains” and “regions” based on climate and other landscape features, then into “classes” by geomorphic setting, and finally into “subclasses” and “families” by the sources of water for the wetland and how that water moves (Hruby et al. 1999, 2000, Hruby 2004a,b). These are some of the primary controls of wetland functions as described earlier. This section focuses on the wetland domains and regions. Section 2.4.4 describes the wetland classes and Section 2.4.5 the subclasses for Washington State.

The wetlands in Washington were divided into two ecological domains, East and West, when the Washington State wetland rating systems were first developed (Ecology 1991, 1993). The teams of wetland experts who revised the rating systems have kept this division (Hruby 2004a,b). At this highest level, the domains are based on the national classification of the environment (called *ecoregions*) developed by federal agencies (Bailey 1995). Wetlands on the west side of the Cascade Crest fall within the domain called *Humid Temperate* and those on the east side are in the *Dry* domain.

The term *ecoregion* was coined by J.M. Crowley (1967) and popularized by Robert J. Bailey (1976) to define a classification of ecosystems in the United States. Ecoregions are generally considered to be regions where climatic conditions are similar. As a result, the ecosystems there, including wetlands, are relatively homogeneous (Omernik and Gallant 1986). The concept was developed to help resource managers better understand regional differences in the environmental factors that maintain ecosystems and the relative importance of different factors that can change ecosystems (Omernik and Gallant 1986). The local maps of the ecoregions and their definitions are continually being updated by the U.S. Environmental Protection Agency laboratory in Corvallis, Oregon. The latest maps of ecoregions are available on the web at <http://www.epa.gov/bioindicators/html/ecoregions.html>.

The wetland experts working on assessments of function in the state further divided the domains into smaller regions because the two domains are too coarse a division for understanding how wetlands function in the state in a more detailed way (Hruby et al. 1999, 2000). At present there are five regions in the state (Figure 2-4) including three regions in the eastern domain and two in the western domain:

- Eastern domain:
 - Montane
 - Columbia Basin
 - Lowlands of Eastern Washington
- Western domain:
 - Montane
 - Lowlands of Western Washington

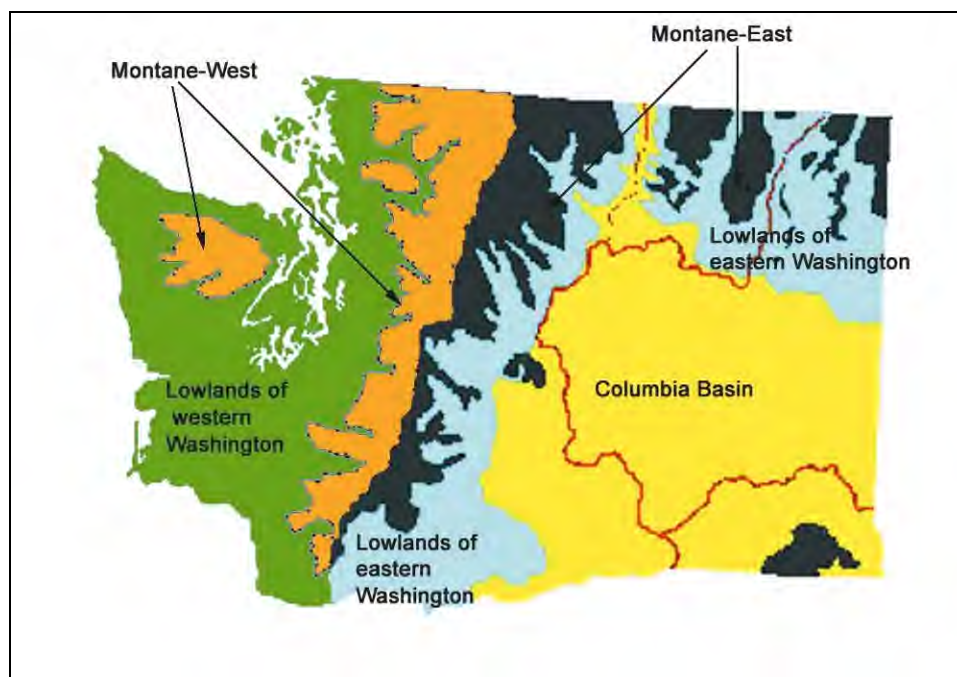


Figure 2-4. Regions in Washington used for classifying wetlands.

As mentioned previously, these regions of Washington are linked to the national classification of ecoregions developed by several federal agencies. The boundaries of the regions used in Washington, however, in some cases include parts of multiple ecoregions defined at the national level. The geographic extent of the Lowlands of Western Washington includes portions of three ecoregions within the Humid Temperate domain defined at the national level: the Coast Range, the Puget Lowlands, and the Willamette Valley (Hruby et al. 1999). Characteristics of these ecoregions are detailed in Omernik and Gallant (1986). The geographic extent of the Columbia Basin region, however, is the same as the Columbia Basin Ecoregion identified by Omernik and Gallant (1986).

At present, final definitions of regions have been developed only for the Lowlands of Western Washington and the Columbia Basin because these are the only two regions for which methods to assess wetland functions have been developed. The Montane regions (east and west of the Cascades) and the Lowlands of Eastern Washington have been defined with less detail because methods for assessing functions in these regions have not yet been developed. Generally the Montane regions include areas above 3,000 feet (915 m) elevation, and the Lowlands of Eastern Washington includes all other areas in the Dry domain, outside the Columbia Basin, and below 3,000 feet (915 m) elevation.

2.4.4 Description of the Wetland Classes for Washington

A brief description of wetlands in the different classes in Washington is given below. More detailed descriptions are available in Hraby et al. (1999, 2000).

2.4.4.1 Riverine Wetlands

The distinguishing characteristic of riverine wetlands in Washington is that they are frequently flooded by overbank flow from a stream or river (Hraby et al. 1999). Riverine wetlands are found in a valley or adjacent to a stream channel (Figure 2-5). They lie in the active floodplain of a river or stream and have important links to the water dynamics of the river or stream. The flooding waters are a major environmental factor that structures the environment in these wetlands and controls wetland functions. Riverine wetlands in some regions of Washington are defined by the frequency of overbank flooding (Hraby 2004a,b).



Figure 2-5. Riverine wetlands. Located in active floodplains where overbank flooding of the river or stream structures the wetland environment and controls its functions.

2.4.4.2 Depressional Wetlands

Depressional wetlands occur in topographic depressions that have closed contours on three sides (Figure 2-6). Elevations within the wetland are lower than in the surrounding landscape. The shapes of depressional wetlands vary, but in all cases the movement of surface water and shallow subsurface water is toward the lowest point in the depression. The depression may have an outlet, but the lowest point in the wetland is somewhere within the boundary, not at the outlet (Hruby et al. 1999).



Figure 2-6. Depressional wetlands. Located in topographic low areas that are closed on at least three sides (they may or may not have an outlet).

2.4.4.3 Slope Wetlands

Slope wetlands (Figure 2-7) occur on hill or valley slopes where groundwater surfaces and begins running along or immediately below the soil surface. They are usually found where the topography and local geologic conditions forces groundwater to the surface creating a zone of perennial or near-perennial moisture (Stein et al. 2004). Water in these wetlands flows only in one direction (down the slope) and the gradient is steep enough that the water is not impounded. The “downhill” side of the wetland is always the point of lowest elevation in the wetland (Hruby et al. 2000).



Figure 2-7. Slope wetlands. Located on slopes where groundwater daylights and runs at or just below the soil surface.

2.4.4.4 Lacustrine (Lake) Fringe Wetlands

Lacustrine fringe wetlands in Washington are found along the edges of deeper bodies of water such as lakes or reservoirs (Figure 2-8). These wetlands occur at the margin of topographic depressions in which surface water covers more than 20 acres (8 ha) and is deeper than 7 feet (2 m) in western Washington or 10 feet (3 m) in eastern Washington. The amount of open water and deep water also has to exceed 30% of the total area of wetland. The dominant surface water movement in lacustrine fringe wetlands has a horizontal component due to winds or currents, but there may also be a corresponding vertical component resulting from wind or seasonal water fluctuations (Hruby et al. 1999, 2000).

The definition of *lake fringe* is more specific than the definition of *lacustrine* used in the Cowardin classification described previously. The local teams of experts developing methods for assessing functions and the rating system decided to refine the definition of lacustrine to better reflect environmental conditions in the state.



Figure 2-8. Lacustrine fringe wetlands. Located along the edge of large bodies of water, such as lakes.

2.4.4.5 Flats Wetlands

Flats wetlands are rare in Washington. They occur in topographically flat areas that are hydrologically isolated from surrounding groundwater or surface water. The main source of water in these wetlands is precipitation. They receive virtually no groundwater discharge or surface runoff from areas outside the wetland boundary. This characteristic distinguishes them from depressional and slope wetlands (Hruby et al. 1999).

2.4.4.6 Tidal Fringe Wetlands

Tidal fringe wetlands occur along the coasts and in river mouths to the extent of tidal influence. The dominant source of water is from the ocean or a river that empties into the ocean; therefore these wetlands can be fresh or saline. The unifying characteristic of this class is the hydrodynamics. All tidal fringe wetlands have water flows dominated by tidal influences and water depths controlled by tidal cycles (Hruby et al. 1999). This document does not address tidal fringe wetlands.

2.4.5 Subclasses of Wetlands in Washington

Developing the HGM classification for Washington is an ongoing process, and not all subclasses for wetlands in the different regions have been defined. The wetland subclasses and families that have been defined in the four regions of Washington (as of February 2005) are listed in Table 2-4.

Although the HGM classification for wetlands in the state is not yet complete, the categories listed in Table 2-4 provide a useful tool to help separate wetlands into different types.

Table 2-4. Subclasses and families of wetlands in different regions of Washington State. (Hruby et al. 1999, 2000)

Class	Subclasses and Families by Region			
	Lowlands of Western WA	Lowlands of Eastern WA	Columbia Basin	Montane (East and West)
Riverine	• Impounding • Flow-through	ND	ND	ND
Depressional	• Outflow • Closed	ND	• Alkali • Freshwater • Long-duration • Short-duration	ND
Slope	ND	ND	ND	ND
Flats	ND	Probably does not occur in the region.	Probably does not occur in the region.	ND
Lacustrine (Lake) Fringe	ND	ND	ND	ND
Tidal Fringe	• Salt Water • Fresh Water	Does not occur in the region.	Does not occur in the region.	Does not occur in the region.
ND = Subclasses in the region have not yet been defined.				

2.4.6 Summary of Key Points

- The physical structure and functions of wetlands vary by region. The diverse regions of Washington support many kinds of wetlands that provide different functions. These differences are documented in the wetland function assessment methods and rating systems for Washington State.
- Wetlands in Washington are grouped first into domains and regions based on climate, then by geomorphic setting, and finally by the sources of water for the wetland and how that water moves. This is called the hydrogeomorphic (HGM) method for classifying wetlands.
- Hydrogeomorphic classes in Washington State include riverine, depressional, slope, lacustrine (lake) fringe, flats, and tidal fringe. Subclasses and families of wetlands are also defined by region (see Table 2-4).

2.5 Overview of Wetland Functions in Washington State

As described in the previous section, our current knowledge about wetland functions in different regions of Washington and among different HGM classes is based largely on the work of experts involved in developing the function assessment methods and ratings for wetlands in the state (Hruby et al. 1999, 2000, Hruby 2004a,b). Experts have developed methods to assess functions of riverine and depressional wetlands in several regions of the state. They have not discussed or identified the functions of freshwater wetlands in the flats, slope, tidal fringe, or lacustrine fringe classes, nor any functions of wetlands in the montane regions.

As mentioned in Section 2.3.2 there are many ways to group wetland functions. Functions that are currently defined for the state are listed on the following pages. The definitions are compiled from Hruby et al. (1999, 2000) and Hruby (2004a,b). Not all wetlands in a region, class, or subclass perform all of these functions. A more detailed description of each function is given in Section 2.6. As noted previously, functions are coarsely grouped into three main categories, those that improve water quality, those related to water regime in a watershed, and those that pertain to wildlife habitat.

The functions selected for the Washington State wetland function assessment methods and the rating systems are narrowly defined to provide a level of specificity that is important to managing wetlands by decision-makers. The list of functions defined here does not represent all the functions performed by wetlands in the state. It does, however, represent the functions that were determined to be valuable by the experts that developed them and that need to be considered when managing wetlands (Hruby et al. 1999, 2000, Hruby 2004a, b).

2.5.1 Functions Related to Improving Water Quality

Removing Sediment: This function is defined in terms of the processes and characteristics that retain sediment within a wetland and prevent its downstream movement. A wetland performs this function if there is a net annual decrease of sediment load to downstream surface waters.

Removing Nutrients/Phosphorus: This function is defined in terms of the processes and characteristics within a wetland that remove phosphorus present in surface waters and prevent its movement into surface waters and groundwater.

Removing Nutrients/Nitrogen: This function is defined in terms of the processes and characteristics within a wetland that remove dissolved nitrogen present in surface waters or groundwater and prevent its further movement into surface waters or groundwater.

Removing Metals and Toxic Organic Compounds: This function is defined in terms of the processes and characteristics within a wetland that retain toxic metals and toxic organic compounds coming into the wetland and prevent their movement into surface waters and groundwater.

Removing Pathogens: This function can be defined in terms of the processes and characteristics within a wetland that retain or kill pathogenic organisms such as viruses and bacteria that can cause diseases in humans. This function was originally excluded from the water quality functions identified by the expert teams who developed the assessment methods and revised the rating system. They judged that the characteristics that determine this function are the same as those for removing sediment and removing toxic compounds. It has been added to the list of functions because reviewers of this document suggested it and it is a commonly recognized function (Kadlec and Knight 1996).

2.5.2 Functions Related to Maintaining the Water Regime in a Watershed (Hydrologic Functions)

Reducing Peak Flows: This function is defined in terms of the processes and characteristics within a wetland by which the peak flow in a watershed can be reduced during a major storm or snowmelt (i.e., events that would otherwise cause flooding).

Reducing Erosion: This function is defined in terms of the processes and characteristics within a wetland that detain high flows during storms and reduce the duration of erosive flows, thus decreasing downstream erosion in streams. This definition was developed for riverine and depressional wetlands. Wetlands along the shores of lakes (Jude and Pappas 1992) also protect resources from erosion but in a different way. For wetlands classed as lacustrine fringe, the function can be called “dissipation of erosive forces.” This is defined as the processes by which wetlands reduce wave and current energies, thus reducing erosion of shorelines.

Recharging Groundwater: This function is defined in terms of the processes and characteristics within a wetland that allow surface water to infiltrate into the groundwater system.

2.5.3 Functions Related to Habitat

General Habitat: This function is defined in terms of the processes and characteristics within a wetland that indicate a general suitability and opportunity as habitat for a broad range of species. A suitable habitat for a suite of different fauna can be provided by a broad range of structures, vegetation, and interspersed habitat types within the wetland and the upland habitats contiguous to a wetland. Characteristics in a wetland can be quite different and continue to provide highly suitable conditions for a range of species.

Habitat for Invertebrates: This function is defined in terms of the processes and characteristics within a wetland that help maintain a high number of invertebrate species.

Habitat for Amphibians: This function is defined in terms of the processes and characteristics within a wetland that contribute to the feeding, breeding, or refuge needs of amphibian species.

Habitat for Anadromous Fish: This function is defined in terms of the processes and characteristics within a wetland that contribute to the feeding, breeding, or refuge needs of anadromous fish species.

Habitat for Resident Fish: This function is defined in terms of the processes and characteristics within a wetland that contribute to the feeding, breeding, or refuge needs of resident native fish.

Habitat for Wetland-Associated Birds (called *Aquatic Birds* in the methods for eastern Washington): This function is defined in terms of the processes and characteristics within a wetland that provides habitats or life resources for species of wetland-associated birds. Wetland-associated bird species are those that depend on aspects of the wetland for some part of their life needs: food, shelter, breeding, or resting.

Habitat for Wetland-Associated Mammals (called *Aquatic Mammals* in the methods for eastern Washington): This function is defined in terms of the processes and characteristics within a wetland that support one or more life requirements of aquatic or semi-aquatic mammals.

Richness of Native Plants: This function is defined in terms of the degree to which the wetland provides a habitat for many different native plant species.

Supporting Food Webs (also called *Primary Production and Export* in the methods for western Washington): This function is defined in terms of the processes and characteristics within a wetland that support complex food webs within the wetland and surrounding resources through the export and assimilation of the primary productivity of the wetland. The function combines three major environmental processes: primary production, secondary production, and export of production.

2.5.4 Summary of Key Points

- Wetland functions are currently defined for Washington State in a relatively narrow manner to facilitate better wetland management and regulation by decision makers.
- Wetland functions defined in Washington fall into three general groups: functions related to improving water quality, functions related to the water regime in a watershed (hydrologic functions), and functions related to habitat.
- Not all wetlands in a region, class, or subclass perform all functions.

2.6 How Wetlands Perform Functions in Washington State

Table 2-5 summarizes the information on the functions that are, or are not, performed by the different freshwater wetland classes in Washington State. The following sections synthesize information available about each function and how the different wetland types in the state perform that function.

Table 2-5. Functions potentially performed by wetlands in different HGM classes in Washington. Data compiled from Hruby et al. (1999, 2000), Hruby (2004a, b).

Functions	Riverine	Depressional	Slope	Lacustrine Fringe	Flats
Improving Water Quality					
Removing Nutrients	P	P	P	P	P
Removing Sediment	P	P	P	P	NS
Removing Metals/Toxic Organic Compounds	P	P	P	P	P
Removing Pathogens	P	P	P	P	P
Hydrologic					
Reducing Peak Flows	P	P	N	N	NS
Decreasing Downstream Erosion/Dissipating Erosive Forces	P	P	P	P	NS
Recharging Groundwater	P	P	N	N	NS
Food Webs and Habitat					
General Habitat	P	P	P	P	P
Habitat for Invertebrates	P	P	P	P	P
Habitat for Amphibians	P	P	P	P	P
Habitat for Anadromous Fish	P	P	N	P	N
Habitat for Resident Fish	P	P	N	P	N
Habitat for Wetland-Associated Birds	P	P	NS	P	P
Habitat for Wetland-Associated Mammals	P	P	NS	P	P
Plant Richness	P	P	P	P	P
Support Food Webs	P	P	P	P	P
Key to symbols used in table: P = Functions are performed N = Functions are not performed NS = (not significant) Functions are performed to a minor degree, but probably not at levels that are of importance to society.					

2.6.1 Functions that Improve Water Quality

Wetlands greatly influence the quality of water in a watershed by removing many different types of contaminants. They help improve water quality, including that of drinking water, by intercepting surface runoff and removing or retaining inorganic nutrients, processing organic wastes, removing pathogens and reducing suspended sediments before they reach open water. The dominant processes for removing contaminants in wetlands are settling, chemical reactions in and with the soils, and biotransformations (reviewed in Hammer 1989, Moshiri 1993, Kadlec and Knight 1996).

Table 2-6 summarizes some of the major groups of contaminants that can enter wetlands and the primary mechanisms by which they are removed. The following sections discuss in more detail each of the major functions by which wetlands improve water quality.

Table 2-6. Primary mechanisms for removing contaminants in wetlands. Extracted from Hammer 1989, Moshiri 1993, Kadlec and Knight 1996.

Contaminant	Physical	Chemical	Biological
Sediment and other solids	Settling, Filtration		
Oxygen demand	Settling	Oxidation	Biodegradation
Hydrocarbons	Diffusion, Volatilization, Settling	Photochemical oxidation	Biodegradation, Evapotranspiration
Nitrogen compounds			Denitrification
Phosphorus compounds	Settling	Precipitation, Adsorption	
Metals	Settling	Precipitation, Adsorption, Ion Exchange,	Biotransformation
Pathogens	Residence time	UV radiation	Die-off, Other microbes

2.6.1.1 Removing Sediment

Sediment may enter wetlands in direct runoff from surrounding areas, as windblown dust, or in streams or rivers that flow through the wetland. Sediments deposited in wetlands are removed from surface flows, thereby improving water quality down-gradient. A wetland, however, will perform this function only if surface water contaminated with sediment actually enters the wetland.

Some general properties may be applied to all wetlands with respect to their ability to remove sediments (Phipps 1986). Within a given wetland, the deposition of sediment depends on several factors including (Phipps 1986, Johnston 1991, Fennessy et al. 1994, Gilliam 1994, Kadlec and Knight 1996):

- Residence time of the water that allows sediments to settle
- Wind and wave action that re-suspend sediments
- Size and amount of incoming sediment
- Vegetation

Generally, a high residence time for the water that allows settling and the filtration by vegetation are the major processes by which sediment is removed from surface water (Fennessy et al. 1994). Filtration is the physical adhesion and cohesion of sediment facilitated by vegetation (Adamus et al. 1991). The size of the particles that settle out is directly related to the increase in settling time achieved in the wetland (Adamus et al. 1991).

Typically a wetland with vegetation traps 80% to 90% of sediment from runoff entering the wetland (Johnston 1991, Gilliam 1994). Other studies have found that wetlands with open, deep, water may be as effective, or more effective, than vegetation in trapping sediments (Fennessy et al. 1994) because the residence time increased.

Wetlands can be more important for removing excessive amounts of sediments compared to other components of the landscape (Adamus et al. 1991). Another way to consider the importance of wetlands for removing sediments in a watershed is to analyze how much wetland area is needed to effectively remove sediments. Fennessy et al. (1994) report the following from their review of the literature:

- Watersheds in Wisconsin with only 5% of their area in wetlands trapped up to 70% of the sediment in the system
- In a North Carolina watershed, more than 20% of the total sediment deposition occurred in wetlands that represented only 11% of the area

The importance of any wetland for improving water quality depends, however, on the amount of sediment pollution in the watershed. Watersheds in which human activities loosen the topsoil (agriculture, development, and logging) are prone to have high sediment loadings. Wetlands in these watersheds are very important for maintaining water quality (National Research Council 1995).

Removal of Sediment by Wetlands of Various Classes and in Different Domains and Regions

The way wetlands remove sediment is not judged to be different in the two major domains of the state (the east side and the west side of the Cascades) (Hruby et al. 1999, 2000). However, the processes by which wetlands in Washington remove sediments differ somewhat among the different wetland classes as described below.

Wetlands in the Flats Class

Wetlands in the flats class, in general, do not remove sediment because by definition their major source of water is precipitation that falls within the wetland itself (Brinson 1993b). There is no opportunity for sediment-laden water to enter the wetland. All other types of wetlands perform this function to some degree because they receive surface water from outside their boundaries, and the surface water is never completely free of sediments.

Wetlands in the Depressional Class

Depressional wetlands that hold back all the surface water coming in (that is, those without a surface outlet) trap all the sediment they receive. Such wetlands are very effective at this aspect of water quality improvement wherever they are found in Washington (Hruby et al. 1999, 2000).

The removal of sediment in depressional wetlands with an outflow depends on how effectively they slow the water and allow settling, as well as the density of the vegetation that filters the incoming water. The same processes are present in depressional wetlands of both eastern and western Washington (Hruby et al. 1999, 2000).

Wetlands in the Lacustrine Fringe Class

Wetlands along the shores of lakes (lacustrine fringe) trap and retain suspended sediment by anchoring the shoreline, reducing resuspension of bottom mud by wind mixing, and slowing water velocities (Adamus et al. 1991). Even aquatic bed vegetation, which typically provides less resistance to water flow than emergent or woody plants, may reduce water movement enough to induce settling (Adamus et al. 1991).

Wetlands of this class have not yet been subjected to the thorough analysis required for developing a function assessment method. More definitive conclusions about Washington wetlands are, therefore, not available. However, no evidence has been reported that would negate the observations made in lacustrine wetlands in other parts of the U.S. that were reviewed by Adamus et al. (1991).

Wetlands in the Slope Class

Slope wetlands by definition (Brinson 1993b) do not impound surface water. The removal of sediment through settling is therefore not a factor in this class of wetlands.

Unpublished data collected during the calibration of the eastern Washington wetland rating system, however, suggest that slope wetlands may still play a role in removing sediment. For

example, slope wetlands in eastern Washington have vegetation that is usually thicker than the vegetation in the surrounding uplands (Figure 2-9). This vegetation acts like a filter to trap sediments coming from further upslope because it provides more resistance to the water flowing down the hillside (Hruby 2004a).



Figure 2-9. Slope wetland in the Columbia Basin that formed at a break in the slope. It has dense emergent plants that can trap sediment coming from the upslope areas.

Slope wetlands in western Washington have not yet been analyzed in terms of their potential to remove sediments, and it is not possible to report if similar processes and structure are found there. Models for assessing slope wetlands have, however, been developed for the Willamette Valley in Oregon. Two characteristics of slope wetlands identified there that contributed to the retention of sediments were the amount of ground covered by vegetation and the relative area of the wetland covered in hummocks (Adamus and Field 2001).

Wetlands in the Riverine Class

The removal of sediment in riverine wetlands is a somewhat different process. The vegetation and depressions within these wetlands trap sediment, but sediments are eroded by floods that recur every few years. The function of riverine wetlands is to stabilize sediment during the period between floods (Adamus et al. 1991). Wetlands are an integral part of the cycle of erosion and deposition in floodplains.

Phipps (1986) stated that the efficiency of sediment trapping by riverine wetlands in the Pacific Northwest has not been measured. This conclusion is still valid today, since no studies were found that quantified this function. The process of trapping sediments is still judged to be an important function on a watershed scale in Washington State (Hruby et al. 1999) and was

modeled during the development of function assessment methods. The characteristics of riverine wetlands that were judged important in removing sediments were as follows (Hruby et al. 1999):

- How much the stream or river meanders through the wetland
- How wide the wetland is relative to the width of the stream
- How much of the wetland is covered in vegetation that can act as a filter
- The amount of constriction in the outlet (if the wetland has an outlet)

2.6.1.2 Removing Phosphorus

Phosphorus can enter wetlands with suspended solids or as dissolved phosphorus. It is usually transported attached to particles rather than dissolved in the water (Raisin and Mitchell 1995). The major processes by which wetlands keep phosphorus from going farther downstream are (Mitsch and Gosselink 2000):

- The trapping of sediment on which phosphorus is adsorbed
- The removal of dissolved phosphorus by adsorption to soils that are high in clay content or organic matter
- Precipitation with calcium to form calcium phosphate

Wetlands that are effective at trapping sediments, therefore, are also effective at removing phosphorus. The discussion in Section 2.6.1.1 on the classes of wetlands that are effective at removing sediments also applies to removing phosphorus (Hruby et al. 1999).

The adsorption of phosphorus on soils is not permanent. Certain conditions during periods of extensive anoxia (lack of oxygen) may release phosphorus into the overlying waters (Adamus et al. 1991, Reddy and Gale 1994). In general, however, wetlands are a sink for phosphorus in watersheds (Adamus et al. 1991).

Other data also shows that phosphorus retention in wetlands is highly variable. Whigham et al. (1988) concluded that wetlands where waters had extensive contact with vegetation and/or organic litter were the most effective at phosphorus removal. Forested wetlands were only effective during flood events (when there was contact between waters and vegetation and more sediment deposition occurred). They found open water, lacustrine systems to be the least effective at phosphorus removal.

Johnston et al. (1997) observed that a wetland may remove phosphorus from incoming waters during one part of the year but at other times of year it may add phosphorus to water leaving the wetland. They hypothesized that the release of phosphorus from a wetland is due to the leaching of phosphorus from dying wetland vegetation.

The different pathways by which phosphorus can be trapped or released in wetlands are summarized in the quotation from a North Carolina State University web site in the box on the following page. Other sources that describe the many different ways phosphorus can be

adsorbed, de-sorbed, precipitated and bound to soils depending on pH, alkalinity and hardness of the water are Kadlec and Knight (1996), Richardson and Vepraska (2001) and Wetzel (2001).

Mechanisms of phosphorus removal

The following discussion from North Carolina State University summarizes the scientific literature on the ways in which wetlands remove and process phosphorus. (North Carolina State University undated).

Phosphorus removal from water in wetlands occurs through adsorption by aluminum and iron oxides and hydroxides; precipitation of aluminum, iron, and calcium phosphates; and burial of phosphorus adsorbed to sediments or organic matter (Walbridge 1993, Johnston 1991, Richardson 1985). Wetland soils can, however, reach a state of phosphorus saturation, after which phosphorus may be released from the system (Richardson 1985). Phosphorus export from wetlands is seasonal, occurring in late summer, early fall and winter as organic matter decomposes and phosphorus is released into surface water.

Dissolved phosphorus is processed by wetland soil microorganisms, plants, and geochemical mechanisms (Walbridge 1993). Microbial removal of phosphorus from wetland soil or water is rapid and highly efficient; however, following cell death, the phosphorus is released again. Similarly, for plants, litter decomposition causes a release of phosphorus. Burial of litter in peat can, however, provide long term removal of phosphorus. Harvesting of plant biomass is needed to maximize biotic phosphorus removal from the wetland system.

The potential for long-term storage of phosphorus through adsorption to wetland soil is greater than the maximum rates of phosphorus accumulation possible in plant biomass (Walbridge 1993, Johnston 1991). In alkaline wetlands, such as found in the West, phosphorus precipitates with calcium as calcium phosphate (Novotony and Olem 1994, Walbridge 1993). However, the presence of aluminum is the significant predictor of dissolved phosphorus sorption and removal from water in most wetland systems (Reddy and Gale 1994, Walbridge 1993, Richardson 1985). The capacity for phosphorus adsorption by a wetland, however, can be saturated in a few years if it has low amounts of aluminum and iron or calcium (Richardson 1985).

Wetlands along rivers have a high capacity for phosphorus adsorption because as clay is deposited in the floodplain, aluminum (Al) and iron (Fe) in the clay accumulate as well (Gambrell and Trace 1994). Thus floodplains tend to be important sites for phosphorus removal from the water column, beyond that removed as sediments are deposited (Walbridge 1993).

Removal of Phosphorous by Wetlands of Various Classes and in Different Domains and Regions

The way wetlands remove phosphorus is considered to be similar in the two domains of the state (the east and west sides of the Cascades). Firstly, wetlands that are effective at trapping sediments are also effective at removing phosphorus regardless of their location (Hruby et al. 1999, 2000). Wetlands of all types in both domains have the potential of trapping sediments and therefore removing any phosphorus adhered to it. This conclusion is based on data showing that most of the phosphorus entering a wetland is bound to sediment (Dortch 1996, Mitsch et al. 1995, Mitsch and Gosselink 2000).

Secondly, phosphorus entering a wetland in a dissolved form can also be retained because it binds to clay and organic soils (see box on the previous page). The HGM classification, however, does not separate wetland types by soil content (Brinson 1993b), so the presence of clay or organic soils is not specific to a particular wetland class or region. As a result it is not possible to differentiate this function between wetland types. In the absence of research to the contrary, it can be hypothesized that wetlands in all domains and regions of the state and in all wetland classes have the potential to remove phosphorus if they contain organic or clay soils that can bind phosphorus.

2.6.1.3 Removing Nitrogen

Wetlands in general act as sinks for nitrogen under both nutrient-enriched and un-enriched conditions (Adamus et al. 1991, Jansson et al. 1994). Nitrogen enters a wetland in the form of ammonium from animal wastes in runoff, as nitrate/nitrite from fertilizers in runoff and groundwater, or from air pollution (Adamus et al. 1991).

The efficiency of nitrogen removal is greater with longer retention times of the water, earlier plant community stages, and lower loading rates (Dorge 1984 as reported in Adamus et al. 1991). Wetlands are far more efficient at removing nitrogen from up-basin loading than either rivers or streams (Saunders and Kalff 2001), even though soluble nitrogen may be flushed out of wetlands at times of high flow (Johnston et al. 1990).

The major biochemical processes by which wetlands remove nitrogen are nitrification and denitrification. These respectively occur in alternating conditions where oxygen is present (aerobic) and oxygen is absent (anaerobic) (Johnston et al. 1990, Mitsch and Gosselink 2000, Vought et al. 1995, Saunders and Kalff 2001). Denitrification transforms the majority of nitrogen entering wetlands into nitrogen gas, causing between 70% and 90% to be removed from the aquatic system (Reilly 1991, Gilliam 1994).

In aerobic substrates, the bacteria *Nitrosomonas* can oxidize ammonium to nitrite. The bacteria *Nitrobacter* oxidizes nitrite to nitrate. This process is called nitrification (Mitsch and Gosselink 2000).

Nitrogen is completely removed from the aquatic system only by anaerobic bacteria that reduce nitrate to gaseous nitrogen during denitrification. The gaseous nitrogen volatilizes, and the nitrogen is eliminated as a water pollutant. Thus, the alternating reduced and oxidized conditions (anaerobic and aerobic respectively) of wetlands complete the nitrogen cycle and maximize

denitrification rates (Johnston 1991). First the aerobic bacteria change ammonium and organic nitrogen (decomposing plants and animals) to nitrate and nitrite, and then the anaerobic bacteria change the nitrate and nitrite to nitrogen gas.

Plants or microorganisms can use nitrate and ammonium for growth. Plant growth, however, does not really remove the nitrogen from the aquatic system because it becomes available again with the death of the plants or microorganisms that absorbed the nutrients (Adamus et al. 1991).

Nitrogen Removal by Wetlands of Various Classes and in Different Domains and Regions

The way wetlands are judged to remove nitrogen is similar east and west of the Cascades (Hruby et al. 1999, 2000, Hruby 2004a,b). Furthermore, the HGM classification does not separate wetland classes by the amount of oxygen in the soils (Brinson 1993b). The presence of alternating cycles of anaerobic and aerobic conditions is not specific to wetland types or regions. Therefore, it is not possible to differentiate this function between wetland types and regions.

Whether a specific wetland removes nitrogen or does not depends on the conditions found within the wetland, not on the type of wetland or its position in the landscape. The conditions that promote removal of nitrogen in wetlands of the state are seasonal inundation or saturation (Hruby et al. 1999, 2000). This indicates the soils alternate between aerobic conditions (when dry) and anaerobic conditions (when wet), and provides the optimal conditions for the gasification of nitrogen as described above.

2.6.1.4 Removing Metals and Toxic Organic Contaminants

The major physical, biological, and chemical processes by which wetlands reduce the amount of toxic materials moving into down-gradient waters are through sedimentation, adsorption, precipitation, oxidation, bio-degradation, and plant uptake (Adamus et al. 1991, Kadlec and Knight 1996, ITRC 2003).

- **Sedimentation** is a major process by which wetlands remove toxic compounds because some toxic compounds are bound to sediments or form insoluble compounds that settle out. For example, most heavy metals in urban runoff are adsorbed to sediment particles and are buried in sediment deposits within wetland soils (Newton 1989). Arsenic, Cadmium, Copper, Iron, Lead, Nickel, Silver, and Zinc are all metals that can be trapped through sedimentation (review in ITRC 2003). Thus, wetlands that are effective at removing sediments are also effective at trapping many toxic metals.
- **Adsorption** of the contaminants to the wetland soil is promoted by soils high in clay or organic matter (Adamus et al. 1991, Mitsch and Gosselink 2000). For example, wetlands can remove toxic metals from surface and groundwater if they contain clays, peat, aluminum, iron, and/or calcium (Gambrell and Trace 1994). Metals entering wetlands will bind to the negatively ionized surface of clay particles, or precipitate as inorganic compounds (metal oxides, hydroxides, and carbonates, depending on pH), or form a complex with humic materials (Gambrell and Trace 1994).

- **Chemical precipitation** is promoted by wetland areas that are inundated and remain aerobic, as well as those with pH values below 5 (Mengel and Kirkby 1982). Also, precipitation of dissolved iron is common in wetlands where anaerobic groundwater containing reduced iron compounds surfaces. In the aerobic surface environment the iron compounds oxidize into insoluble forms and precipitate out from solution. During this process metals and other compounds bind to the iron, and co-precipitate with the iron hydroxides (Kadlec and Knight 1996, Wetzel 2001).
- **Photochemical oxidation** is a pathway by which organic contaminants can be broken down into less toxic compounds through the action of sunlight (Kadlec and Knight 1996).
- **Biodegradation** is similar to oxidation, but in this case bacteria and other microbes break down organic contaminants. Degradation occurs under both aerobic and anaerobic conditions depending on the chemical structure of the contaminant (Kadlec and Knight 1996, ITRC 2003).
- **Plant uptake** of toxic compounds is maximized when there is significant wetland coverage by emergent plants (Kulzer 1990).

Removal of Toxic Contaminants by Wetlands of Various Classes and in Different Domains and Regions

Wetlands on the east and west sides of the Cascades were judged to function similarly in removing toxic contaminants (Hruby et al. 1999, 2000, Hruby 2004a,b). There may be some differences based on wetland class because some of the characteristics (such as effectiveness at trapping sediment) that are important for removing toxic compounds are dependent on the wetland class. Other differences do not depend on wetland class. In Washington, the experts who developed assessment methods judged that wetlands that remove sediments effectively are also effective at removing toxic compounds (Hruby et al. 1999, 2000).

The HGM classification, however, does not separate wetland types by the soils present or by how well they trap sediments (Brinson 1993b). The presence of clays, organic soils, aluminum, iron, or calcium in the soils is not specific to any wetland type. In the absence of research to the contrary, it can be assumed that wetlands in all regions of the state and in all wetland classes have the potential to remove toxic metals and organic compounds if they have the appropriate conditions that allow contaminants to sediment out, adsorb to soils, precipitate, biodegrade, or oxidize.

Wetlands with Clay Soils in Washington

As mentioned above, wetlands with clay soils can remove toxic contaminants because of the chemical properties of this type of soil. The term “clay” however, is applied both to materials having a particle size of less than 2 micrometers (25,400 micrometers = 1 inch) and to the family of minerals that has similar chemical compositions and common characteristics of crystal structure (Velde 1995). In Washington we find soils that are called “clays” that fit both aspects of the definition. In reviewing the descriptions of soils in the county soil surveys (e.g., Pringle 1990), there are three types of clay soils described in Washington.

- Those that consist of very finely ground rock formed by glaciers (called clays based on the size of the particles)
- Those that were deposited in lakes and the ocean (called clays either because of size or mineral composition)
- Those derived from the weathering of rocks in place (called clays based on mineral composition)

The scientific literature on the chemical properties of clays in relation to the adsorption of metals and organic pesticides, however, is based on the clays that are defined by their mineral composition and that are derived from weathered rocks such as bentonite, montmorillonite, and kaolinite (Fushiwaki and Urano 2001).

There is little information on the chemical properties of clays derived from glacial activity or aquatic sediments. County soil surveys (e.g., Debose and Klugland 1983) indicate that glaciers have played an important role in forming clays in western and northeastern Washington. Lacustrine (lake) and marine clays are also common in Whatcom County (Natural Resources Conservation Service 1992). These clays may contain chemically reactive minerals but it was not possible to confirm this assumption. Information from the soil survey of Whatcom County (Table J2 on the chemical properties of soils, released November 18, 2002), however, suggests that the clay soils of marine origin have a high cation exchange. This would indicate a high potential to bind metal and organic contaminants.

Wetlands with Volcanic Ash

Washington is relatively unique in the U.S. because it contains extensive areas where soils developed in volcanic ash (called Andisols). In addition, wetlands in the Columbia Basin often have a very fine layer of volcanic ash near the surface from the Mt. St. Helens eruption in 1980 (observations made by the technical team during the calibration of the methods for assessing wetland functions, Hruby et al. 2000).

In general, the cation exchange capacity of volcanically derived soils is high, due to a high surface area of the mineral and organic compounds (McSweeney 2004). Furthermore, volcanic ash that is washed or deposited into wet areas is in time transformed into bentonite clays (Bohor et al. 1976, Bohor et al. 1979). Thus, the ash found in wetland soils of Washington can be hypothesized to perform as clays to remove toxic compounds.

Wetlands with Organic Soils

Soils with a high content of organic matter have a high cation exchange capacity, and they are thus able to bind contaminants (Kadlec and Knight 1996). This is because the break down of plant material produces organic colloids that form complexes with contaminants (McSweeney 2004). Wetlands with organic soils such as peat bogs and fens in Washington State have the necessary soil conditions by definition (high content of organic matter) to react with and adsorb toxic contaminants.

Wetlands in the Depressional Class

A number of the characteristics that enhance the removal of toxic compounds are present more often in depressional wetlands, although all depressional wetlands do not have these characteristics. A higher number of depressional wetlands have slower moving water and finer sediments compared to riverine or slope wetlands (Brinson 1993b). Wetlands in which water moves slowly are better at removing toxics than those in which water moves rapidly. Slow moving water allows more time for chemical processes to occur before the water moves out of the wetland. This promotes the settling of fine sediments and the formation of organic soils (North Carolina State University 2002).

Depressional wetlands in the state more often have organic soils than wetlands in the other classes (observation is based on unpublished data collected by Ecology during the calibration of the Washington State wetland function assessment methods and the wetland rating systems 1998-2004). Depressional wetlands, therefore, can be assumed to usually have a higher potential to remove toxic compounds than wetlands in the other classes.

2.6.1.5 Removing Pathogens

Surface runoff coming into wetlands often contains large quantities of bacteria, particularly coliform bacteria and pathogens such as *Salmonella* (Hemond and Benoit 1988). Probably the most important mechanism for removing pathogenic bacteria from surface water is detention which is a function of residence time (reviews in Hammer 1989, Kadlec and Knight 1996).

Detention of the water in wetlands results in a natural die-off, and therefore removal from the water column, because many pathogenic bacteria cannot survive for long periods outside their host organism (Hemond and Benoit 1988). In addition, protozoa and other micro-organisms often found in wetlands actively feed on bacteria and can speed up the process of die-off (Hemond and Benoit 1988).

Removal of Pathogens by Wetlands of Various Classes and in Different Domains and Regions

The HGM classification does not separate wetland classes by their retention time or their populations of protozoa and other micro-organisms. Since these are the two major factors that account for the die-off of pathogens, it is not possible to differentiate how wetlands perform this function based on regional and hydrogeomorphic differences. Whether a specific wetland removes pathogens depends on the conditions found within the wetland, not on the type of wetland or its position in the landscape.

2.6.2 Functions Related to Maintaining the Water Regime in a Drainage Basin (Hydrologic Functions)

Wetlands play an important role in the water regime of watersheds (Mitch and Gosselink 2000, Bullock and Acreman 2003). Sipple (2002) provides a good summary of their role:

Because of their low topographic position relative to uplands (e.g., isolated depressions, floodplains), wetlands store and slowly release surface water, rain, snowmelt, groundwater and flood waters. Trees and other wetland vegetation also impede the movement of flood waters and distribute them more slowly over floodplains. This combined water storage and slowing action lowers flood heights and reduces erosion downstream and on adjacent lands. It also helps reduce floods and prevents water logging of agricultural lands. Wetlands within and downstream of urban areas are particularly valuable in this regard, counteracting the greatly increased rate and volume of surface-water runoff from pavement and buildings.

Because of their position on the landscape, wetlands at the margins of lakes, rivers, bays, and the ocean help protect shorelines and stream banks against erosion. Wetland plants hold the soil in place with their roots, absorb the energy of waves, and break up the flow of stream or river currents. The ability of wetlands to control erosion is so valuable that some states (e.g., Florida) are restoring wetlands in coastal areas to buffer the storm surges from hurricanes and tropical storms by dissipating wave energy before it impacts roads, houses, and other man-made structures.

The information available, however, indicates that the role of a wetland in the hydrologic cycle of a watershed is highly varied and depends on many factors. Bullock and Acreman (2003) reviewed 169 publications that report the results of scientific studies that quantified the hydrologic functions of wetlands. Their review confirms that wetlands exert a strong influence on the hydrologic cycle, but the actual functions performed by individual wetlands vary greatly. In many cases wetlands reduce floods and recharge groundwater while in other cases they may exacerbate floods or cause a net loss of groundwater (Bullock and Acreman 2003).

The following sections describe the characteristics of wetlands that reduce peak flow, reduce erosion, and recharge groundwater in Washington as determined by the teams of experts developing the methods for assessing functions and the rating system.

2.6.2.1 Reducing Peak Flows

Surface water that may otherwise cause flooding is stored to a greater degree in wetlands than typically occurs in terrestrial environments (Adamus et al. 1991). As a result, peak flows in streams and rivers are directly related to the total area of wetlands in the watershed, or to the area of wetlands in the headwaters of the system (National Research Council 1995). Wetlands reduce peak flows in streams and rivers by slowing and storing water in overbank areas and by holding back runoff that would otherwise flow directly downstream and cause more severe flooding (Reinelt and Horner 1995).

The function of reducing peak flows as defined in Washington State also includes the process of “floodflow desynchronization” (Hruby et al. 1999). This is a process that occurs at a larger, landscape scale. Desynchronization occurs when floodwaters are stored in many wetlands within the watershed. The release of water from these wetlands is staggered and gradual, resulting in more persistent flows but much lower peak flows (Adamus et al. 1991).

The characteristics of a wetland that indicate a potential to reduce peak flows include (Hruby et al. 1999, Mitsch and Gosselink 2000):

- The volume of water storage (depth of water stored multiplied by wetland area)
- The *live storage*, which is the storage above the bottom of the outlet
- Proximity of the wetland to flood waters
- Location of the wetland (e.g., along a river, lake, or stream)
- The amount of storage in the wetland relative to the volume of the flooding waters
- Lack of other upstream storage areas such as ponds, lakes, and reservoirs

Reduction in Peak Flows by Wetlands of Various Classes and in Different Domains and Regions

The importance of wetlands in reducing peak flows and how they perform this function differ in eastern and western Washington. This is a result of differences in the patterns of precipitation and snowmelt between the two areas (Hruby et al. 1999, 2000). The processes by which wetlands in Washington reduce peak flows also vary among wetland classes.

Wetlands of Western Washington

In **depressional wetlands of western Washington**, the characteristics within a wetland that reduce peak flows are the short-term storage capabilities of the wetland and the relative amount of flow captured from the upgradient contributing basin (Hruby et al. 1999). Short-term storage is often called *live storage* by hydrologists. It is the amount of water stored above the level of the outlet (if the wetland has one). Water stored below the outlet is called *dead storage* and was not considered to be important in reducing peak flows in western Washington (Hruby et al. 1999). The dead storage is usually filled by the time a flood event occurs and thus is not available to capture storm flows. Since most flooding events occur later in the fall, winter, and early spring, reductions in peak flow will occur only when a depressional wetland has some live-storage as well (Adamus et al. 1991, Hruby et al. 1999).

The expert teams who developed assessment methods for the state determined that the same assumption applies to the storage within the interstices of the soil (spaces between soil particles). Wetland soils in western Washington are usually saturated by the time most flood events occur, and storage in the soils was not judged to be important in reducing peak flows (Hruby et al. 1999) although it has been suggested as an important characteristic in other parts of the nation (Adamus et al. 1991).

Depressional wetlands with no outlet store all surface waters coming into them and therefore have the highest potential to reduce peak flows (Hruby et al. 1999).

In **riverine wetlands of western Washington**, the major characteristic judged to reduce peak flows is the storage provided by overbank areas (Hruby et al. 1999). As floodwaters rise, the waters overtop the banks of the river and fill the adjacent areas, many of which are riverine wetlands. The presence of a wide surface with an elevation at or near that of the river bank is the most important factor in reducing peak flows. As the flood waters overtop the banks they are

slowed down and the height of the flooding is reduced because the excess water is stored in these wetlands longer than the duration of the peak flows (Adamus et al. 1991, Hruby et al. 1999).

The **lacustrine fringe, flats, and slope classes of western Washington** have not been analyzed relative to reducing peak flows. The information available suggests wetlands in the flats and slope class do not play a major role in this function. Wetlands in the flats class by definition do not receive any runoff from surrounding areas (Brinson 1993b). Their effectiveness at reducing peak flows is to store only the precipitation that falls within their boundaries.

Wetlands in the slope class do not provide storage because by definition they do not impound any surface water (Brinson 1993b). Water flows to the lowest point on the slope and is then discharged. In fact, some studies show that slope wetlands may increase peak flows relative to surrounding uplands because their surface is saturated and rainfall in the wetland does not infiltrate (Bullock and Acreman 2003). The one role slope wetlands may play is to reduce the velocity of surface runoff by way of the thick vegetation often growing there (see Figure 2-9 for an illustration). The importance of vegetation on slopes in reducing flows has been well documented in studies of logging, though not specifically for slope wetlands (Lewis et al. 2001). It can be assumed that vegetation in slope wetlands plays the same role as vegetation in forested areas in reducing velocities of surface runoff (Hruby 2004a,b).

Wetlands of Eastern Washington

In **depressional wetlands of eastern Washington**, the characteristics within the wetland that reduce peak flows are the total storage capacity of the wetland and the relative amount of flow it captures from the upgradient contributing basin (Hruby et al. 2000).

The events that cause flooding in eastern Washington are different than in the western part of the state. Summer thunderstorms can cause flooding at times when most depressional wetlands are dry. As a result, the entire storage capacity of the wetland is available rather than just the live storage (Hruby et al. 2000). Depressional wetlands with no outlet store all surface waters coming into them and therefore have the greatest potential to reduce peak flows.

Riverine wetlands in eastern Washington are judged to function in a fashion similar to those on the west side (Hruby 2004a). Although function assessment methods have not been developed, the field work undertaken in calibrating the revised wetland rating system suggests that the major characteristic that reduces peak flows is also the storage provided by overbank areas (Hruby 2004a). See the previous discussion of riverine wetlands in western Washington for a more detailed description of storage by overbank areas.

Wetlands in **the lacustrine fringe and slope class** have not been analyzed in eastern Washington for their ability to reduce peak flows. The information collected during the calibration of the eastern Washington rating system, however, suggests wetlands in these two classes provide this function but not at the same levels as riverine or depressional wetlands (Hruby 2004a). Wetlands along the shores of lakes and reservoirs in eastern Washington tend to be small relative to the area of the lake (based on unpublished data, Hruby 2004a). They have some capacity to store water as the water levels in a lake rise, but the extra amount stored is often very small compared to the storage in the lake itself.

Furthermore, many lakes and reservoirs in this region have controlled and manipulated outlets. This means that the reduction in peak flows is directly controlled by humans and not by ecological processes. It is not possible, therefore, to assess how well these wetlands function to reduce peak flows based on their characteristics without an understanding of the protocols used to regulate the water levels in each reservoir.

By definition, wetlands in the slope class do not provide storage because any water flows to the lowest point and then is discharged (Brinson 1993b). However, their frequently dense vegetation reduces the velocity of surface runoff (see Figure 2-9) and thus can reduce the velocity of water somewhat. A wetland with dense vegetation will intercept more runoff and be more capable of reducing runoff velocity (and thus peak flows) than a wetland with less dense vegetation (Richardson and McCarthy 1994).

The importance of vegetation on slopes in reducing flows has been well documented in studies of logging (Lewis et al. 2001) though not specifically for slope wetlands. In eastern Washington the assumption is that vegetation in slope wetlands plays the same role as vegetation in forested areas in reducing peak flows (Hruby 2004a).

2.6.2.2 Reducing Erosion

The major process by which wetlands reduce downstream erosion is by slowing the velocity of water flowing downstream (Reinelt and Horner 1995, Adamus et al. 1991). The reduction in velocity depends on (Adamus et al. 1991):

- Channel constrictions that slow the flow of water
- Frictional resistance of the bottom
- Frictional resistance of vegetation

Jadhav and Buchberger (1995) state that the drag induced by plant stems increases with water velocity. This means that the relative reduction in velocity caused by plants increases as the speed of the water increases.

Reduction of Erosion by Wetlands of Various Classes and in Different Domains and Regions

The ways by which wetlands decrease erosion are somewhat different east and west of the Cascades. This is a result of the differences in the patterns of precipitation and snowmelt between the two areas (Hruby et al. 1999, 2000). The processes by which wetlands in Washington reduce erosion can also differ among wetland classes, as described below.

Wetlands of Western Washington

In **depressional wetlands of western Washington**, several characteristics were judged to influence a wetland's function in reducing water velocities (Hruby et al. 1999):

- Short-term storage capabilities of the wetland
- Characteristics of its outlet

- Amount of woody vegetation present
- Relative amount of flow captured from the upgradient contributing basin

Depressional wetlands with no outlet store all surface waters flowing into them. They have the greatest potential, therefore, to decrease erosion because no water leaves the wetland that could cause erosion (Hruby et al. 1999).

In **riverine wetlands of western Washington**, the major characteristic that reduces erosion is the amount of woody vegetation present that can provide a barrier to water flows (Hruby et al. 1999). As flood waters overtop the river banks, they are slowed down. The width of the wetland relative to the channel indicates how well the wetland can reduce velocity; the wider the wetland, the more water can spread out, becoming shallower and slowing down (Hruby et al. 1999).

Methods for assessing functions have not been developed for the **lacustrine fringe, flats, and slope classes in western Washington** and there is little information available on how these types of wetlands may perform this function. Wetlands in the flats class, however, are not expected to play a major role in this function. By definition, they do not receive any runoff from surrounding areas and therefore do not intercept waters that can cause erosion (Brinson 1993b).

Wetlands in the slope class, however, may decrease erosion to some degree because they often have thick vegetation relative to the surrounding uplands that reduces the velocity of surface runoff. Jadhav and Buchberger (1995) state that under dynamic conditions (high flows such as those found on slopes during storms) velocity is reduced by the drag induced by plant stems. Wetland detention time is therefore increased with vegetation density.

It can also be hypothesized that wetlands along the shores of lakes in western Washington (lacustrine fringe) may reduce erosion along the shore because of the vegetation they support. This would both anchor the shoreline and dissipate erosive forces (Adamus et al. 1991). Wetlands that have extensive, persistent (especially woody) vegetation provide protection from waves and currents associated with large storms and snowmelt that would otherwise penetrate deep into the shoreline (Adamus et al. 1991).

Wetlands of Eastern Washington

In **depressional wetlands of eastern Washington**, the characteristics within the wetland that decrease erosion are the total storage capacity of the wetland and the relative amount of flow captured from the upgradient contributing basin (Hruby et al. 2000). The events that cause erosion in eastern Washington are different than in the western part of the state. Summer thunderstorms can cause highly erosive flows at times when most depressional wetlands are dry (Hruby et al. 2000). As a result, the entire storage capacity of the wetland is usually available to reduce water velocities rather than just the live storage. Depressional wetlands with no outlet store all surface waters coming into them and therefore have the most potential to decrease erosive flows.

Riverine wetlands in eastern Washington function in a similar fashion to those on the west side (Hruby 2004a). Although experts have not developed function assessments, the field work

undertaken in calibrating the revised wetland rating system suggests that woody vegetation within the wetland is key in reducing erosive flows by slowing velocities during floods.

Function assessment methods for the **lacustrine fringe and slope classes** have also not been developed in eastern Washington. There is therefore no clear understanding of how they function to decrease erosion. It can be hypothesized, however, that wetlands of both classes can function to reduce erosion to some degree in a manner similar to these types of wetlands in western Washington (see discussion above).

2.6.2.3 Recharging Groundwater

The recharge of groundwater is the movement of surface water, usually downward, into the ground. In wetlands, the function is described in terms of the wetland structures and processes that allow surface water to infiltrate into the groundwater system. Adamus et al. (1991) and the expert teams developing the Washington State wetland function assessment methods (Hruby et al. 1999, 2000) concluded that the movement of water into the ground depends primarily on:

- The elevation of the wetland relative to the groundwater
- The mass and pressure of water (“pressure head”) in the wetland
- The physical characteristics and frictional resistance of the sediments and strata underlying the wetland (hydraulic conductivity)

If the surface of the water in a wetland is groundwater, or the primary source of water to the wetland is groundwater (e.g., a seep), the wetland cannot recharge that groundwater. By definition, recharge occurs only if water from surface runoff infiltrates into groundwater.

The information available on the potential for wetlands to recharge groundwater is contradictory. In a review of scientific studies that quantified the hydrologic functions of wetlands, Bullock and Acreman (2003) found 32 studies that documented that recharge occurs and 18 studies where no recharge was found. Adamus et al. (1991) conclude, from an extensive review of the literature, that four site-specific conditions determine how well a wetland performs this function:

- Groundwater flow rates under the wetland (linked to hydraulic conductivity)
- The storage capacity of the wetland (linked to the pressure head of water)
- Water movement within the wetland (linked to elevation relative to groundwater and hydraulic head)
- Evapotranspiration (linked to “pressure head” of water in the wetland)

These conclusions about these site-specific conditions were more recently confirmed by Hunt et al. (1996).

Adamus et al. (1991) were unable to find any patterns among wetland types or regions of the country. They also concluded that “for recharge, adjacent undeveloped uplands are usually, but not always, more important than wetlands.” This conclusion was confirmed by Bullock and Acreman (2003).

Groundwater Recharge by Wetlands of Various Classes and in Different Regions

The characteristics within a wetland that result in the recharge of groundwater are the same for wetlands in both the eastern and western parts of the state. The potential for recharge in a wetland occurs when wetlands hold back precipitation and surface flows to create ponded areas. This ponded water then infiltrates into the groundwater system because of the “head” or pressure created by the depth of water on the surface. If the hydraulic head created by upslope groundwater is greater than the hydraulic head created by the ponded water, recharge will not occur (Adamus et al. 1991).

Groundwater recharge occurs only in a subset of **depressional wetlands** and some **riverine wetlands** that impound and hold surface water. Wetland types that do not impound surface water do not have the potential to recharge groundwater (Hruby et al. 1999, 2000, Hruby 2004a,b).

A new perspective on the function of supporting baseflow

One aspect of groundwater recharge that is often attributed to wetlands in Washington is called *baseflow support*. Wetlands are assumed to augment base flows in streams during the drier seasons because of the water they store. The information available, however, indicates this assumption is not valid in most cases, and in fact wetlands may reduce baseflow because of water lost through evapotranspiration. In a review of scientific studies that quantified the hydrologic functions of wetlands, Bullock and Acreman (2003) found that 49 out of 75 studies (2/3) conclude that wetlands reduce the flow of water downstream during dry periods. Only 16 studies conclude that wetlands sustain low flows and ten studies found that wetlands had no impact on low flows.

In Washington, the teams of experts that developed the methods for assessing functions and the rating systems concurred with the majority of studies (Hruby et al. 1999, 2000, Hruby 2004a,b). Surface outflow from wetlands was not judged to be an important factor in maintaining low flows in streams in Washington State. A wetland may be in a location where groundwater is discharged, but the source of this groundwater is not within the wetland itself. Thus, the discharge is not a function of the wetland; rather it is, as reported by Adamus et al. (1991), a function of the entire groundwater system.

Given the highly seasonal rainfall patterns in the region, the teams also judged that most surface water will be discharged into streams before the late summer when low flows are biologically the most critical. Water stored in the soils of wetlands was not considered to be a factor because of the types of soils present. Wetlands on alluvial soils would not hold water long enough into the dry season to support baseflow because they are so permeable (review in Bullock and Acreman 2003). On the other hand, wetlands with organic and peat soils would hold water and not release very much of it because the hydraulic conductivity is generally very low. The hydraulic conductivity of water in peat soils ranges between 0.000001 cm/sec to as high as 0.001 cm/sec (less than 3 ft per day) (Reeve et al. 2000) depending on the structure of the peat or the mineral soil.

2.6.3 Functions Related to Habitat

This section focuses on three aspects of wetlands as habitat:

- Structures and processes found within wetlands that make them an important habitat feature of the landscape
- The number and types of vertebrate species using wetlands in the Pacific Northwest
- Important features of wetlands that meet the habitat requirements of some groups of species that are closely associated with wetlands and that were modeled in the Washington State wetland function assessment methods

The discussion is not subdivided by wetland class or domain and region of the state because habitat requirements differ widely for various species. Furthermore, habitat requirements for a single species may even differ between locations (Adamus et al. 1991). Therefore, this literature review does not attempt to identify all the life requirements of all wildlife species that use wetlands in Washington. The intent of this synthesis is to identify some of the basic structures and processes in wetlands that are important habitat features.

2.6.3.1 The Use of Wetlands by Species of Wildlife

Animals use wetlands to varying degrees depending upon the species involved. Some live in wetlands for their entire lives; others require wetland habitat for at least part of their life cycles; still others use wetlands much less frequently, generally for feeding (Johnson and O'Neil 2001). Thus, species using wetlands are often grouped by their dependency on the habitat provided by wetlands, but unfortunately there is no consistency in the terms used to describe the dependency.

For example, Adamus et al. (1991) grouped species into two categories. *Wetland-dependent species* are those that: “(a) normally use wetlands exclusively for food and cover throughout most of their U.S. range and spend most of their lifetime within wetlands, or (b) would be extirpated from a large region if all wetlands were to be filled.” The latter case includes species that may use wetlands for only part of their life cycles such as amphibians and many insects. The larvae of amphibians and many insects are aquatic even though the adults migrate out of the wetlands. The species are still considered to be wetland dependent because they could not survive without the presence of wetlands. *Wetland users* are those species that use wetlands for occasionally obtaining some life requirements such as sources of drinking water, winter cover (e.g., white-tailed deer and ring-necked pheasants), or dispersal centers within urban areas (e.g., opossum) (Adamus et al. 1991).

Adamus et al. (1991) also state the following about how species use wetlands:

The degree of dependence by any given species on wetlands often varies greatly depending on the abundance and distribution of wetlands and on suitable alternative habitats within the region. For example, urban wetlands and riparian wetlands in the arid Southwest support species that, in other parts of their ranges, are much less likely to inhabit wetlands.

The Washington State wetland function assessment method uses the terms *wetland dependent* for western Washington (Hruby 1999) and *wetland associated* for eastern Washington (Hruby 2000). More recently, Johnson and O’Neil (2001) have developed a grouping based on three categories that are specific to wildlife in Washington and Oregon that is based on the consensus of numerous experts in the region. These authors use the terms *closely associated*, *generally associated*, and *present* when describing the relationship between species and wetlands, and these are defined as follows:

- *Closely Associated* – A species is widely known to depend on a habitat for part or all of its life history requirements. Identifying this association implies that the species has an essential need for this habitat for its maintenance and viability.
- *Generally Associated* – A species exhibits a high degree of adaptability and may be supported by a number of habitats. In other words, the habitat plays a supportive role for its maintenance and viability.
- *Present* – A species demonstrates occasional use of a habitat. The habitat provides marginal support to the species for its maintenance and viability.

2.6.3.2 Characteristics that Make Wetlands Important as Habitat

Wetlands are among the most productive ecosystems in the world, comparable to rain forests and coral reefs (Mitsch and Gosselink 2000, Sipple 2002). As a result, wetlands support numerous species from all of the major groups of organisms—from microbes to mammals (Sipple 2002). The support they provide for these organisms includes sources of food, shelter, and refuge. All of these aspects are generalized by the term *habitat*.

General reviews of wetlands as habitat (Adamus et al. 1991, Mitsch and Gosselink 2000) conclude that physical and chemical characteristics (factors that control the suitability of a wetland as habitat) determine what plants and animals inhabit various wetlands, including:

- Climate
- Topography (landscape shape)
- Geology
- Nutrients
- Hydrologic regime (quantity and movement of water)

In addition, some of the larger organisms such as beaver and muskrats manipulate wetlands to create habitat suitable for themselves and other organisms, such as fish, amphibians, waterfowl, insects, and other mammals (Mitsch and Gosselink 2000).

Four general ecological features contribute to species richness and abundance in a landscape (Knutson and Naef 1997):

- Structural complexity
- Connectivity with other ecosystems
- Abundant food source and available water
- Moist and moderate microclimate

Wetlands have all of these attributes, especially wetlands that are linked to riparian areas and floodplains. The following sections describe each of these features in more detail.

Structural Complexity

Structural complexity is a term used to represent the variety of environmental characteristics that increase the number of niches for wildlife (Knutson and Naef 1997). These characteristics can include biological features such as a high richness of plant species or physical features such as open water, rocks, and mudflats. The interspersed in wetlands between open water and vegetation, or between types of vegetation, is important because the edges created between these elements (see Figure 2-10) increase the number of niches present (Adamus et al. 1991). Wetlands also often contain different vegetation communities within their boundaries that add structure (and therefore niches). For example, a higher interspersed of plant types in wetlands is likely to support a higher diversity of invertebrates (Dvorak and Best 1982, Lodge 1985).



Figure 2-10. Features of wetlands that increase structural complexity.

This wetland has open water and plants of different heights and different types (woody, herbaceous, aquatic bed) as well as snags and woody debris.

Riparian wetland systems in the semi-arid West often provide the only structurally complex habitat in regions dominated by open land or land cleared for agriculture (Adamus et al. 1991). This has also been found to be true in the semi-arid areas of eastern Washington, especially in the areas where rainfall is less than 12 inches per year (Hruby et al. 2000). Figure 2-11 shows a wetland with high structural complexity in the semi-arid terrestrial environment of eastern Washington that otherwise does not have much complexity.



Figure 2-11. Depressional wetland in the Columbia Basin. A structurally complex ecosystem in a terrestrial environment with low complexity. The average annual rainfall at this site is 8 inches per year.

Connectivity to Other Natural Resources

Many wetlands are linked to other aquatic or terrestrial resources by surface water, riparian corridors, or by relatively undisturbed vegetated corridors. Riverine wetlands form part of riparian corridors, depressional wetlands may be part of a small stream system or may be linked by surface water, and lacustrine fringe wetlands are connected to adjacent lakes. The role that corridors play in maintaining biodiversity, however, is very complex. For some species corridors are essential to maintain populations and genetic exchange (Kauffman et al. 2001, Haila 2002, Fahrig 2003). In other cases they may reduce populations of some species because they facilitate the movement of predators or invasive species (review in Fahrig 2003). See Chapters 3 and 4 for further discussion of habitat connectivity and corridors to both aquatic and terrestrial habitats.

Abundant Food Sources

The wet and moist microclimate of wetlands and their rich soils lead to the enhanced growth of plants. Wetlands are known for their high primary productivity (production of plant material) and the subsequent movement of this “food” to adjacent aquatic ecosystems (Mitsch and Gosselink 2000).

“Wetlands can be thought of as biological supermarkets” (Sipple 2002). For example, the number of invertebrates in small seasonal wetlands can exceed 700,000 animals per square meter (Leeper and Taylor 1998). Many of these invertebrates serve as food for larger predatory amphibians, reptiles, fish, birds, and mammals (Wissinger 1999).

Moist and Moderate Microclimate

The presence of water and thick vegetation in wetlands results in a microclimate that is generally more moist and that has milder temperature extremes than the surrounding areas. These conditions provide a habitat that is desirable to many species, particularly amphibians, ungulates, and other large mammals during hot, dry summers and severe winters (Knutsen and Naef 1997).

2.6.3.3 Use of Wetlands by Vertebrates in Washington

Wetlands in the state have been shown to be critical in maintaining regional biodiversity. Although wetlands represent only 2.1% of the area of the state (Dahl 1990), over two-thirds of all terrestrial vertebrate species in Washington can be considered “wetland users” (Knutson and Naef 1997, Kaufmann et al. 2001). A comprehensive review of wildlife in Washington and Oregon (Johnson and O’Neil 2001) provides a compilation of all wildlife species found in Washington and the different habitats in which they are found. Of the 32 types of habitat identified in the review, four are specific to wetlands. Table 2-7 lists the four types of wetland habitats identified in the compilation and the number of wildlife species found in each type. Appendix 2-B lists all the species found in each type of wetland as compiled in the review.

Table 2-7. Number of wildlife species by type of wetland habitat and by their association.
From O’Neil and Johnson 2001. See Appendix 2-B for definitions of the types of wetlands.

Habitat Type	Total	Closely Associated	Associated	Present	Unsure
Herbaceous wetland	228	105	90	31	2
Westside Riparian-Wetlands	256	74	145	35	2
Montane Coniferous Wetlands	148	17	101	28	2
Eastside Riparian-Wetlands	271	81	149	36	5

Reptiles and Amphibians

There are 59 species of reptiles and amphibians in Washington and Oregon. Two species of reptiles, the western pond turtle (*Clemmys marmorata marmorata*) and the painted turtle (*Chrysemys picta*), are wetland dependent. Many more species of reptiles are wetland users. On the other hand, all but one species of amphibians are wetland dependent and require an aquatic habitat for part of their life cycle (Kauffman et al. 2001). Figure 2-12 shows how many of the 59 species of reptiles and amphibians in the two states are found in three of the four types of wetland habitat.

In Figures 2-12 to 2-14 the data are from (Kauffman et al. 2001). The lists of actual species in each type of habitat and the definitions of each type of habitat are summarized in Appendix 2-B.

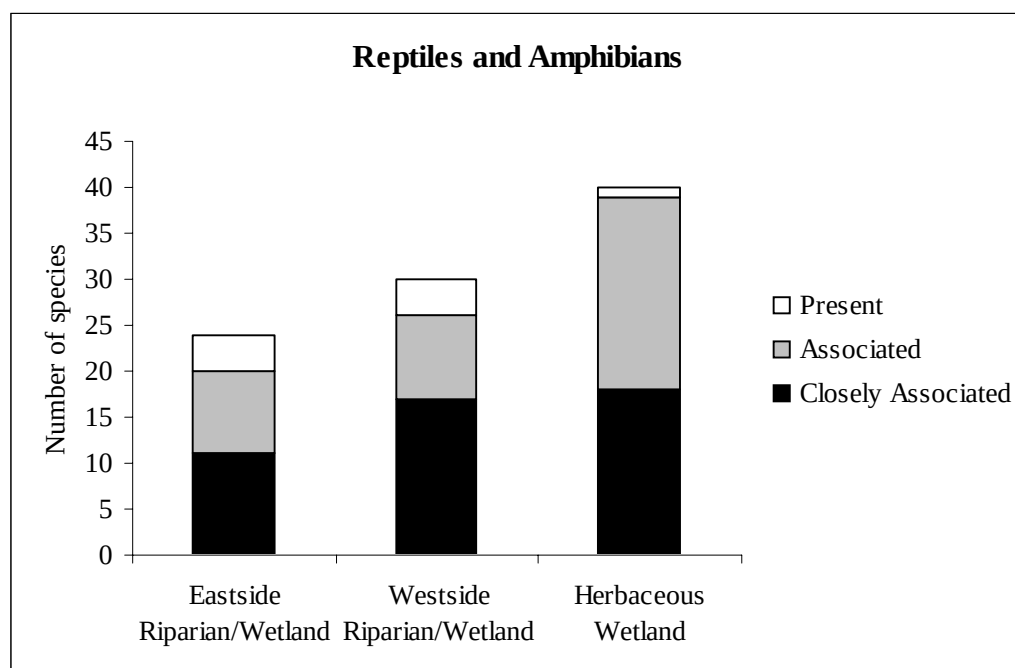


Figure 2-12. The number of reptile and amphibian species found in wetlands in Washington and Oregon. (from Kauffman et al. 2001)

Birds

Overall, 266 (72%) of the 367 species of birds in Oregon and Washington use freshwater, riparian, and wetland habitats. More striking, 204 (77%) of the 266 species of inland birds that breed in the two states do so in wetland environments (Kauffman et al. 2001). Figure 2-13 shows the number of bird species that use three types of wetlands in the region.

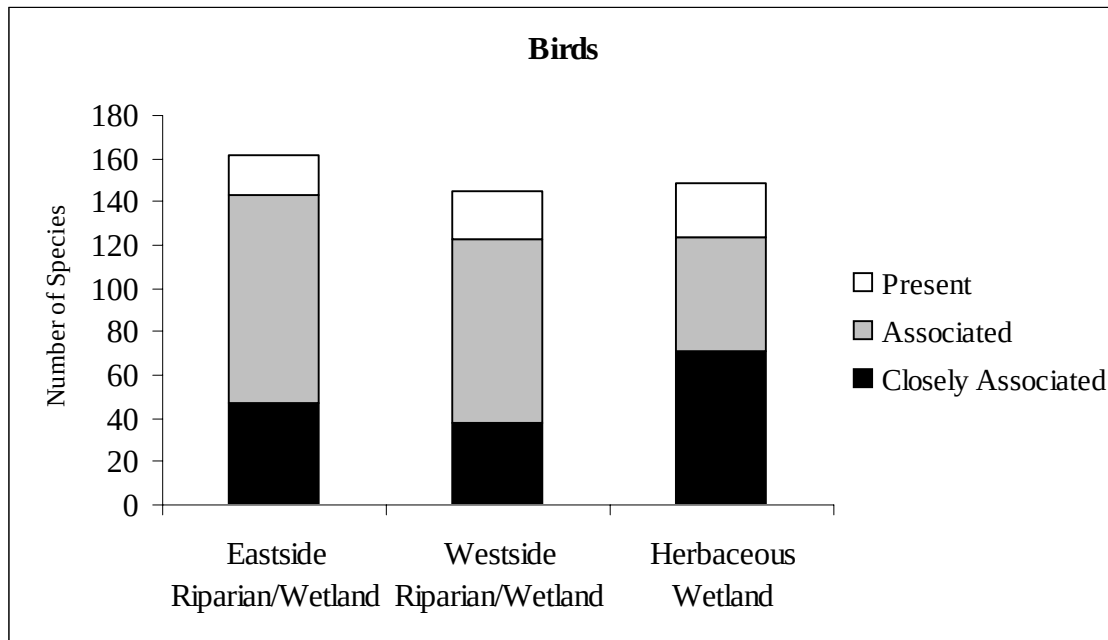


Figure 2-13. The number of bird species found in wetlands in Washington and Oregon (from Kauffman et al. 2001).

Mammals

Ninety-five of the 147 mammal species (65%) in the two states use the riparian/wetland ecosystem (Kauffman et al. 2001). All the “furbearers” (e.g., mink, otter, beaver, raccoon, etc.) use these habitats, and all but one of the big game animals (deer, elk, moose, etc. with the exception of bighorn sheep) rely on these areas for part of their habitat requirements. Figure 2-14 shows the number and degree of association of mammals to the three types of wetland habitats considered in Kauffman et al. (2001).

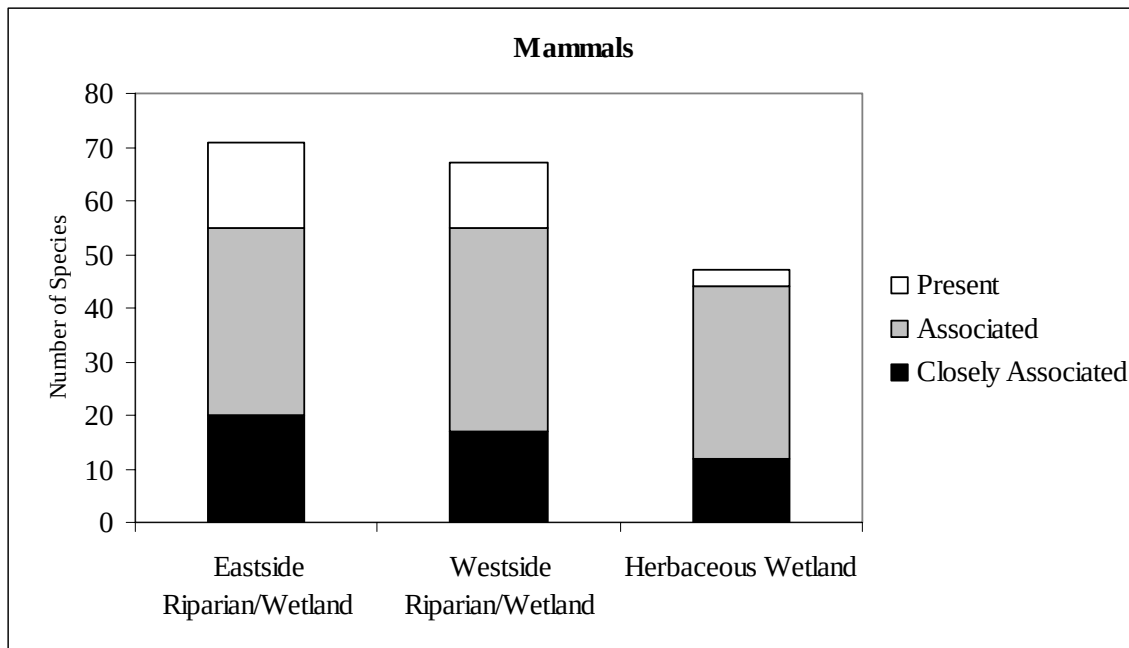


Figure 2-14. The number of mammal species found in wetlands in Washington and Oregon (from Kauffman et al. 2001).

2.6.3.4 Habitat Requirements of Some Wetland-Dependent Species in Washington

Invertebrates

Invertebrates have evolved unique adaptations enabling them to occupy most wetland habitats and most parts of the food web. In fact, wetland invertebrates can be distinguished from terrestrial and aquatic species at multiple taxonomic levels (family and genus) (Wissinger 1999). Wetlands are dominated by invertebrate families that are uniquely adapted to shallow and often fluctuating water levels (Wissinger 1999).

Wetland invertebrates are considered pivotal components of the food webs in wetlands (Mitsch and Gosselink 2000). As filter feeders, shredders, and scrapers, insects convert microorganisms and vegetation into biomass, providing much of the food for animals higher in the food web (secondary and tertiary consumers). Research focusing on aquatic invertebrates in wetlands indicates the importance of invertebrates in energy and the transfer of nutrients within aquatic

ecosystems (Rosenberg and Danks 1987, Wissinger 1999). Invertebrates have adapted to processing the plant material produced in wetlands of every type and geomorphic setting. They are considered a major link in the movement of energy in the food web of wetlands (review in Wissinger 1999).

The abundance of invertebrates in wetlands can be extremely large. Leeper and Taylor (1998) measured annual densities in excess of 700,000 organisms per square meter in shallow depressional wetlands of South Carolina.

Factors found to influence the distribution, richness, and abundance of invertebrates in wetlands include the following:

- **Water interspersed with stands of emergent vegetation** in wetlands result in high species richness of invertebrates (Voigts 1976).
- **Decaying wood** provides an important habitat for invertebrates (Maser et al. 1988).
- A **mix of plant assemblages** exhibits greater richness of invertebrate species than a single assemblage (Andrews and Hasler 1943, Dvorak and Best 1982, Lodge 1985, Balla and Davis 1995). Furthermore, the density of invertebrates varies considerably among species of submerged aquatic plants (Murkin and Batt 1987), and different invertebrate species are found on different plant species (Cyr and Downing 1988). Vegetation is a major factor shaping wetland invertebrate communities (Krieger 1992, Wissinger et al. 1999).
- **Permanent flowing water** is a habitat feature that supports a unique assemblage of invertebrate species (Needham and Needham 1962, Wiggins et al. 1980, Rolaufts et al. 2001). Furthermore, the invertebrates in flowing permanent channels are an important resource for many other aquatic species such as fish (Needham and Needham 1962).
- **Marked seasonal changes in water regime** in wetlands result in higher richness of invertebrate species compared to wetlands with little water level fluctuation (Balla and Davis 1995).
- **Water regime** in wetlands is an important factor for individual species of invertebrates. Factors associated with water regime include: permanence of surface water, predictability of drying and filling, seasonal timing of drying and filling, duration of dry and wet phases, and the harshness during dry and wet phases (temperature, salinity, oxygen levels) (reviewed in Wissinger 1999).

Not much is known about invertebrate distributions in different soil surfaces within a wetland. However, data from rivers, streams, and lakes show that the local invertebrate species have preferences for specific surfaces (Gorman and Karr 1978, Dougherty and Morgan 1991). In streams it is well known that the composition of midges (chironomids) is strongly affected by characteristics of the sediment surface (McGarrigle 1980, Minshall 1984).

Amphibians

Amphibians are a vertebrate group that, in the Pacific Northwest, includes wetland-breeding frogs and salamanders. Both the richness and abundance of amphibians in wetlands indicate that they

are important in wetland food webs (Leonard et al. 1993, Hruby et al. 1999). Some native species only breed for a short time in wetlands and then live in uplands as adults. Other species are found in or close to wetlands throughout the year. However, the eggs and larvae of all wetland-breeding species require water for development (Hruby et al. 1999).

Other information known about amphibians in wetlands includes the following.

- The **presence of buffers and undisturbed uplands and forest cover** leading to other wetlands or to upland habitat is critical. Relatively undisturbed migration routes between a wetland and upland feeding and hibernation sites are important for many amphibian species (Heusser 1968, Berven and Grudzien 1990, Beebee 1996). Moreover, dispersal routes for recolonization are critical when populations are eliminated by random processes including drought (Pounds and Crump 1994), disease (Bradford 1991), or pollution (K. Richter, PhD. personal communications 2000), or when populations produce insufficient offspring to permanently occupy a site (Gill 1978a, 1978b, Sinsch 1992). Finally, inbreeding is minimized when the amphibians within a wetland are members of a population that extends across several wetlands (Gulve 1991, 1994, Pechmann and Wilbur 1994).
- **Conditions in the buffers** of a wetland are especially important in providing cover to amphibian females and to newly metamorphosed animals. Female red-legged frogs (*Rana aurora*), Northwestern salamanders (*Ambystoma gracile*) (K. Richter, PhD. personal communication, 2000), and long-toed salamanders (*A. macrodactylum*) (Beneski et al. 1986, Leonard and Richter 1994) generally wait in buffers near wetlands until environmental and biological conditions are favorable to spawning. They then enter wetlands during one or a few nights to spawn, thereafter quickly retreating to the cover provided by buffers. Buffers are important to the tiger salamander (*A. tigrinum*, a species found in eastern Washington) seeking shelter in rodent burrows during the first days following emigration from ponds in which they are born (Loredo et al. 1996).
- Most species of amphibians select **areas with interspersed vegetation and exposed water** in which to lay eggs (K. Richter, PhD. personal communication 2000). Most species of amphibians generally avoid both exposed water and densely vegetated sites, instead selecting habitats with an interspersed of both features (Strijbosch 1979, Ildos and Ancona 1994).
- **Stable water levels** provide optimum habitat conditions for amphibians from spawning through hatching. Water level fluctuations are known to have a significant influence on amphibians (Richter 1996, 1997). Most species of amphibians in temperate climates minimize exposure of eggs to fluctuating depths and temperatures by both spawning at mid-depth and by submerging eggs below the surface (Richter 1997). Amphibian egg development also depends on permanent or partial submergence. In most Puget Sound species stable water levels occurs from mid-December through mid-May. Although mean water level fluctuations exceeding approximately 8 inches (20 cm) have been correlated to decreased amphibian richness in wetlands, experiments by Azous and Richter (1995) suggest that extended drops of more than approximately 3 inches (7 cm) from the time of egg laying through hatching may harm the Northwestern salamander.

- **Vegetation structure**, particularly plant shape and stem diameter, rather than the species of the plant has been suggested to be most important to salamanders. Wetland surveys and controlled field studies of several Northwest salamanders confirm that distinct stem widths are preferred (Richter 1997).

Anadromous Fish

Anadromous fish are those that spend all or part of their adult lives in salt water and return to freshwater streams and rivers to spawn. There are 12 species of anadromous fish in the Pacific Northwest (PSMFC 2001), but not all are regular users of wetlands.

The Pacific Northwest salmonids (species of the genus *Oncorhynchus*) have recently been the focus of much research because of the status of some species as threatened or endangered. The most common anadromous species that uses wetlands is the coho salmon (*Oncorhynchus kisutch*). Other anadromous fish noted in wetlands found in side channels, or old oxbows, of rivers and streams (off-channel wetlands) include cutthroat trout (*O. clarki*) and steelhead (*O. mykiss*) (Peterson 1982).

It is not the intent of this review to summarize all the information available on the habitat needs of salmonids. Some of the most important habitat structures in wetlands that have been found to be important for anadromous fish are summarized below:

- The **presence of ponded or impounded surface water** that is either seasonal or permanent is critical. “Slope” wetlands in Washington are the only class of wetlands that do not have the potential to provide habitat for anadromous fish because, by definition (Brinson et al. 1995) they do not have ponded or impounded surface water that is either seasonal or permanent.
- A wetland must have a **surface water connection** to a salmon-bearing stream or river if fish are to enter or exit the wetland (Hruby et al. 1999).
- **Interspersion between land and water** in a wetland is important because the contact zones between exposed water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries (Golet and Larson 1974).
- Anadromous fish need a certain **water depth** for optimum habitat conditions. Narver (1978) observed juvenile coho moving into areas with water depth over approximately 18 inches (45 cm) and lower velocities (6 inches [15 cm] per second) when temperatures decline below approximately 41°F (7°C). Beaver ponds and off-channel areas with similar depths also provide habitat (Reeves et al. 1989). Survival and growth of overwintering fish may be maximized in systems that contain both shallow pools and deeper ones (Peterson 1982).
- **Cover** provided by wetlands is important for salmonids. Overhanging vegetation provides both temperature control and protection from predation. McMahon (1983) reported the need for streamside vegetation for shading. Small coho juveniles tend to be harassed, chased, and nipped by larger juveniles unless they stay near the bottom, obscured by rocks

or logs (Groot and Margolis 1991). Cover for salmonids in wetlands can be provided by (Giger 1973):

- Overhanging vegetation
- Submerged vegetation
- Submerged objects such as logs and rocks
- Floating debris
- Deep water
- Turbulence
- Turbidity (the assumption seems to be that cloudy water reduces the visibility of fish in open water where birds may prey on them)

Resident Fish

Fish that do not migrate out of wetlands are considered “resident fish.” Many different fish species use wetlands and it is not practical to list all that occur in Washington’s wetlands.

Before the late 1800s, the only resident freshwater game fish living in Washington State were trout, char, whitefish, burbot, and squawfish. Since then there has been a widespread and often indiscriminate introduction of game species from other parts of the nation (Washington State Department of Fish and Wildlife 1999b).

Some of the characteristics in wetlands that provide habitat for resident fish include the following.

- Resident fish, like anadromous fish, need a **range of water depths** for different parts of their life cycles (Hruby et al. 1999). Shallow waters provide refuge for young fish, while the deeper waters provide refuge for the larger adults. Varying water depths also provide different potential food sources since they are host to different populations of plants and invertebrates (see the earlier discussion of invertebrate habitat). Olympic mud-minnows rear in wetlands with water only a few inches deep in floodplains (R. Ziegler, Washington State Department of Fish and Wildlife, personal communications 2003).
- **Shorelines between exposed water and vegetation** provide protection from wind, waves, and predators, and may provide natural territorial boundaries (Golet and Larson 1974).
- **Overhanging vegetation** provides both temperature control and protection from predation (McMahon 1983).
- **Large woody debris** plays an important role in the Pacific Northwest, creating and enhancing fish habitat (Bisson et al. 1987).

Birds That Are Closely Associated With Wetlands

Bird species that are *closely associated* with wetlands are those that depend on part or all of its life requirements; these include food, shelter, breeding, or resting. Kauffman et al. (2001)

reviewed the literature and found a very high richness and abundance of birds in wetlands of the Pacific Northwest. They found that:

All 23 species of waterfowl that breed regularly in the western U.S. south of Alaska do so in riparian and wetland environments. Similarly, all 14 western species of waders, a group consisting of cranes, rails, herons, and ibises, depend on riparian and wetland habitats for most of their life cycles. Shorebirds, which include stilts and avocets, sandpipers, and plovers are typically dependent on freshwater, riparian, and wetland habitats. Interior wetlands (i.e., east of the Cascades) also provide crucial stopover habitat for 37 species during migration.

A review of the specific habitat requirements of all birds using wetlands is beyond the scope of this document. General characteristics of wetlands and their buffers that provide good habitat for wetland-dependent birds include the following:

- The **condition of the wetland buffer** is an important characteristic for bird habitat. Trees and shrubs provide screening for birds, as well as providing additional habitat in the buffer itself (Johnson and Jones 1977, Milligan 1985).
- The **width of the buffer** as well as its condition is important (see Chapter 5 for a more detailed discussion of the use of buffers by birds).
- **Snags** are a source of cavities and perches for wetland-associated birds. Several species of birds use already existing cavities for nesting and/or refuge locations. Dead wood attracts invertebrates and other organisms of decay, which in turn provide a food source for many species of birds (Davis et al. 1983).
- Some bird species may require **several habitat types** such as open water and grasslands in close proximity to aid their movements from one type to another (Gibbs et al. 1991, Hunter 1996).
- **Embayments and peninsulas** in a wetland with open water provide “micro-habitats” for certain species that require hiding cover or those seeking security within a more enclosed system (U.S. Department of the Interior 1978).
- The **proximity of a wetland to open water or large fields** increases its utility to migrant and wintering waterfowl. If there is strong connectivity between relatively undisturbed aquatic areas, the suitability of a wetland as waterfowl habitat increases (Gibbs et al. 1991).
- **Open water of varying depths** provides greater diversity of foraging habitat for a greater variety of water birds (U.S. Department of the Interior 1978).
- **A full canopy can limit access** to open water in a wetland because birds have difficulty flying in and out. This may be best illustrated by great blue herons (*Ardea herodias*), which will be reluctant to fly down to a body of water if the tree canopy above is totally closed because rapid escape may be difficult or impossible (U.S. Department of the Interior 1978).

Mammals That Are Closely Associated With Wetlands

For the purpose of this review it is not practical to synthesize the specific habitat requirements of all mammal species using wetlands. The richness of mammal species using wetlands can be very high. Kauffman et al. (2001) report that 79 mammal species east of the Cascades and 69 on the west side use riparian wetlands. The wetlands associated with stream corridors characteristically have greater species richness than upland sites and provide habitat for some species that are not found elsewhere. About half of the species using riparian wetlands in the Pacific Northwest breed and feed in them (Kauffman et al. 2001.)

The following bullets summarize some general information about the characteristics of wetlands that provide good habitat for four mammal species that were modeled as wetland dependent in the Washington State methods for assessing functions (Hruby et al. 1999). These species include the beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), river otter (*Lutra canadensis*), and mink (*Mustela vison*).

- Wetlands with a **relatively undisturbed buffer** are important to these four species (and others) because the buffers:
 - Minimize disturbance (Allen and Hoffman 1984, Burgess 1978)
 - Provide habitat for prey species and food sources for mammals (Allen 1983, Dunstone 1978, Brenner 1962)
 - Provide cover from predators (Melquist et al. 1981)
 - Allow den sites for resting and reproduction (Allen 1983)
- Beavers prefer a **seasonally stable water level** (Slough and Sadleir 1977). Large fluctuations in water levels may also affect the suitability of a wetland for muskrats (Errington 1963). Wetlands subject to heavy spring runoff or flash floods that rapidly raise the water level may cause flooding of burrows (Errington 1963).
- For beavers and muskrats, **water depth must be of sufficient depth. For beavers the water must be deep enough** to accommodate lodges and bank dens and to allow free movement from the lodge to food caches during the winter. For example, freezing of the food cache is a limiting factor on beaver and muskrat survival in the Columbia Basin (J.Tabor, Washington State Department of Fish and Wildlife, personal communication 2000). Freezing of a pond to the bottom can be disastrous to muskrat populations (Schmitke 1971). Deep water will also provide protection from predators (Easter-Pilcher 1987). In the Columbia Basin beavers and muskrats need at least 4 feet (1.3 m) of permanent water to allow access to food caches during the winter when the surface is frozen (Hruby et al. 2000).
- **Vegetated corridors** leading to and from wetlands are considered an important feature in assessing the suitability of a wetland as habitat for wetland dependent mammals (Hruby et al. 2000). Dispersal is a fundamental process in regulating populations among these and other mammals (Kauffman et al. 2001).

- Muskrats and beavers use **persistent emergent cover** for security and feeding (Errington 1963). Allen (1983) believes that beavers prefer herbaceous vegetation over woody vegetation during all seasons, if available.
- **Interspersion of vegetation and open water** is an important characteristic of wetlands as habitat for mammals. High interspersion rates increase the abundance of prey for mink and river otter (i.e., muskrats, water birds, fish) (King 1983). Food abundance and availability appeared to have the greatest influence on habitat use by river otter in Idaho in studies by Melquist and Hornocker (1983). Classic studies of muskrats by Dozier (1953) and Errington (1937) indicate that optimum muskrat habitat is 66% to 80% of the wetland in emergent vegetation with the remainder in open water.

2.6.3.5 Habitat for Plants

Relatively few plant species of the thousands on Earth have adapted to the harsh conditions in wetlands. Major stressors are lack of oxygen, salt, and water level fluctuations in an environment that is neither fully aquatic nor terrestrial (Mitsch and Gosselink 2000). These strong selective pressures have produced a group of plant species that is unique to wetlands and whose maintenance has become an issue in regional biodiversity (Gibbs 2000). Furthermore, wetlands can provide habitat for a wide range of other plant species when conditions are not as harsh. Of the 2969 plant species found in Washington, 1515 (or 51%) have been found in wetlands (FEMAT 1993).

All wetlands provide the four basic requirements for plant growth (space, water, light, and nutrients) to some degree. Differences can be found among wetlands in the number of plant species they contain. Recent research has been focused on the characteristics of wetlands that affect plant richness, as summarized below:

- **Specific water regimes**, such as permanent inundation, seasonal flooding, or saturation, result in unique plant communities (Mitsch and Gosselink 2000).
- The **duration of individual flooding events** is important in separating plant communities because the duration affects germination of seeds in different ways (Casanova and Brock 2000).
- The **water regime** in a wetland can either limit the number of species present or enhance it, depending on types of water level fluctuations and physical energy of the water regime (Mitsch and Gosselink 2000).
- Plant richness in a wetland generally follows the ecological theory that maximum richness occurs at **intermediate levels of environmental stress** (Johnson and Leopold 1994). For example, water level fluctuation is an environmental stress (Mitsch and Gosselink 2000). Wetlands with large water level fluctuations, therefore, would be expected to have fewer plant species than those with moderate water level fluctuations. On the other hand, wetlands with very small water level fluctuations (low stress) would also be expected to have fewer plant species.

- Wetlands with **different water depths** tend to have higher richness than those with fewer (Hruby et al. 1999). Observations show that the distribution of species within a wetland is primarily a function of water depths (Spence 1982 as cited in van der Valk et al. 1994).
- The **proximity of other wetlands** as a source of seed (Brock et al 1994, Brown 1998).

2.6.3.6 Supporting Food Webs (Primary Production and Export)

Wetlands are known for their high primary productivity (i.e., production of plant material) and the subsequent export of this organic matter to adjacent aquatic resources. The exported organic matter provides an important source of food for most downstream aquatic ecosystems (Mitsch and Gosselink 2000).

Plant material produced in wetlands breaks down into smaller and smaller particles and becomes increasingly nutritious due to the activity of bacteria, fungi, and protozoa (Sipple 2002). This decomposed plant material, including the various microbes that colonize it, feeds many small aquatic invertebrates and small fish. These invertebrates and fish then serve as food for larger predatory amphibians, reptiles, fish, birds, and mammals (Sipple 2002).

The following summarizes general characteristics of wetlands that have high production and provide excellent support for aquatic food webs.

- In general, wetlands **where water flows through the system** have higher levels of primary production and export than those where water is impounded without leaving (Mitsch and Gosselink 2000).
- The **water level fluctuation** as well as movement of water mentioned above through the wetland and its **soils** is one of the most important determinants of primary productivity (Mitsch and Gosselink 2000).
- Performance of this function requires both that **organic material** is produced and that a mechanism is available to move the organic matter to adjacent or contiguous aquatic resources (Hruby et al. 1999).

2.6.4 Summary of Key Points

- The residence time of water in the wetland and filtering by wetland vegetation are major processes influencing removal of sediments, phosphorus, and toxics from surface water. Wetland vegetation typically removes 80% to 90% of sediment from runoff. Wetlands with seasonal inundation or saturation have conditions that promote removal of nitrogen from surface runoff. In order for a wetland to provide functions that improve water quality, however, surface water containing pollutants must first enter the wetland.
- The capacity of a wetland to store surface water affects its ability to reduce peak flows, as do the amount of flow from the upper watershed that enters the wetland and the amount of woody vegetation present. Reducing peak flows helps to decrease downstream erosion.

- Only wetland types that impound surface water have the potential to provide groundwater recharge.
- Wildlife species can be *wetland dependent* or *wetland users*. Wetland-dependent species (such as amphibians) require a wetland for at least part of their life cycles. Wetland users (such as deer) come to wetlands for such needs as water or cover.
- The characteristics of wetlands that provide habitat depend on species and life stage. Characteristics that are important for many species include vegetation structure, water depth, water level fluctuation, buffers, snags, and connections to other habitats and wetlands in the landscape.
- Wetlands have high productivity of plant material. Decomposed plant material can be exported downstream, providing food for insects, fish, and other organisms in the food web.

2.7 Chapter Summary and Conclusions

The functions of wetlands are things that wetlands “do.” They represent the many interactions possible among the different components of the environment found in wetlands. There are many interactions that occur in wetlands and they occur at many scales. In general, however, functions are grouped into three broad categories: 1) biogeochemical interactions, 2) hydrologic interactions, and 3) interactions that maintain food webs and habitats for plants and animals.

The primary factors that control wetland function are climate, geomorphology, the source of water, and the movement of water. These factors affect wetland functions directly or through a series of secondary factors including nutrients, salts, toxic contaminants, soils, temperature, and the connections created between different patches of habitat. The factors that control wetland functions interact with each other and there are many feedback loops. A number of conceptual models have been developed to help visualize and understand the complexity of the interactions between environmental factors, environmental processes, and wetland function.

The major environmental factors of geomorphology, source of water, and the movement of water are the basic characteristics used to classify wetlands in Washington into groups of wetlands that have similar functions. These groups can be expected to perform these functions in similar ways. Freshwater wetlands in Washington are divided, based on how they function, into two domains, five regions, and six classes.

The environmental factors that control the structure and functions of a wetland occur at both the landscape scale and the site scale. For example, riverine wetlands will be affected to a great degree by processes operating at the scale of the entire watershed of the river. Depressional wetlands will be subject to processes that occur only within the basin that contributes surface or groundwater to the wetland.

The most important factors that control functions at an individual site may occur somewhere else in the landscape. Information about factors that control functions at the larger scale is still evolving. The importance of the environmental factors that occur at the larger, landscape scale,

however, should not be minimized for lack of information. Ongoing research is continually strengthening our understanding of these critical factors.

The links between wetland functions and the landscape have been well described by the National Academy of Sciences (National Research Council 1995):

Individual wetlands function to a large degree through interaction with the adjacent portions of the landscape and with other wetlands. For example, wetlands whose principal source of water is groundwater depend on that water infiltrating in the surrounding uplands. If these uplands are paved, clear-cut, or farmed, the amount of water recharge is significantly reduced and the wetland may dry up or become smaller. No single wetland or aquatic site could support anadromous fish. The connections between individual wetlands, aquatic systems, and terrestrial systems are critical to the support of many species. Furthermore, flood control and pollution control are determined by the number, position, and extent of wetlands within watersheds. Thus, the landscape gives proper context for the understanding of some wetland functions.

An understanding of wetland functions for the purposes of managing and protecting them will require knowledge of how the major controls of functions change or are impacted by humans at all scales. We need to understand how climate, topography, and the movement of water, nutrients, sediment, etc. are affected by human activities in the entire watershed, as well as in the immediate vicinity of the wetland. Chapter 3 describes the environmental disturbances caused by different human uses of the land. Chapter 4 then carries this information forward to discuss how the disturbances caused by human activities affect specific functions of wetlands.

Chapter 3

Environmental Disturbances Caused by Human Activities and Uses of the Land

3.1 Reader's Guide to this Chapter

In Chapter 3, the discussion shifts from wetland functions and the environmental factors that control the performance of functions to the major disturbances created by human activities and uses of the land and water. In this context, a *disturbance* is an event that changes an environmental factor that controls wetland functions.

3.1.1 Chapter Contents

Major sections of this chapter and the topics they cover include:

Section 3.2, Introduction to Human-Caused Disturbances provides an overview of how human land uses change the dynamics and structure of the ecosystems by creating various types of disturbances. The section provides a general overview of how human activities affect the movement and quality of water and connections between habitats across the landscape.

The chapter continues with separate sections for four of the major types of human land uses in Washington State (agriculture, urbanization, logging, and mining) and how they cause disturbances. The different uses of the land by humans are divided into these four categories because most of the literature found discusses the disturbances and impacts of human activities in these terms.

Each major land use is addressed in a separate section, as follows:

Section 3.3, Disturbances Caused by Agriculture, discusses the changes in the physical structure of wetlands such as conversion to fields or pasture, changes in water regime such as changes to the amount and fluctuation of water, and the input of nutrients, salt, sediment and contaminants caused by agriculture.

Section 3.4, Disturbances Caused by Urbanization, discusses the changes urbanization has made, causing a loss of wetlands as well as changes to the water regime in watersheds. It describes how this land use has resulted in sedimentation, increase in nutrients, input of contaminants, and fragmentation of habitat.

Section 3.5, Disturbances Caused by Forest Practices, refers the reader, after a brief summary, to another synthesis that summarizes the literature on the disturbances created by logging.

Section 3.6, Disturbances Caused by Mining, discusses the increased level of heavy metals and acidity in surface waters that results from mining.

Section 3.7, Chapter Summary and Conclusions, ties together the major concepts presented in the chapter in a tabular form. Also, the disturbances caused by each of the four land uses are summarized.

3.1.2 Where to Find Summary Information and Conclusions

Each major section of this chapter concludes with a brief summary of the major points resulting from the literature review on that topic in a bulleted list. The reader is encouraged to remember that a review of the entire section preceding the summary is necessary for an in-depth understanding of the topic.

For summaries of the information presented in this chapter, see the following sections:

- Section 3.2.6
- Section 3.3.11
- Section 3.4.9

As previously mentioned, Section 3.7 provides a summary and conclusions about the main themes synthesized from the literature and presented in this chapter.

3.1.3 Sources and Gaps in Information

There is abundant data on some of the topics related to wetlands and the effects of land uses on water quantity, water quality, and some habitat issues. For example, the Puget Sound Wetlands and Stormwater Management Research Program was one important source of scientific information on how changes in land uses affect the physical, chemical, and biological factors that control wetland functions in the lowlands of Puget Sound. The research program has published numerous articles in scientific journals and has summarized much of the information developed in a book by Azous and Horner (2001).

In contrast, information on the effects of agricultural practices in the Pacific Northwest, especially in eastern Washington, is limited. Most studies originate from the prairie pothole region of the United States, the high mountain West, or California. The literature related to agriculture from outside the Pacific Northwest region has been included in this synthesis when it was judged to be relevant to Washington.

No scientific studies were found that examined the question of whether some wetlands in eastern Washington existed before the onset of irrigation projects. Research has been conducted by Adamus on irrigated agricultural lands from the high basin country of Colorado (Adamus 1993), but may not be germane to eastern Washington because soils and the surface geology are different. However, this study is included in the section on the influence of irrigation on wetlands because it discusses some of the issues that are relevant to the Columbia Basin.

3.2 Introduction to Human-Caused Disturbances

Human activities on the land increasingly represent a fundamental source of change in the global environment (Dale et al. 2000). Alterations to land use and land cover can often change the environmental factors that control functions within a wetland. Modifications in the environment that cause changes in how ecosystems function are called *disturbances*. Pickett and White (1985) define *disturbance* as “any relative discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.”

Disturbances to ecosystems are commonly viewed negatively as a disruption of equilibrium in an ecosystem. A growing science based on non-equilibrium theory, however, indicates that disturbances are an essential ecological process. They are necessary at some level of intensity and periodicity for the long-term maintenance of most, if not all, ecosystems (Averill et al. 2003). Disturbance occurs as a continuum from frequent intervals of low intensity to infrequent occurrences of high intensity (Pickett and White 1985). The average frequency of a given disturbance is inversely proportional to its intensity (Waldrop 1992). Large, intense, disturbances are rare and small ones frequent. Ecosystems have evolved in response to specific regimes of disturbances that have recurred over millions of years (Averill et al. 2003).

The disturbances caused by humans, however, often differ from those that occur naturally. They occur at different scales, different intensities, and different geographic locations (Dale et al. 2000). As a result ecosystems tend to respond in unexpected ways to human activities and many functions that ecosystems provide change or are diminished. Scientists sometimes use the term *stressor* to distinguish those disturbances that have a major impact on an ecosystem from those that maintain the usual structure and function of an ecosystem (see for example Adamus et al. 2001, Laursen et al. 2002). For the purposes of this discussion, however, only the term *disturbance* is used to simplify the discussion. All the disturbances discussed herein are stressors considered to have major impacts on ecosystems, and they are not the ones that maintain the existing structure and functioning in an ecosystem.

3.2.1 The Link between Wetland Functions, Human Land Uses, and Changes in Wetlands

In terms of wetlands and their functions, a disturbance can be considered as a condition or event that changes one of the environmental factors that control wetland functions. For example, nutrients are a factor that controls wetland functions. If nutrients from residential lawns flow to a depressional wetland that has limited nutrients, such as a bog, the excess nutrients can change the dominant plants in the bog and its habitat structure. In this case, the addition of nutrients that are in excess of those found in the absence of human activities is a disturbance on the functions of the wetland.

This example illustrates how changes in land use can influence large-scale environmental processes, resulting in disturbances to the factors that control wetland functions. It also illustrates how the topics discussed in Chapters 2, 3, and 4 of this volume are linked:

- The movement of nutrients throughout a basin, as described in the example, is one of several environmental factors that control wetland functions. These factors and the way in which they control wetland functions are the subject of Chapter 2.
- The maintenance of residential lawns is an example of a human activity that may affect the movement of nutrients in a basin. The application of excess nutrients (fertilizer) creates a disturbance when the nutrients flow from the lawn into a bog. This chapter (Chapter 3) describes how different kinds of human activities and uses of the land create environmental disturbances.
- When the excess nutrients reach the bog, they cause a change in its plant community and its habitat structure because the plant communities are adapted to a low-nutrient, acidic environment. Chapter 4 describes how disturbances caused by human land uses result in changes to wetland functions.

Figure 3-1 reviews the connection between the factors that control wetland functions, human-caused disturbances, and the functions of wetlands.

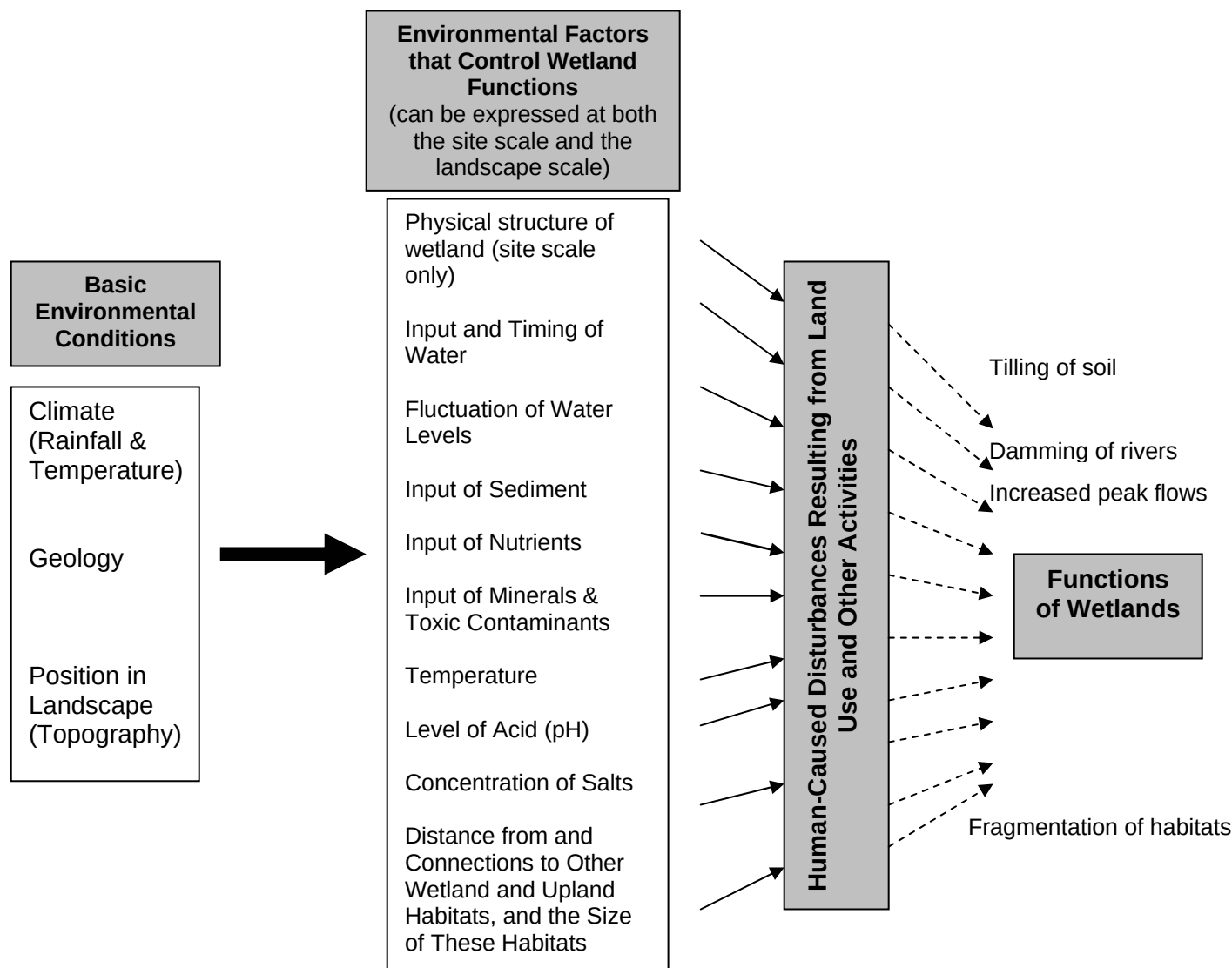


Figure 3-1. Diagram summarizing some major environmental factors that control functions of wetlands and how they interact with human-caused disturbances.

The basic environmental conditions establish and determine the factors that control the functions of wetlands. The controls can occur at both the landscape and site scales. Human activities cause disturbances that affect these controls in many different ways and thereby alter the performance of wetland functions. The figure gives some examples of the disturbances. This figure is the same as that in Chapter 2, Figure 2-3.

3.2.2 Types of Disturbances Resulting from Human Land Uses

Many different types of disturbances have been identified in the literature. For the purposes of organizing the information in this chapter, the list developed by Adamus et al. (2001) and shown in Table 3-1 is used because it was developed specifically to address impacts to wetland functions. Table 3-1 lists the types of disturbances that can impact wetlands and the scale at which the disturbances can occur. Many disturbances

that result from human uses of the land can occur over large areas such as basins and sub-basins (called the landscape scale), as well as in the wetland itself and in its immediate vicinity (called the site scale).

Table 3-1. Summary of human-caused disturbances and the scale at which they can occur.

Disturbance	Scale of Disturbance
Changing the physical structure within a wetland (e.g., filling, removing vegetation, tilling soils, compacting soils)	Site
Changing the amount and velocity of water (either increasing or decreasing)	Landscape and site
Changing the fluctuation of water levels (frequency, duration, amplitude, direction of flow)	Landscape and site
Changing the amount of sediment (increasing or decreasing the amount)	Landscape and site
Increasing the amount of nutrients	Landscape and site
Increasing the amount of toxic contaminants	Landscape and site
Changing the temperature	Mostly site
Changing the acidity (acidification)	Landscape and site
Increasing the concentration of salt (salinization)	Mostly site
Fragmentation (decreasing area of habitat and its spatial configuration)	Landscape
Other disturbances (noise, etc.)	Landscape and site
This table is a synthesis of the information presented by Adamus et al. (2001) and in the literature review done for this document.	

3.2.3 Disturbances to the Movement of Water at the Landscape Scale

The movement and sources of water in the landscape are two critical factors controlling how wetlands function. Many human land uses change the movement and sources of water, thereby creating a disturbance that affects the performance of functions in wetlands. The following provides some background on how human activities result in disturbances to the movement and sources of water.

The literature is quite clear that the frequency, timing, and duration of water in the landscape determine the presence of a wetland and the functions that it provides (see Chapter 2). How water enters a wetland, how long it is present, and the depths to which it is impounded all influence the functions that a wetland can provide or perform (Brinson 1993a, Mitsch and Gosselink 2000).

Surface and subsurface water flows through the landscape within “drainage systems.” These drainage systems are often called basins, sub-basins, watersheds, or river basins depending on the size of the area. In this document, drainage systems are generally referred to using one of two terms:

- **Watershed** - A geographic area of land bounded by topographic high points in which water drains to a common destination.
- **Contributing basin** - The geographic area from which surface water drains to a particular wetland.

Booth (1991) succinctly summarizes the concept of a drainage system as follows:

Drainage systems consist of all of the elements of the landscape through which or over which water travels. These elements include the soils and the vegetation that grows on it, the geologic materials underlying that soil, the stream channels that carry water on the surface, and the zones where water is held in the soil and moves beneath the surface. Also included are any constructed elements, including pipes and culverts, cleared and compacted land surfaces, pavement and other impervious surfaces that are not able to absorb water at all.

The movement and routing of water above and below the surface is the primary force in transporting nutrients, sediment, salts, and contaminants, and this in turn affects the functions provided by wetlands (Naiman et al. 1992). Water moves (or carries) sediment, nutrients, and energy throughout a watershed (Naiman et al. 1992). Changes in the amount of water, as well as in the frequency and fluctuations of water volumes, can alter how sediments, nutrients, and toxic contaminants come into a wetland. Changes in the movement of water resulting from human activities at the scale of the landscape can therefore have severe impacts on wetland functions throughout a watershed.

The following subsections provide background on how water moves in undisturbed landscapes as well as those that have been changed by human activities. The purpose of this discussion is to provide a context for understanding how human activities and uses of the land create the disturbances discussed later in the chapter.

Terms used to describe water regimes: hydrology vs. hydroperiod vs. hydrologic

Hydrology and hydroperiod are often used interchangeably to mean how water moves. *Hydrology*, as defined by Webster, is “the scientific study of the properties, distribution, and effects of water in the atmosphere, on the earth’s surface, and in soil and rocks.”

The term hydrology means the study of how water moves.

Hydroperiod (not defined by Webster) is commonly used to refer more precisely to the periodicity of water; the timing (seasonal or otherwise) and duration of water’s presence or absence within a particular aquatic feature, such as a wetland. It is “the seasonal occurrence of flooding and/or soil saturation, encompassing the depth, frequency, duration and seasonal pattern of inundation” (Azous et al. 2001). Mitsch and Gosselink (2000) define hydroperiod as “the seasonal pattern of the water level of a wetland . . . a hydrologic signature of each wetland type.” Hydroperiod, in this context, refers to seasonal changes in wetland water level conditions caused by regular annual changes in water availability. This should be differentiated from the water level fluctuations driven by single or serial storm events.

Hydrologic is an adjective derived from the word “hydrology.” It refers to the properties, distribution, and effects of water. Thus a term such as “hydrologic processes” refers to the environmental processes that involve the properties, distribution, and effects of water.

In this document, “hydroperiod” is used to refer to the pattern of water movement in a particular wetland or type of wetland. The term “hydrology” has been retained when direct quotes from sources use that term even if it has been misused. “Hydrologic” is used when an adjective is needed to describe the patterns of water movement.

3.2.3.1 Movement of Water in Undisturbed Landscapes

In undisturbed conditions, very little of the precipitation falling on the ground ends up in surface runoff, even in areas of high annual rainfall such as the Pacific Northwest. Areas with natural vegetation provide high rates of interception, infiltration, and evapotranspiration (Ziemer and Lisle 1998). The water either drips off leaves to the soil below; flows down the stems, leaves, and bark to the soil; or evaporates into the air, never reaching the ground.

Water that infiltrates into permeable surfaces either moves downgradient as shallow groundwater, infiltrates into a deeper water table, or is taken up by plant roots and transpired back into the atmosphere. Shallow groundwater flows downgradient through the pore spaces in the soils until it surfaces in a stream, wetland, or swale, sometimes in the form of a seep or spring.

Precipitation falling onto naturally impervious surfaces (e.g., bedrock), however, flows along the surface. Precipitation also flows along the surface if the soils become saturated and cannot hold any more water.

3.2.3.2 Movement of Water in Disturbed Landscapes

Human activities on the land change the movement of water across and through the landscape such that there are significant changes in runoff patterns and hydroperiods in a watershed (Booth 1991, Vought et al. 1995, Azous and Horner 2001). Surface runoff, rather than infiltration, comes to dominate water flows, as shown conceptually in Figure 3-2. The movement of water in a landscape can be altered by any of the following conditions:

- Removal of vegetation
- Compaction of soil (through grazing, earthwork, lawns, or playfields)
- Reduction in size of soil particles or the spaces between particles (through tilling or grading)
- Reduction in the organisms that aerate the soil
- Placement of drain tiles, ditching, road cuts, utility lines
- Construction of impervious surfaces
- Construction of dams and reservoirs

These conditions result from human land uses such as agricultural conversion, urbanization, and forest practices (Dunne and Leopold 1978, Booth 1991, Euliss and Mushet 1996). The disturbances from specific land uses to the movement of water and its sources are described later in this chapter. Information on the resulting impacts on wetland functions is synthesized in Chapter 4.

Removing vegetation allows precipitation to reach the soil surface faster, and therefore soil saturation occurs more rapidly. As soils become saturated, additional precipitation accumulates more rapidly on the surface and moves as sheet or surface flows. When soils are compacted, the precipitation cannot enter the soils readily and surface water accumulates more rapidly. Loss of permeability in the soil can persist even after compacted soils become vegetated as urban lawns, playfields, and in some agricultural conditions (Dunne and Leopold 1978).

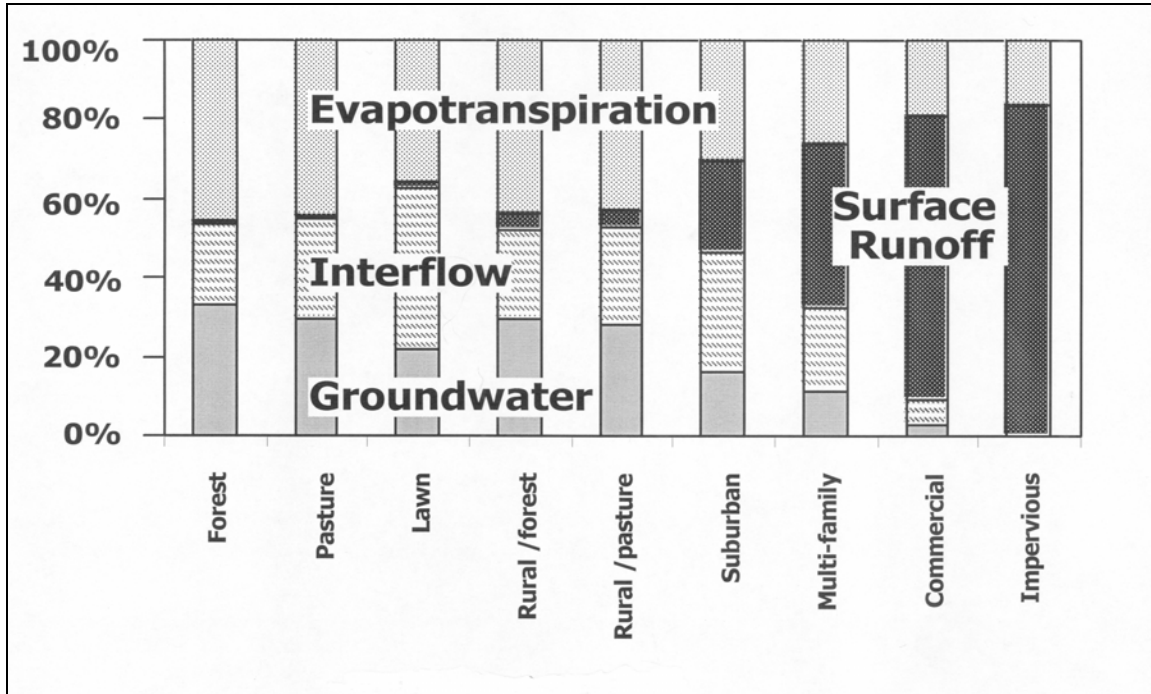


Figure 3-2. Changes in the proportion of groundwater, interflow, evapotranspiration, and surface runoff with different types of land cover in western Washington (Beyerlein 1999; reprinted with permission).

Under any of these conditions, runoff essentially becomes surface flow. Water flowing along the surface carries sediment and any other dissolved or adsorbed materials downgradient more rapidly than if the water is allowed to infiltrate in undisturbed soils (Ziemer and Lisle 1998). Studies in the Puget Sound region found that peak flows increase during storms as a result of urban development, but that the annual mean flow decreases (Konrad 2000).

In general, alteration of water flow in uplands results in a “shortening” of the path that water would naturally follow on its route through a watershed. It reduces the residence time of water in the ground and in bodies of surface water, such as streams or wetlands, within the watershed. On the other hand the construction of dams and weirs has resulted in the retention of water and a reduction in water velocity once the water reaches a stream or river.

Changing the water flow in uplands also results in increased rates and volumes of stormwater and changes the timing of stormwater entering aquatic systems. This can have numerous effects on aquatic systems as described in Section 3.4.2 on the effects of urbanization. For example, these changes circumvent or reduce:

- The removal of nutrients, pathogens, and toxics in the soil
- The filtering of sediment from surface flows through vegetated buffers and wetlands
- The reduction of downstream peak flows

3.2.3.3 The Role Of Impervious Surface In Changing Water Regimes

According to research throughout the country and in the Pacific Northwest described below, the degree of alteration in hydrologic processes and the subsequent impacts to aquatic habitats (including wetlands) is governed by the percent of impervious area and the percent of forested cover within a watershed. When soil is covered with impervious surfaces there is no opportunity for infiltration. All precipitation that falls on an impervious surface becomes surface water which flows downgradient.

Research in western Washington generally indicates that increases in the amount of impervious cover within a watershed can result in significant impacts to the habitat structure and function of freshwater aquatic systems (Azous and Horner 2001). Reinelt and Taylor (2001) discovered that 20% impervious cover in upstream development increased the peak and volume of stormwater runoff to the point that it began to dominate the hydroperiod of downstream wetlands. However, some scientists have concluded that trying to identify a specific threshold may not be accurate. As stated by Dr. Richard Horner “We are thoroughly convinced that there is no threshold; deterioration begins immediately and progresses at a rapid rate as soon as any amount of urban development begins” (Horner, University of Washington, personal communication 2004).

Defining and assessing impervious surface

The term *impervious surface* as used in the literature and in this document means more than just a hard impermeable surface such as an asphalt parking lot. There are many actions humans take that reduce the permeability of soils, and these are included in the calculations of “percent impermeable surface.” For example, compacted soils found in lawns and landscaped areas function just as impervious surfaces do during storm events (May 1996).

Total impervious area (TIA) is sometimes challenging to assess without high-resolution aerial photographs and accurate GIS mapping capabilities (especially in watersheds with extensive forested coverage). Reinartz and Warne (1993) found that using road density as an indicator of basin impervious area resulted in findings nearly identical to those resulting from estimation of imperviousness from aerial photographs.

Reinelt and Taylor (2001) concluded that removing as little as 3.5% of the forested cover in a rural, low-density residential area resulted in changes in the pattern of water movement in the basin. Looking at percent forested cover in the Puget Sound Basin; Booth et al. (2002) have determined that natural hydrologic processes are maintained if 65% of a watershed remains in a forested condition. Because each watershed has different physical, chemical, and biological characteristics and patterns of impervious cover, the threshold at which aquatic resources experience significant effects will vary.

Table 3-2 summarizes additional findings on the effects of impervious cover on various biological characteristics of aquatic resources. As noted previously, specific impacts to wetland functions are described in Chapter 4.

Table 3-2. Summary of findings on the impacts of impervious cover.

Reference	Impacts to:	Key Finding
Booth (1991)	Fish habitat; channel stability	Channel stability and fish habitat quality declined rapidly with over 10% impervious cover
Taylor (1993)	Wetland plants and amphibians	Mean annual water level fluctuations are inversely correlated to density of plants and amphibians. Sharp declines occur when impervious cover exceeds 10%
Steedman (1988)	Invertebrates	Negative correlation between biologic integrity and increasing development at 209 streams. Degradation started at 10% impervious cover

3.2.3.4 The Role Of Dams In Changing Water Regimes

The construction and operation of dams affects the movement of water across large areas of the landscape. Regardless of their purpose, all dams trap particles to some degree and most alter the flood peaks and seasonal distribution of flows (Kondolf 1997). Dams disrupt the continuity of processes that occur at the landscape scale. Areas where water flowed fast may now have slow water movement and vice-versa (Kondolf 1997). In cases where water is transferred for irrigation or other purposes the reductions in discharge may greatly influence the hydrophysical conditions in the floodplain (Fjellheim and Raddum 1996).

There are four major aspects of changes to water regimes that result from the construction of dams (Bunn and Arthington 2002). These are:

- Reduction of the variability in flows
- Loss of some seasonal fluctuation in the wet/dry cycle
- Erratic daily patterns in the flow below hydroelectric dams
- Conversion of river and floodplain water regime (and habitat) to a lake water regime

Thus dams can change the water regime in a riverine and floodplain system to one that was not there previously, nor that could have been easily created by non-human factors.

For example, there are 211 major dams in the Columbia River Basin, 34 of which are on the main stems of the Columbia and Snake Rivers. The water levels in the reservoirs behind the dams operated by the Army Corps of Engineers rise and fall on a schedule unrelated to natural fluctuations. Levels in reservoirs may drop suddenly on a daily basis. The 211 dams also significantly reduce and slow the movement of water (Northwest Environmental Advocates, <http://www.advocates-nwea.org/programs/U.html>, accessed October 7, 2004).

3.2.4 Disturbances to the Quality of Water at the Landscape Scale

Two principal mechanisms have been documented to describe how land uses in a watershed change water quality in that watershed:

- Changes in hydroperiod increase erosion and sedimentation (Booth 1991, Booth and Reinelt 1993, Horner et al. 1996)
- Human uses of the land generate pollutants that are then transported into aquatic systems (Reinelt and Horner 1995)

Larger volumes of water, moving at faster rates, scour channels and cause rills in unvegetated soils. Moving water picks up and transports sediment and the pollutants associated with sediment particles. In addition, research shows that water flowing across the ground surface tends to pick up and convey dissolved nutrients and toxics directly into receiving waters (Young et al. 1980, Emmett et al. 1994, Gilliam 1994, Brenner 1995, Reinelt and Horner 1995, Vought et al. 1995, Crosbie and Chow 1999, Sheridan et al. 1999, Azous and Horner 2001).

Pollution conveyed by surface runoff (called *non-point-source pollution* by the U.S. Environmental Protection Agency) has been identified as the dominant source of pollutants in surface water. Non-point-source pollution is not discharged from the “end of a pipe” such as a large factory. Instead it is caused by sediment, metals, excess nutrients, and bacteria from a variety of dispersed sources (Reinelt and Horner 1995) such as stormwater, contaminated runoff from urban settings, agricultural runoff, and construction runoff (Baker 1992). These pollutants can have numerous impacts on wetlands and their functions as described in Chapter 4.

3.2.5 Disturbances to Habitats at the Landscape Scale (Fragmentation)

Human activities within a landscape often break up environment into small patches of habitat that are separated by roads, buildings, or tilled fields. The breaking up of the environment into habitat “patches” separated by areas altered by human land uses is a disturbance that is called *fragmentation*. Habitat fragmentation consists of both the reduction in the area of the original habitat and a change in spatial configuration of what remains (Haila 2002).

Suburban and urban development, farmlands, roads, railroads, powerline corridors, and other land uses cause various kinds and degrees of fragmentation (Heinz Center for Science 2002). These are discussed in more detail in subsequent sections of this chapter. In addition, human activity can create landscapes that are less varied than the landscapes historically present. Particularly in the West, natural fires create a patchy landscape, where forest and grasslands are intermingled in a mosaic. Fire suppression and the large

fires that result after long periods of suppression can create broad expanses of very similar vegetation (Heinz Center for Science 2002).

All environments, with or without human activities, are fragmented to some degree and are subjected to continuous change due to “natural” causes. As a result, no straightforward standard is available for assessing human-caused fragmentation. Furthermore, different ecosystems and the species they support experience the effects of fragmentation in variable, even contradictory ways (Haila 2002). For example, the breaking up of a certain habitat into patches may increase the populations of certain species by keeping predators from moving between patches. Such patches, however, will reduce the populations of predators because their access to prey will be reduced (Fahrig 2003).

The effect of human-caused fragmentation needs to be considered at different spatial and temporal scales, and the relevant scales will vary across species, geographic regions, and types of environment (Haila 2002). The types of fragmentation caused by the major land uses is described in this chapter, and the impacts of fragmentation on the functions of wetlands are described in Chapter 4.

3.2.6 Summary of Key Points

- Many human land uses change the movement and sources of water in a watershed, thereby creating a disturbance that affects the performance of functions in wetlands.
- In general, alteration of water flow by human uses of the land results in a “shortening” of the path that water would follow on its route through a watershed. It reduces the residence time of water in the ground and in the bodies of surface water, such as streams or wetlands, within a watershed.
- Changes in the amount of water and the frequency and fluctuations in water volumes can also change how sediments, nutrients, and toxic contaminants come into a wetland.
- Research in western Washington generally indicates that increases in the amount of impervious cover within a watershed can result in significant impacts to the habitat structure and function of freshwater aquatic systems.
- Two principal mechanisms have been documented to describe how land uses in a watershed change the water quality in that watershed: (1) land uses increase erosion and sedimentation, and (2) human uses of the land generate pollutants that are then transported into aquatic systems.
- Human activities within a watershed often break up the nevis and habitats into small patches and this disturbance is called fragmentation.

3.3 Disturbances Caused by Agriculture

This section describes the types and severity of disturbances that can be caused by agricultural practices. As mentioned previously, these disturbances can, in turn, affect factors that control wetland functions and are discussed in Chapter 4.

Wetlands have historically been some of the first places on the landscape that were used for agriculture. In western Washington, sites with flat topography suitable for agriculture were often located in river or stream floodplains. Many areas of these floodplains were wetlands with high water tables that persisted late into the growing season. Most early descriptions of Northwest rivers tell of valleys so wet that trails followed ‘the borders of mountains’ (Sedell and Luchessa 1982). Much of the flooding was a result of beaver activity that modified the flood plain and created areas where sediments could accumulate. Because the bottom land had accumulated fine silts and organic matter of alluvial origin, the land was fertile and drained early in the development of Oregon and Washington (Sedell and Luchessa 1982).

Agricultural practices play a significant role in influencing water movement in many regions of Washington. However, much of the research on wetlands in Washington over the last 10 years has been on the effects of urbanization. Although some of the consequences and effects of agriculture and urbanization may be the same or similar, others may be quite different. For example, agricultural practices in some parts of the state such as the Columbia Basin may have resulted in the creation of wetlands, or the expansion of pre-existing wetlands through the introduction of water from irrigation (Foster et al. 1984).

Cranberry growing operations in Washington are a type of agricultural land use that affects wetlands. However, cranberry production is limited to very small areas along the southern Washington coast in Pacific and Grays Harbor counties. The types of impacts that occur from conversion of wetlands to cranberry production are very different from other types of agricultural impacts. Due to the limited area affected, and time and funding limitations, this synthesis does not attempt to address the effects of cranberry production on wetlands in the state.

3.3.1 Loss of Wetlands and Changes to the Physical Structure of Wetlands from Agricultural Practices

Agriculture disturbs the physical structure of wetlands directly through conversion of the wetland to fields or pasture that often leads to the elimination of wetlands themselves. Conversion activities include filling or tilling, draining through tiles or channels, or removing the wetland vegetation and planting upland vegetation or crops. For example, tilling the soil within a wetland will disturb its soil structure (Nowak 1980, Hayes 1995). Livestock grazing in riparian wetlands also has well documented effects on the structure of plants and soils in wetlands as described below. Another example of disturbing the physical structure of riparian wetlands is the building of dams for irrigation since water

flow is a major determinant of the physical habitat in aquatic systems (Bunn and Arthington 2002). The disturbances created by dams are discussed in Section 3.2.3.4.

In studying riparian wetlands, Chappell et al. (2001) concluded that wetland loss in western Washington has been caused primarily by conversion to land development and agriculture. Although Chappell et al. (2001) do not estimate the loss that can be attributed to the different types of land uses, Bell (2002) found that 40% of the losses to peat wetlands in King County between 1958 and 2000 could be attributed to agriculture.

A recent study in the Willamette Valley (an urbanizing area similar to the Puget Sound Area) found that wetlands continue to be lost due to agriculture. Approximately 2.1% of the wetland area (3,800 hectare) was lost, and of this 70% was associated with agriculture, 6% to urbanization, and 24% to other causes (Bernert et al. 1999).

Outside of Washington, tremendous loss of wetland acreage has been attributed to agricultural filling, draining, and ditching in the prairie pothole regions of North America (Tiner 1984, Turner et al. 1987, Bardecki 1988). Researchers in Canada estimated 73% to 95% of the original wetlands in the area studied had been lost to agricultural conversion by the late 1960s (Snell as quoted in Bardecki 1988). Their work in Canada parallels the findings of Tiner (1984) that up to 87% of wetland loss in the United States was related to agricultural practices.

The literature on the effects of grazing on the physical structure of wetlands is focused primarily on riparian habitats, including riparian wetlands. Only a few of the studies found on this topic are located in the Pacific Northwest. However, much of the literature from the Midwest and even some from Australia may also be relevant because the types of disturbances caused by grazing are not geographically isolated. Many of the studies focused on riparian areas without differentiating between riparian upland and riparian wetland areas.

In summary, the effects of grazing in riparian areas include (Armour et al. 1991, Busby 1979):

- Loss of the structure provided by vegetation
- Trampling and related sloughing and erosion of streambanks
- Shallower and wider streams

The effects of grazing on riparian vegetation vary significantly depending on the frequency and intensity of grazing (Clary 1995, Clary et al. 1996, Jansen and Robertson 2001). Soil compaction and a reduction in ground-cover vegetation lead to erosion and greater volumes of runoff from the compacted areas. Also, as native plant species are trampled and grazed and shading is reduced, there is more opportunity for establishment of species that can tolerate disturbance (see Chapter 4).

3.3.2 Increased Amounts of Water in Wetlands Resulting from Agricultural Practices

Water availability was a limiting factor for agricultural practices in the areas of low rainfall until the U.S. Bureau of Reclamation began intensive damming and irrigation projects in the early 1900s (Lemly 1994). Since then, irrigation practices have been influencing the presence of wetlands and their functions in areas in the rain shadow of the Olympic Mountains and the arid parts of eastern Washington. Most of the scientific literature concerns western states such as Colorado and Wyoming as well as Washington east of the Cascade Mountains. No information was found regarding the disturbances caused by irrigation practices on the Olympic Peninsula.

Irrigation can increase the amount of water at or near the surface (Adamus 1993). This may result in the creation and maintenance of wetlands in locations where they did not previously exist. New wetland areas have formed because of the sustained higher water table from seepage out of irrigation reservoirs, irrigation channels, and irrigation runoff. Leakage from irrigation channels and ditches often allows the formation of wetlands along channel margins or immediately downslope of ditches. Excess irrigation water applied to fields that exceeds the capacity of the soils to absorb water (“tailwater”) may also form wetlands in low-lying areas that collect excess runoff. Tailwater also includes the spillage that occurs during operation of the irrigation system (Adamus 1993). For example, the Potholes Reservoir area within the Columbia Basin Irrigation Project contains wetland complexes that exist because of high groundwater caused by the high water levels in the reservoir (Tabor, Washington State Department of Fish and Wildlife, personal communication 1998).

Studies in Wyoming by Peck and Lovvorn (2001) support the idea that irrigation can be significant in creating and supporting wetlands and the biotic communities that depend upon them. The authors noted that 65% of inflows into wetlands in the Laramie Basin were derived from irrigation waters. They reached this conclusion by studying the loss of wetlands when irrigation practices were made more efficient (this is discussed further in Section 3.3.3).

In some instances, pre-existing wetlands experience deeper water for longer durations in the summer due to runoff from irrigation. Wetlands in the Potholes Reservoir that may have been seasonally inundated have become permanently inundated because of irrigation (Creighton et al. 1997).

In Colorado, Adamus (1993) differentiated between types of irrigation-related wetlands during a study of bird use of wetlands associated with irrigation waters. His work is cited here for relevant insights into the complexities of wetlands associated with irrigation.

However, due to physiographic and climatic differences between the Colorado Plateau and Washington, not all of his findings may be directly relevant to irrigated agricultural lands of the state. He identified the following types of irrigation-related wetlands:

- **Irrigated wetlands** are those that are created on farmed lands as the result of the duration and frequency of inundation from irrigation waters. The wetlands are most often created on the farmed lands within the actual zone of irrigation.
- **Enhanced wetlands** are those that are enlarged or their hydrologic regime extended (i.e., longer inundation or saturation) as the result of runoff from irrigation waters.
- **Induced wetlands** are those that develop as a result of irrigation runoff (from the farmed lands) where wetlands did not exist previously. These wetlands may or may not be located on the lands that are irrigated, but the source of the runoff water that creates these wetlands is excess runoff from irrigated fields.

Adamus (1993) also noted:

However, even after visiting a site it is difficult to determine conclusively the primary source of water that sustains a wetland. Irrigated wetlands, as considered by this project, can range from wetlands that are completely supported by irrigation runoff at all seasons, to wetlands that exist naturally but for which any measurable amount of their water originates from irrigation, however indirectly (e.g., through seepage or raised water tables). ...determining whether the primary water source of a wetlands is irrigation-related in many cases requires considerable judgment, and no highly replicable approach exists that is applicable to all situations.

Adamus (1993) determined that the following are not adequate criteria to distinguish the water source and, therefore, whether the major source of water to a wetland is irrigation:

- **Seed species richness.** Wetlands that are the result of irrigation water and are more than a few decades old are difficult to distinguish from pre-existing wetlands based on the species richness of the seed bank.
- **Organic content of soils.** Organic material is not an appropriate indicator of water origin. Organic detritus likely accumulates at different rates based on a variety of influencing factors. Much of the organic detritus appears to mineralize by the end of the growing season.
- **Presence of large willows and black cottonwoods.** A lack of large mature stands of black cottonwood and willows is also not an indicator of pre-existing vs. irrigated systems. Cottonwood stands may have been harvested or may never have become established. Anecdotal information concludes that cottonwood regeneration may not occur as frequently in irrigated wetlands due to overgrazing and the effects of flood management.

In the Wyoming setting studied by Peck and Lovvorn (2001), salinity of groundwater was also a factor in wetlands receiving shallow groundwater inputs from irrigated fields. Vegetation and biotic communities in the wetlands were correlated to both the water availability and the relative salinity of waters reaching wetlands. In summary, "...different irrigation practices have contrasting effects on a range of wetland types. These effects will change seasonally to impact different organisms with varying life histories, flooding requirements, and salinity tolerances" (Peck and Lovvorn 2001). The effects of changes in salinity are discussed in Section 3.3.8.

3.3.3 Decreased Amounts of Water in Wetlands Resulting from Agricultural Practices

Creighton et al. (1997) note that extensive areas of the landscape in the Columbia River Basin of eastern Washington have been altered by irrigation and the building of dams. One result of irrigation projects, they note, was "a sharp reduction in the amount of water available to native wetlands." In some instances sources of fresh water for wetlands, not resulting from irrigation, were diverted for agricultural uses and less water reached the wetlands.

In Wyoming, Peck and Lovvorn (2001) investigated the potential consequences of increasing efficiency in irrigation practices by lining ditches and using sprinkler systems (rather than flooding the fields). The authors noted that 65% of inflows into wetlands in the Laramie Basin were derived from irrigation waters. Therefore, with increased efficiency of water used for irrigation, the presence of wetlands in irrigated arid lands could decline. (The Wyoming data may be relevant to eastern Washington although the underlying geology and irrigation practices may not be identical.)

In California, the drought of 1985 through 1992 resulted in implementation of greater water conservation measures and therefore a decrease in the production of irrigation tailwater. There was a subsequent decrease in the volume of water reaching wetlands (Creighton et al. 1997).

Lower water levels in a wetland can also result from the direct ditching and draining for agricultural purposes. In this case the water entering the wetland is not reduced, rather it is shunted through the wetland and the storage capacity of the wetland is diminished. The ditching may be so effective that the area becomes upland. If, however, the draining is only partial the wetland may remain, but with lower water levels and probably a reduced area. The literature review did not disclose any information on how many wetlands in Washington may be impacted in this way.

3.3.4 Increased Fluctuations of Water Levels in Wetlands Resulting from Agriculture

The findings of Euliss and Mushet (1999) in North Dakota on the effects of agriculture on water level fluctuations in wetlands are probably significant for wetlands in the arid

grasslands of the Columbia Basin. These areas have similarities in precipitation and geologic patterns. These authors found that the hydroperiods for temporary, seasonal, and semi-permanent wetlands were all significantly affected by agricultural practices within the wetland's contributing basin. There was a three-fold increase in water level fluctuations of wetlands within tilled agricultural landscapes (average 5.5 inches [14 cm] fluctuation) compared to those surrounded by natural grasslands (average 1.6 inches [4 cm] fluctuation). The authors concluded, "Tillage reduces the natural capacity of catchments to mitigate surface flow into wetland basins during precipitation events, resulting in greater water level fluctuations in wetlands with tilled catchments."

3.3.5 Increased Input of Sediment Resulting from Agriculture

Tillage and grazing adjacent to a wetland or in a watershed can disrupt the soil, creating a source of sediment for surface runoff to transport downstream into wetlands and other aquatic systems. In addition, ditching wetlands in agricultural areas increases the rate of water movement by removing or reducing vegetation that acts to decrease the velocity of water. Unvegetated channels and ditches may be the source of sediment through increased erosion within the ditch (Brown 1988).

Baker (1992) compared sediments in agricultural runoff to those of wastewater plant effluent. He found that agricultural runoff can have suspended solids in the range of 100 to 1,000 milligrams per liter (mg/l), compared to less than 30 mg/l for wastewater that had received secondary treatment. Baker (1992) also found that non-point-source pollution from agricultural lands is driven by storms. It is therefore highly variable in extent and timing. He noted that in agricultural settings large storms can increase the sediment load by two to three orders of magnitude in a year, while the loads in wastewater discharge remain relatively consistent.

Wind-borne sediments that are eroded from tilled fields also generate high sediment loads to wetlands and streams in eastern Washington. The U.S. Department of Agriculture estimates that about half of the total farmland in Washington lost more than 2 tons of soil per acre per year through the action of wind in 1997. About 10% of the total farmland lost more than 10 tons per acre per year (Natural Resources Conservation Service 1997). By adding up the estimates of erosion rates and area that is farmland, it can be estimated that in 1997 about 15 million tons of topsoil were lost through wind erosion from fields in the state.

Sediment will eventually be transported into rivers and streams or deposited in wetlands. Wetlands found in depressions are often the low points in a landscape and will receive sediments that fall in the surrounding areas. The field teams that are calibrating both the methods for assessing wetland functions and the Washington State Wetland Rating System have observed wind-blown sediments in many wetlands of eastern Washington that were several inches deep.

3.3.6 Increased Input of Nutrients Resulting from Agriculture

In the United States the export of phosphorus and nitrogen from agricultural land can be three times higher for phosphorus and 12 times higher for nitrogen than from forested lands (Omernik 1977). Many of these nutrients are transported to wetlands, streams, rivers, and lakes because they are washed out of fields or infiltrate into groundwater. In Washington State, Williamson et al. (1998) found elevated levels of nutrients in the groundwater below irrigated fields on the Columbia Plateau. Their assumption is that the source of these nutrients is their application to fields above the groundwater.

The changes in the input of nutrients as a result of agriculture are illustrated by a study in Estonia in eastern Europe that documented what happened when agricultural fertilizers were no longer placed on agricultural lands. There was a four-fold to 20-fold decrease in pollutants associated with agricultural runoff after the collapse of agricultural collectives and the subsequent decline in the application of commercial fertilizers and manure (Mander et al. 2000). Based on 10 years of data (1987 through 1997), the researchers determined that total nitrogen, total phosphorus, biochemical oxygen demand (BOD), and sulfate all declined significantly with the demise of agricultural practices in the contributing watersheds. Forested portions of the watersheds upstream of the agricultural lands did not experience measurable changes in water quality parameters, eliminating the possibility that climatic change was the cause.

3.3.7 Increased Input of Toxic Contaminants Resulting from Agriculture

Several authors have identified agriculture across the country as one of the primary causes of non-point-source pollution in aquatic systems (Brenner 1995, Reinelt and Horner 1995, Thurston 1999). Agricultural chemicals are used to control noxious weeds, insect pests, and damaging fungi and bacteria.

Agricultural chemicals applied to fields enter downstream aquatic resources such as wetlands through three primary pathways (Neely and Baker 1985):

- Adsorbed to sediment particles
- Dissolved or suspended within surface flows
- Dissolved within subsurface drainage

Farming practices and the type of chemicals used determine how the pollutant is transported into wetlands. For example, some herbicides applied to corn are water soluble. Neely and Baker (1985) reported that water flowing across crop residue left after harvesting may wash off remnant herbicides. The concentration of such an herbicide in wetlands downgradient of a corn field may increase as a result. Similarly, Donald et al. (1999) documented that wetlands in the Canadian, prairie-pothole region receive high levels of pesticides when pesticides are applied to fields prior to significant

rains (precipitation totaling more than 2 inches [50 mm] after application). Another study, in California's Central Valley, found that surface water runoff from irrigated fields could have elevated levels of pesticides and herbicides if there had been aerial application of the chemicals or a recent land-based application (Lemly 1994).

Subsurface drainage may also contain pollutants at low levels. Lemly (1994) reported that subsurface waters from irrigated fields had low levels of herbicides or pesticides. These substances were removed from the water column through adsorption as the water filtered through the soils before draining into the subsurface collection system. Williamson et al. (1998) found elevated levels of pesticides in the groundwater below irrigated fields on the Columbia Plateau.

3.3.8 Increased Levels of Salt Resulting from Agriculture

Agricultural practices in irrigated areas can increase the salt content of water in a watershed or in areas immediately adjacent to a field. This means that wetlands receiving water from irrigated areas may also be subject to higher salt concentrations.

The soils in dry areas have developed in an environment of limited rainfall and significant periods of drying. In these areas the rate of evapotranspiration is higher than rainfall, and this draws water from below the ground's surface and causes many soluble minerals to accumulate in the upper soil horizons (Caltech 2003).

Soluble salts in irrigation water will be deposited in soils near the root zones of plants because much of the water in arid regions is lost by evaporation rather than downward transport. This salinization occurs with nearly any type of irrigation. Even if the irrigation water is only slightly saline, repeated cycles of evaporation lead to build-up of toxic salt levels in the soil (Caltech 2003). Thus, irrigation return waters are often high in salt content (Adamus et al. 2001) and this may impact wetlands that receive runoff from irrigation.

3.3.9 Fragmentation of Habitat Resulting from Agriculture

No information specific to fragmentation, the disruption of the connections between wetlands and between wetlands or other habitats, resulting from agricultural activities was found in the literature. It can be hypothesized, however, that such fragmentation has occurred because agricultural practices have fragmented habitats in general (Dale et al. 2000, Fahrig 2003). The direct loss of wetlands through conversion to uses such as agriculture increases fragmentation by removing "patches" of wetlands in the landscape. The conversion of wetlands to agricultural uses is discussed in the beginning of this section.

3.3.10 Other Disturbances Resulting from Agriculture

Several other types of disturbances that have been attributed to agricultural activities:

- Alteration of soils
- Construction of roads
- Noise
- Invasion by exotic plant and animal species

These disturbances are not discussed in detail in this chapter because little information was found describing how agricultural practices create these disturbances. The impacts of these disturbances, however, have been documented and are summarized in Chapter 4.

3.3.11 Summary of Key Points

- Agriculture may affect wetlands directly through conversion of the wetland to fields or pasture. This is often done by direct filling or tilling, by draining through tiles or channels, or by removing the wetland vegetation and planting upland vegetation.
- Livestock grazing in streams and riparian wetlands also has documented effects on the physical structure of wetlands.
- Irrigation can result in the creation and maintenance of wetlands in locations where they did not previously exist. This is a controversial regulatory issue in areas of the state that are irrigated.
- Conversely, agriculture can reduce the amount of water available to wetlands by either diverting water that would otherwise reach pre-existing wetlands, or imposing more efficient irrigation practices that reduce the amount of leakage reaching irrigation-related wetlands.
- Wetlands in tilled areas may experience greater water level fluctuations.
- Disruption of the soil through tilling and grazing can create a source of sediment than can be transported further downgradient. Sediments may also be carried by winds from tilled fields.
- Agricultural areas can have an increased load of nutrients and pesticides in surface runoff and groundwater.
- Agricultural practices in irrigated areas can lead to accumulation of salts in the upper soil horizons. Irrigation may leach out the accumulated salts.
- Fragmentation of wildlife habitat is a secondary consequence of loss of wetlands through agricultural practices. Clearing land for farming removes natural cover and connections between habitats.

3.4 Disturbances Caused by Urbanization

Urbanization creates disturbances that affect wetland functions, both at the scale of the watershed and within individual wetlands. These disturbances impose a variety of changes that profoundly affect watershed processes and, therefore, the downgradient drainage system and the wetlands found there. Changes include filling wetlands, clearing of vegetation, compaction of soil, modifications to water conveyance, alterations to riparian corridors, human intrusions, introduction of chemical contaminants, and increased areas of impervious surface.

A summary report by the U.S. Environmental Protection Agency (1993) concludes that urbanization strongly affects water movement within a watershed by increasing rates of surface flow, reducing subsurface volumes, and reducing baseflow. These pervasive, landscape-level changes commonly affect virtually all areas of an urban watershed (Dunne and Leopold 1978, Booth 1991, Booth and Reinelt 1993, Hollis and Thompson 1998).

Much of the scientific research on urbanization in the Pacific Northwest comes from the Puget Sound Wetlands and Stormwater Management Research Program initiated in 1986 in King County. Published results include theses by Azous (1991), Chin (1996), Ludwa (1994), and Taylor (1993). The book *Wetlands and Urbanization: Implications for the Future*, edited by Azous and Horner (2001), is a summary of the significant findings of the research. More information about the research done is available on the web site for the Center for Water and Watershed Studies at the University of Washington <http://depts.washington.edu/cuwrp/>.

3.4.1 Loss of Wetlands Resulting from Urbanization

Approximately 13% of the wetland losses in the United States can be attributed to urbanization, road building, and other types of conversion (Tiner 1984). Kusler and Niering (1998) estimate that 85% of the wetlands in urban areas of the nation have been destroyed, and most of the remaining 15% are moderately to severely impaired in function. Data specific to Washington are very limited. One study (Bell 2002) found urban and residential development in King County accounted for 28% of the peat wetlands lost between 1958 and 2000.

The information available suggests that this trend will likely continue. It is estimated that more than 80% of the U.S. population will be living in urban areas by 2025, up from 74% in 1989 (Gerguson and Robinette 2001). Increases in urban population are generally accompanied by increased development density and sprawl. Wetlands in these areas are either converted to urban land uses or, if they are not directly disturbed, are degraded through a variety of causes as described in the following sections.

3.4.2 Increased Amount of Water in Wetlands Resulting from Urbanization

Urbanization is recognized as both increasing and decreasing the flows that reach downgradient aquatic systems such as wetlands. Greater volumes of water are generated more quickly while smaller, long-duration flows that would occur under less developed conditions are reduced or perhaps eliminated. Research has shown that collecting stormwater through modern storm drains, culverts, and catchments results in the rapid transport of large volumes of stormwater runoff into rivers, lakes, and wetlands at much faster rates and higher volumes than under predevelopment conditions (Dunne and Leopold 1978, Booth 1991, May 1996). Although some of the research has focused on the effects of urbanization on streams, the findings on changes in flow volumes, rates, and frequency apply equally to wetlands that receive storm drainage. Streams and wetlands are “intimately interconnected in the watersheds of western Washington” (Booth 1991).

Research conducted in the Puget Sound lowlands has shown statistically significant correlations between the effects of urbanization in a watershed and the hydrologic regime in that watershed (Konrad and Booth 2002). The amount of impervious surface within a contributing basin is a key influence on hydrologic patterns, and even small changes in watershed conditions have measurable influences on the flows and volumes of water in the system (Azous and Horner 2001).

3.4.2.1 Increased Frequency of Erosive Flows

One consequence of urbanization is an increase in the frequency of erosive flows within a watershed. As reported by Booth (1991), several studies concluded the most common effect of urbanization was an up to five-fold increase in peak flow rates from a given storm event. The largest relative increases in erosive flows were found for the smallest storm events. This is very significant because small storm events are the most frequently occurring storms. A small storm event is the *two-year-event*, a storm with a given volume of rain falling within a 24-hour period that has the statistical likelihood of occurring every two years (the statistics are based on over 40 years of measured rainfall). That means that small storm events have the greatest percent increase in flows over natural conditions, and frequent small storms have the greatest relative increase in erosive flows. Contrary to what might be expected, it is these recurring small storms that have the greatest cumulative effect on erosion and sedimentation, not the large, less frequent storm events (Booth 1991).

Thus, larger volumes of water enter channels and wetlands more rapidly after a given storm event in a basin where the removal of forests and the increase in impervious surfaces have altered hydrologic processes (Booth 1991). After an area has been developed and the forest canopy removed, high rates of flow continue for a longer duration. These flows may carry sediment and other pollutants into downgradient wetlands.

3.4.2.2 Increased Volume of Runoff and Longer Duration of Flows

Booth and Reinelt (1993) notes that a basin with increased imperviousness will experience an increase in the magnitude of runoff volume from a given storm event. The “typical” event occurs far more frequently. For example, the peak flows created from a two-year storm event, after urbanization, will occur far more frequently than every two years. Small storm events that did not create measurable peak discharges in forested conditions create measurable peak runoff flows in urbanized conditions, because the removal of the forest canopy makes the same size storm event result in far greater volumes of water reaching aquatic resources such as wetlands and streams. Modeling based on detailed data from basin monitoring identified that larger flows with more erosive force may occur in urbanized basins with much greater frequency, for example increasing from once or twice per decade to several times per year.

In urbanizing watersheds, stormwater ponds are designed to hold the excess volume of stormwater generated from the impervious surfaces. The ponds are designed to release stormwater at the same rate as that modeled for the natural vegetated basin for a given storm in pre-existing conditions (Booth 1991). However, in order for the ponds to discharge the increased volume of water at the same low rates, they must take more time, or cause an increased duration of flows.

3.4.2.3 Consequences of Changes in Water Regime

The consequences of the interplay between rates, volumes, and durations are complex. Research on the impacts of urbanization on stormwater and watershed processes indicates that urbanization results in several disturbances that can impact wetlands (Booth 1991, Azous and Horner 2001, Reinelt and Taylor 2001, Thom et al. 2001):

- Increased erosion
- Sediment movement and deposition
- Burying of vegetation
- Increased depths of inundation
- Water level fluctuations
- Downcutting of natural channels (which can remove riparian vegetation from the floodplain)
- Changes in the seasonal extent and duration of saturation and inundation
- Unstable substrates

Urbanization can also cause a decrease in interflow (shallow, subsurface flow) and base flow from the urbanized watershed (U.S. Environmental Protection Agency 1993). Changes in the volume of interflow may influence the hydroperiod of downgradient wetlands if they are fed by that shallow subsurface flow.

Roads and parking lots are an important component of the impervious surface area in a watershed. The City of Olympia in 1994 determined that transportation features (roads and parking lots) typically composed between 63% and 70% of total impervious area within suburban areas (Schueler and Holland 2000).

3.4.3 Increased Fluctuations of Water Levels Resulting from Urbanization

Reinelt and Taylor (2001) used water level fluctuation as the primary measure of wetland hydroperiod, stating: “Water level fluctuation is perhaps the best single indicator of wetland hydrology, because it integrates nearly all hydrologic factors.” They documented four factors in a depressional wetland and its watershed that have the strongest influence on water level fluctuations:

- Forest cover in the watershed
- Impervious cover in the watershed
- Constriction of the wetland outlet
- Ratio of wetland to watershed area

Wetlands in basins with the highest degree of impervious area had the highest water level fluctuations. Wetlands in basins with 90% or more forested land cover and less than 3% impervious area generally exhibited smaller ranges in water level fluctuations (Reinelt and Taylor 2001). Further information on thresholds at which impervious surface influences aquatic resources is provided in Section 3.2.3.3.

Wetland size is also important in determining the effects of urbanization on water level fluctuations. Reinelt and Taylor (2001) observed that wetlands that were small in relation to their contributing watersheds had greater water level fluctuations and were dominated by surface inflow. Wetlands that were larger in comparison to their contributing watersheds had smaller water level fluctuations and more groundwater influence. Wetlands with a constricted outlet (undersized culvert, beaver dam, or embankment) had a greater water level fluctuation than wetlands with less constricted outlets.

Stormwater runoff from urbanization, as well as other land-use alterations, frequently causes several changes in how water levels fluctuate in wetlands. All aspects of fluctuations in water levels are changed by urbanization:

- The **magnitude** of the effect of storms is changed by causing a two-year event to act like a larger storm. A larger volume of water reaches the wetland more often. Urbanization can also prevent infiltration through native soils into the shallow groundwater zone (Booth 1991, Azous and Horner 2001).

- The **timing** of water's presence and duration is changed by the use of engineered stormwater systems. Water is collected from impervious surfaces into stormwater ponds. Infiltration into shallow groundwater is prevented. The stormwater is discharged at given rates for longer durations into downstream receiving waters (Booth 1991, Azous and Horner 2001).
- The **frequency** of runoff volumes from storm events increases. The volume of runoff normally generated from small storm events is generated by smaller volumes of precipitation (Booth 1991, Azous and Horner 2001, Reinelt and Taylor 2001, Thom et al. 2001).
- The **duration** of particular flows becomes extended as large volumes of stormwater are discharged at metered rates over longer periods of time (Booth 1991, Thom et al. 2001).
- The **rate of change** is increased through increasing the frequency and magnitude of water level fluctuations in urbanizing watersheds (Azous and Horner 2001, Reinelt and Taylor 2001, Thom et al. 2001).

3.4.4 Increased Input of Sediment Resulting from Urbanization

Researchers in the Puget Sound area have documented that urbanization increases erosion and this, in turn, increases the movement and deposition of sediment in depressional and riverine wetlands (Booth 1991, Azous and Horner 2001, Reinelt and Taylor 2001, Thom et al. 2001).

Studies at the national level undertaken by the U.S. Environmental Protection Agency confirm that sediment in urban runoff is a problem nationwide (Tasker and Driver 1988). Sediments and solids constitute the largest volume of pollutant loads to receiving waters in urban areas (U.S. Environmental Protection Agency 2003).

A major source of sediment in urban areas comes from construction when the surface of the soils is disturbed and exposed to erosive forces. Runoff from construction sites is by far the largest source of sediment in urban areas under development (U.S. Environmental Protection Agency 1993).

3.4.5 Increased Input of Nutrients Resulting from Urbanization

Research on the impacts of urbanization in the Puget Sound area (Booth 1991, Azous and Horner 2001, Reinelt and Taylor 2001, Thom et al. 2001) has also documented that urbanization increases the amount of nitrogen entering aquatic systems including wetlands. Studies at the national level undertaken by the U.S. Environmental Protection

Agency confirm that nitrogen in urban runoff is also a problem nationwide (Tasker and Driver 1988).

Nutrients are introduced into runoff from a number of different sources that include nutrients bound to sediment from construction sites, fertilizers applied to lawns, and decomposing grass clippings and leaves left on impervious surfaces (Johnson and Juengst 1997). Nutrients are also increased in groundwater in areas where wastewater is treated by septic systems (Valiela et al. 1993). More specifically, nutrients from septic systems have been correlated with an increase in nutrients in the groundwater that flows into lakes and their associated wetlands in urbanizing areas (Moore et al. 2003).

In addition to the application of fertilizers in residential areas, nitrogen is introduced into aquatic systems and wetlands from the release of nitrogen compounds in car and truck engines and through the burning of wood and coal (Paerl and Whittall 1999). The amount of nitrogen coming from the deposition of these air pollutants in the United States is about 20% of the total excess nitrogen derived from human activities (Prospero et al. 1996). In heavily urbanized areas such as the Eastern Seaboard, the total amount of nitrogen coming from combustion can be as high as 40% or more of the total input by all human activities (Valigura et al. 1996).

3.4.6 Increased Input of Toxic Contaminants Resulting from Urbanization

In addition to sediment and nutrients, urban land uses generate a wide range of pollutants that include the following (U.S. Environmental Protection Agency 1993):

- Heavy metals (copper, lead, zinc)
- Hydrocarbons
- Organic matter that reduces oxygen
- Pesticides

Schueller and Holland (2000) cite a number of studies indicating that urban pollutant loads are directly related to the amount of impervious surface in the watershed. Impervious surfaces such as roads, parking lots, and storage yards are places where toxics from numerous sources collect. Precipitation falling on the impervious surfaces washes the collected chemicals and particles into the storm drain system (Schueller and Holland 2000).

The runoff from many different types of land use in urban areas can be toxic to aquatic life. Pitt et al. (1995) studied the relative toxicity of the runoff from different types of land uses in urban and suburban areas. Parking areas, storage areas, and landscaped areas (lawns, gardens) had the highest toxicity with approximately 20% of the samples being highly toxic. Over half of the samples of runoff from these urban land uses were moderately toxic.

Sriyaraj and Shutes (2001), working in London, documented that hard rains after extended dry periods result in the greatest concentrations of pollutants. This is also known to occur in Washington, where the greatest concentration of pollutants in surface runoff is typically observed in the fall with the first rains following summer drought (Booth 1991).

3.4.6.1 Heavy Metals and Hydrocarbons

Most heavy metals in urban runoff are adsorbed to sediment particles, although copper and zinc can occur in dissolved forms (Canning as referenced in Newton 1989). The sources of heavy metals are various including motor vehicle brake linings, tire particles on roadways, emissions from vehicles, and industrial sources.

Sriyaraj and Shutes (2001) found that sediment from road runoff had high to moderate levels of heavy metals associated with it, and the metals were deposited within the sediments of the receiving wetland. Heavy metals, such as lead, zinc, copper, and cadmium, are some of the pollutants that accumulate on roads during dry summers. These pollutants are particularly concentrated when they are washed off during intense storms following long dry periods (Sriyaraj and Shutes 2001). Thurston (1999) found that lead and petroleum hydrocarbons were the most common pollutants attached to particles in an urban wetland receiving direct runoff from a municipal garage parking lot.

Most of the adsorbed metals are buried in sediment deposits within wetland substrates, thereby becoming substantially “locked up” from further biological activity (Canning as referenced in Newton 1989) when covered by un-contaminated sediment. Where contaminated sediments are constantly being discharged to wetlands (e.g., urban stormwater discharges), however, new contaminated sediments are constantly coming in. Thus, there is always contamination in the biologically active zone. Also, if the pH of the incoming water changes some toxic metals may be released (see Section 2.6.1.4).

3.4.6.2 Organic Matter

Another contaminant present in runoff from urban areas is organic matter (examples listed below). As this organic matter decomposes in the water, it uses up oxygen that is dissolved in the water (called dissolved oxygen or DO). DO plays the same role as atmospheric oxygen in that it is critical for biological activity in aquatic communities. Oxygen is used by aquatic organisms. It is also used by bacteria for the decay of organic matter. This is called the biological oxygen demand (BOD) of the system. In natural systems, BOD fluctuates as oxygen use and organic inputs vary both daily and seasonally. The natural BOD of a system is thrown out of balance when there is excessive organic matter in the system. An increased BOD results in a decreased availability of dissolved oxygen.

Contaminants in urban runoff that cause increases in BOD include:

- Septic system effluent
- Oil and grease
- Organic matter such as dog and cat feces
- Incidental sources from atmospheric fallout

Direct urban runoff can create a demand for oxygen that is equal to or greater than that from sewage effluent. BOD from urban runoff can have substantial cumulative effects (Canning as referenced in Newton 1989).

3.4.6.3 Pesticides

Pesticides in urban areas are used for residential and commercial landscaping. According to studies conducted in the Puget Sound Basin, more types of pesticides were detected in urban streams than in agricultural streams (Bortleson and Davis 1997). Furthermore, more pounds of pesticides were applied in urban areas than in agricultural areas (Tetra Tech 1988 as reported in Voss et al. 1999). Voss et al. (1999) found 23 pesticides in urban streams in King County of which five exceeded the recommended maximum concentrations set by the National Academy of Science. Although all these data were collected from streams it can be assumed that riverine wetlands that intersect these urban streams can be subject to these pesticides as well.

3.4.7 Fragmentation of Habitat Resulting from Urbanization

Urbanization causes fragmentation of habitat as new developments divide undisturbed areas (COST-Transport 2003). Conversion of the land for urbanization has turned large, continuous patches of habitat into numerous small patches, which are isolated from each other and surrounded by land uses that are not hospitable to many native wildlife species (Aurambout 2003). The fragmentation of habitat continues to increase as the human population grows (Dale et al. 2000). Developed lands in the U.S. increased by 18% between 1990 and 2000 to total 4.4% of the area of the country (Dale et al. 2000).

Wetlands, as part of an undisturbed landscape, are also subject to the fragmentation that results from urbanization. Gibbs (2000) analyzed the distribution of wetlands along urban to rural gradients in New York State and in Maine and found statistically significant correlations between the density of human population and two measures of fragmentation – the average distance between wetlands and the percent of the landscape that was in wetlands.

3.4.8 Other Disturbances Resulting from Urbanization

Several other types of disturbances have been attributed to human activities in urbanizing areas:

- Alteration of soils
- Construction of roads
- Noise
- Recreational access
- Invasion by exotic plant and animal species, including household pets

These disturbances are not discussed in detail in this chapter because little information in the literature was found quantifying how urbanization creates these disturbances. The impacts of these disturbances on wetlands have been documented and are summarized in Chapter 4.

3.4.9 Summary of Key Points

- Increases in urban population are generally accompanied by increased development density and sprawl. Wetlands in these areas may be converted to urban land uses or may be degraded through a variety of causes.
- Urbanization results in modifications to water movement, alterations to riparian corridors, human intrusions, introduction of chemical contaminants, and increased areas of impervious surface. These changes profoundly affect environmental processes in contributing basins and, therefore, the downgradient drainage systems.
- Urbanization alters the movement of water into aquatic systems. Consequences of increased amounts of water include an increased frequency of erosive flows, greater volume of runoff, and longer duration of high flows.
- With urbanization comes increased transport of sediment, nutrients, metals, oil, pesticides, and other contaminants in surface runoff.
- Fragmentation of habitat results as the total area of wetlands is reduced and the connections between wetlands and other habitats are eliminated.

3.5 Disturbances Caused by Forest Practices

In general, forest practices cause several types of disturbance that can impact the factors that control wetland functions and therefore affect the performance of those functions. These disturbances include (as reviewed in Cooke in press):

- Increased peak flows
- Increased water level fluctuations
- Increased nutrients
- Increased sedimentation
- Changes in soils
- Invasion by exotic species

The effects of forest practices have recently received much attention. As a result, the scientific literature is being reviewed and synthesized by the Washington State Department of Natural Resources and is now in a draft form (Cooke in press). Therefore, this review of the literature does not cover the disturbances that result from forest practices and their impact on wetland functions.

3.6 Disturbances Caused by Mining

Surface mining generates large quantities of unusable rock that is often left on the surface after it is extracted. This exposes the rock (called spoils) to an oxidizing environment, resulting in a complex series of chemical reactions. The minerals contained in the spoils are not in equilibrium with the oxidizing environment and almost immediately begin weathering and mineral transformations.

The reactions are analogous to “geologic weathering” which takes place over extended periods of time (hundreds to thousands of years) but the rates of reaction are orders of magnitude greater than in “natural” weathering systems. The accelerated reaction rates can release damaging quantities of acidity, metals, and other soluble components into the environment (U.S. Department of the Interior, Office of Surface Mining 2003).

Thus, the two major disturbances created by surface mining are (Adamus et al. 2001):

- An increase in the levels of heavy metals that are toxic to many organisms
- An increase in the acidity of surface waters

Another type of mining activity that occurs in the state is gravel mining in streams and floodplains. We were unable to find any published information on the impacts of gravel mining on wetlands, and research into this question is only beginning at the national level by the U.S. Geological Survey (Spooner 2004). As a result, we were unable to synthesize the information on the impacts of this activity.

3.7 Chapter Summary and Conclusions

The focus of Chapter 3 has been to describe how different land uses may change the environmental factors that control wetland functions. A general conclusion that can be

made from the scientific literature is that disturbances of environmental factors can occur at several geographic scales. Much of the early research focused on disturbances that occur at a single site or wetland. More recent research has documented the significance of disturbances that occur at the much larger scale of a watershed (called the landscape scale). The disturbances created by different land uses are summarized in Table 3-3 (at the end of this section) by the type of land use, the severity of the disturbance, and the scale at which the disturbance occurs. This table represents a synthesis of the severity of impacts by the authors of this document based on the information in the literature.

The effects of different land uses on the flow and fluctuations of water are well documented. Changes in land uses and vegetation communities on the land, whether for agriculture or as a result of urbanization, alter the patterns of surface and shallow groundwater movement across a landscape. Flows of water can be reduced or increased by different land uses as can the frequency and amplitude of water levels.

Removal of vegetation and/or compaction of native soils through agricultural practices, creation of lawns or grazed pastures, or creation of impervious surfaces all have the same relative consequence: increased volumes of water and rates of flows after a given storm event. The threshold of roughly 10% imperviousness within a basin appears to be the point above which significant impacts begin to occur to aquatic resources based on research in the Puget Sound Basin.

While the effects of urbanization on water movement have been extensively studied, agriculture can also influence the water regime of wetlands, leading to loss of wetlands in some areas and creation or maintenance of wetlands in other areas where wetlands did not originally exist, such as areas influenced by irrigation.

Human activities also increase sediment and other pollutants in runoff. In agricultural areas, pesticides and fertilizers can contribute to contamination of surface waters. In urban areas, stormwater runoff frequently contains sediment, organic matter, phosphorus, metals, and other pollutants. Pollutants often adhere to sediment particles that enter wetlands. Mining increases the acidity of surface waters as well as adding toxic heavy metals. Logging increases sediments in a watershed and can also change the amount of water and its fluctuations.

Fragmentation of habitats is of increasing concern. As connections between wetlands and other habitats are broken and more wetlands across the landscape are converted to other uses, the remaining habitat becomes more isolated.

A key finding of this chapter is that different land uses may cause the same change in the controls of wetland functions. For example, urban land uses, agricultural practices, and logging have all been shown to increase sediments in a watershed. From the wetland's "point of view," the source of the sediment is irrelevant—the impact of excess sediments on wetland functions is similar, regardless of the source of sediments.

Chapter 4 shifts from a focus on the disturbances caused by human land uses (agriculture, urbanization, logging, and mining) to describe how these disturbances impact wetlands and their functions.

Table 3-3. Disturbances resulting from different land-use practices that can change the factors that control wetland functions.

Disturbance	Scale of Disturbance	Agriculture	Urbanization	Mining
Changing the physical structure within wetlands (filling, vegetation removal, tilling of soils, compaction of soils)	Site scale	xx	xx	h
Changing the amounts of water	Landscape scale	xx	xx	?
	Site scale	xx	xx	h
Changing fluctuations of water levels (frequency, amplitude, direction of flows)	Landscape scale	xx	xx	?
	Site scale	xx	xx	h
Changing the amounts of sediment	Landscape scale	xx	xx	h
	Site scale	xx	xx	h
Increasing the amount of nutrients	Landscape scale	xx	xx	nm
	Site scale	xx	xx	nm
Increasing the amount of toxic contaminants	Landscape scale	xx	xx	x
	Site scale	xx	xx	xx
Changing the acidity	Landscape scale	nm	nm	x
	Site scale	nm	nm	xx
Increasing the concentrations of salt	Landscape scale	x	nm	nm
	Site scale	x	nm	nm
Fragmentation	Landscape scale	xx	xx	h
Other disturbances	Site scale	xx	xx	h
Key to symbols used in table: (xx) land use creates a major disturbance of environmental factors that affects large areas in the state (x) land use creates a disturbance (nm) studies on impacts of this land use do not mention this disturbance (h) literature is lacking but disturbances can be hypothesized based on authors' experience (?) information lacking				

Chapter 4

Negative Impacts of Human Disturbances on the Functions of Wetlands

4.1 Reader's Guide to This Chapter

Chapter 4 integrates the concepts discussed in Chapter 2 and Chapter 3. Chapter 2 described the functions performed by wetlands and the environmental factors that control functions of wetlands. Chapter 3 discussed the major disturbances to the environment caused by different human activities and uses of the land. This chapter continues by summarizing how each of the disturbances ultimately leads to impacts to wetland functions.

As mentioned in Chapter 3, disturbances to wetlands can alter how they function. Changes that are caused by human disturbances are often called *impacts* to separate them from changes that are caused by “natural” or non-human disturbances. From a legal perspective (National Environmental Protection Act), human impacts are divided into *direct impacts*, those which are caused by the action and occur at the same time and place, and *indirect impacts*. Indirect impacts are caused by an action but occur later in time or are farther removed in distance, but are still reasonably foreseeable.

(<http://ceq.eh.doe.gov/nepa/regs/ceq/1508.htm#1508.1>)

Impacts can be either beneficial or detrimental to the ecosystem, environmental process, or species. Defining an impact as either beneficial or detrimental depends on the values of the society or group making the decision (Beanlands and Duinker 1983). The natural system does not judge a change as either good or bad; it is we, as a society, that make that judgment. Social values, as represented by its laws, provide the means of determining the importance of human impacts (Beanlands and Duinker 1983).

The Growth Management Act and the state and federal clean water acts all have the protection of wetland functions and values as a goal. Thus, human impacts to wetlands, from this perspective, need to be considered in terms of those that reduce the level of functions they perform or the values they represent.

Therefore, the objective of the synthesis in this chapter is to summarize the information on the changes caused by human disturbances that reduce the level of different functions performed by wetlands. For this reason the chapter is titled *negative impacts*. When the word *impact* is used it assumes there is a reduction in the levels of functions and the societal values they represent.

4.1.1 Chapter Contents

Major sections of this chapter and the topics they cover include:

Section 4.2, The Geographic Scale of Impacts to Wetland Functions describes how disturbances that impact functions of wetlands can occur either within the wetland itself or in the surrounding landscape. While the literature generally does not distinguish the scale of the disturbance when assessing impacts on wetland functions, there are some disturbances at the site scale that can remove all or most functions of the wetland (such as changing the physical structure of the wetland through filling).

Following this introduction, the chapter continues by describing how the major types of disturbances resulting from human activities affect wetland functions. As discussed in Chapter 3, different land uses may create the same type of disturbance (for example, both agriculture and urbanization may cause sedimentation). Therefore, each of the remaining sections of this chapter focuses on the different types of disturbances, without division by land-use type, and their impact on each wetland function. The following is a list of the disturbances discussed in this chapter:

Section 4.3, Impacts from Changing the Physical Structure within a Wetland

Section 4.4, Impacts from Changing the Amount of Water in a Wetland

Section 4.5, Impacts from Changing the Fluctuation of Water Levels within a Wetland

Section 4.6, Impacts from Changing the Amounts of Sediment Coming into a Wetland

Section 4.7, Impacts from Increasing the Amounts of Nutrients Coming into a Wetland

Section 4.8, Impacts from Introducing Toxic Contaminants to a Wetland

Section 4.9, Impacts from Changing the Acidity (pH) of Soils or Water in a Wetland

Section 4.10, Impacts from Increasing the Concentrations of Salt in a Wetland

Section 4.11, Impacts from Fragmenting Wetland Habitats

Section 4.12, Impacts from Other Human Disturbances on Wetlands

Within each section, the impact of each disturbance is summarized in terms of the following wetland functions:

- Impacts on hydrologic functions
- Impacts on functions that improve water quality
- Impacts on plants
- Impacts on invertebrates
- Impacts on amphibians and reptiles

- Impacts on fish
- Impacts on birds (species closely associated with wetlands)
- Impacts on mammals (species closely associated with wetlands)

Section 4.13, Chapter Summary and Conclusions ties together the major concepts presented in the chapter.

4.1.2 Where to Find Summary Information and Conclusions

Each major section of this chapter concludes with a brief summary of the key points resulting from the literature on that topic in a bullet list format. The reader is encouraged to remember that a review of the entire section preceding the summary is necessary for an in-depth understanding of the topic.

For summaries of the information presented in this chapter, see the following sections:

- Section 4.3.9
- Section 4.4.9
- Section 4.5.9
- Section 4.6.9
- Section 4.7.9
- Section 4.8.9
- Section 4.9.9
- Section 4.10.9
- Section 4.11.9
- Section 4.12.6

In addition, Section 4.13 provides a summary and conclusions about the overarching themes gleaned from the literature and presented in this chapter.

4.1.3 Sources and Gaps in Information

Data on some of the subjects related to the negative impacts of human disturbances on wetland functions are abundant for select areas in the state. For example, the Puget Sound Wetlands and Stormwater Management Research Program (summarized in Azous and Horner 2001) has provided several studies on how changes in land uses in a watershed affect the physical, chemical, and biological processes in wetlands of the Puget Sound lowlands. The impacts on wetlands in other areas of the state are less well studied.

Similarly, studies on the effects of changes in wildlife habitat resulting from physical changes within wetlands and fragmentation between habitats have been performed in Washington for some species and some types of habitat changes. The impacts to other species are less well studied or have only been examined in other states or other countries. Information from other locales is included for these topics when relevant.

This chapter contains text that was adapted (re-organized and paraphrased) from a review of current scientific literature on the impacts of human activities on wetlands and their functions undertaken by the U.S. Environmental Protection Agency (Adamus et al. 2001). This review represents a very detailed summary of the literature published between 1990 and 2000 regarding wetlands across the United States. Portions of the review that were considered relevant to wetlands in Washington State were adapted for inclusion in this chapter, with permission from Dr. Adamus. The sections of this chapter that incorporate text adapted from the Adamus et al. (2001) review include:

- **Sections 4.3.3 – 4.3.8**, the impacts on plants, and habitat for invertebrates, reptiles and amphibians, fish, and mammals from changing the physical structure in the wetland
- **Sections 4.4.3 – 4.4.7**, the impacts on plants, invertebrates, amphibians and reptiles, fish, and birds from changing the amount of water in the wetland habitat
- **Section 4.5.4**, the impacts on invertebrates from changing the fluctuations of water levels in the wetland habitat
- **Sections 4.6.3 – 4.6.4**, the impacts on plants and invertebrates from changing the amounts of sediment in the wetland habitat
- **Sections 4.7.3, 4.7.4, 4.7.7**, the impacts on plants, invertebrates, and birds from increasing the amount of nutrients in the wetland habitat;
- **Sections 4.8.3 – 4.8.7**, the impacts on plants, invertebrates, amphibians and reptiles, fish, and birds from increasing the amount of toxic contaminants in the wetland habitat;
- **Section 4.9.3 – 4.9.7**, the impacts on plants, invertebrates, amphibians and reptiles, and birds from changing the acidity in the wetland habitat;
- **Sections 4.10.4, 4.10.7**, the impacts on invertebrates and birds from increasing the concentration of salts in the wetland habitat;
- **Section 4.12.1, 4.12.5.4**, the impacts on plant communities from altering soils and the impacts of exotic invertebrates on native invertebrates in wetlands.

The literature sources cited in the portions of the text that were adapted from the report by Adamus et al. (2001) are included in the list of references at the end of Volume 1. These sources, however, were not obtained and reviewed independently.

4.2 The Geographic Scale of Impacts to Wetland Functions

The disturbances that impact functions in wetlands can occur either within the wetland itself or in the surrounding landscape. Chapter 2 introduced the idea that the controls of wetland functions occur at both the “site scale” and the broader “landscape scale.” As with the controls of wetland functions, disturbances caused by human activities can also occur at the same two scales (site and landscape).

For example, increased nutrients can flow into a wetland directly from an adjacent lawn or from animals grazing within the wetland (disturbance at the site scale). The nutrients could also originate from development or fertilized fields somewhere higher in the contributing basin (disturbance at the landscape scale). As another example, the water levels in a wetland can be increased through the direct discharge of stormwater into a wetland (the site scale) or by adding impervious surface higher in the contributing basin (the landscape scale).

Much of the discussion in this chapter does not differentiate the scales at which the disturbance occurs. For example, the impacts on wetland functions resulting from excess nutrients or higher water levels can be expected to be the same whether they are delivered directly to the wetland or come from a distant source in the contributing basin. The literature does not usually differentiate between scales when discussing the impacts on wetland functions.

However, an alteration to the physical structure of the wetland itself is a type of disturbance that occurs only at the site scale. Filling, removing vegetation, tilling, or grazing within a wetland has a direct impact on the functions at that site. The most extreme impact to a wetland is the complete removal of all the factors that contribute to the existence of the wetland. Thus, filling a wetland or draining all the water eliminates all of the wetland functions because the wetland no longer exists.

4.3 Impacts from Changing the Physical Structure within a Wetland

Disturbances that directly change the structure of wetlands can be so severe that the wetland is destroyed. Filling or draining a wetland can so alter the water regime that the land can no longer support the wetland vegetation and maintain hydric soils. If a wetland is lost, most if not all of its wetland functions are also lost. Dahl (1990) estimated that 31% of the wetlands in Washington State had been lost prior to the 1980s as a result of filling or draining to the extent there is no longer enough water to maintain areas as wetland.

There are, however, some human alterations of the structure in wetlands that do not result in the complete loss of functions, including:

- Human removal of vegetation (e.g., logging, mowing, or application of herbicides)
- Animal grazing
- Alteration of the soil through tilling or compaction
- Partial draining

This section describes what the literature reports about how these alterations impact wetland functions. The impacts of grazing and removal of vegetation are better understood than those of alterations to the soils. Information was not available on how some of these alterations affect wetland functions described in the following sections, and some impacts are hypothesized based on synthesizing other information.

4.3.1 Impacts on Hydrologic Functions from Changing the Physical Structure

No information was found on how changing the physical structure of wetlands impacts their hydrologic functions (reducing peak flows, reducing erosion, and recharging groundwater). One could hypothesize that removing erect and persistent vegetation (emergent, shrub, or forest species) may impact the reductions in water velocity that occur in wetlands. The density of vegetation is a factor in reducing water velocity during flooding or storm flows (Adamus et al. 2001). If this vegetation is removed, the wetland will probably not be as effective at slowing these flows (in other words, there will be a change in how this wetland function is performed). As a result, downstream erosion and flooding may increase.

4.3.2 Impacts on Functions that Improve Water Quality from Changing the Physical Structure

No information was found on how changing the physical structure of wetlands affects how well wetlands remove pollutants. Removal of vegetation has impacts on both bacteria and plants, and this may affect the uptake and transformation of nutrients and toxic compounds in a wetland. The same can be hypothesized for direct alteration of soils, which may affect the chemical properties in a wetland. It is not possible, however, to predict or hypothesize how such changes might alter the wetland functions (that is, whether functions to improve water quality will increase or decrease).

4.3.3 Impacts on Plants from Changing the Physical Structure in a Wetland

Plants are one of the major factors that determine the physical structure within a wetland. Thus, changing the physical structure in a wetland means that the plants, and the structure they provide, have been removed or modified. Examples of structure that is based on plants include different layers within a forest (e.g., canopy, sub-canopy, ground cover) or the sub-surface root mass of perennial plants. In addition, removal of any vegetation causes at least a short-term change in plant biomass and possibly a change in the composition of plant species.

Vegetation can be removed by fire, tilling, mowing, or grazing (Newman 1991, Naiman and Rodgers 1997). Mortality from logging, dredging or construction activities, flooding, as well as contaminants such as herbicides can also cause loss of plants (Adamus et al. 2001). The process by which vegetation is removed or damaged appears to influence the type, duration, and magnitude of the impact on plants. Vegetation patterns in some wetlands result in part from the differing causes of plant removal and whether those causes are lethal or not (Heitschmidt and Stuth 1991, Baldwin and Mendelssohn 1998).

Impacts to the population of plants in a wetland also depend partly on the process through which the plants re-establish. When all or nearly all of the plants are removed through methods lethal to vegetation (such as with herbicides), recovery occurs mainly via recruitment of seeds. When removal is by non-lethal methods (such as grazing), recovery often is by re-growth of the plants.

The effects of grazing on plants and other aspects of ecosystems has received much attention in the last three decades because of the potential impacts in semi-arid areas (see review in National Research Council 1984). Impacts on wetlands have been studied less intensively, but some information is available. The impacts of grazing on wetland plants depend partly on the density of grazers, how long, and when they are present in the grazed area, the availability of food and water in nearby alternative habitats, and the season (Clary 1995, Fitch and Adams 1998). Specifically:

- In a laboratory experiment Crossle and Brock (2002) found that simulations of grazing changes the reproductive output of plants in wetlands in different ways and that this can change the populations by changing the proportions of seed produced.
- A study of riparian vegetation in eastern Oregon used different simulated grazing treatments to determine the effects of light and heavy grazing (Clary et al. 1996). While not clearly identified, it is evident that some of the plots were in riparian wetlands and others in non-wetland riparian habitats. The authors observed that herbaceous plants increased in growth and vigor in the ungrazed and moderately grazed plots, particularly if the grazing occurred only in the spring. Heavier grazing that lasted all season had detrimental effects on the vegetation.
- In another study in Oregon of riparian meadows, Clary (1995) found that the biomass of the grass redtop (*Agrostis* sp.) remained stable or increased at a low-elevation site

the year following simulated grazing treatments. At higher elevations, sedge species (almost all of which are found mostly in wetlands) either maintained or declined in biomass production the following year. The author concludes that grazing only annually (for several months once a year as opposed to year-round) would significantly reduce sedge production, while not decreasing redtop production.

4.3.4 Impacts on Invertebrates from Changing the Physical Structure of the Habitat

The presence of invertebrate species in a wetland is influenced by the type of plants that grow there. For example, in a Washington pond, some leeches (*Helobdella*), aquatic sowbugs (*Asellus*), mayflies, and some dragonflies (especially the large-bodied *Anax*) were more commonly associated with emergent vegetation than with submerged vegetation or open water areas. Midges, freshwater shrimp (*Hyaella azteca*), and mollusks (especially *Lymnaea* sp., *Gyraulus* sp., and *Anodonta* sp.) were more common on the submerged plants (Parsons and Matthews 1995).

The removal of vegetation either mechanically or through grazing, therefore, has a significant impact on the presence and abundance of invertebrate species in a wetland. Wetland managers often manipulate the structure of vegetation by mowing, burning, plowing, or planting to encourage or discourage populations of desirable or undesirable invertebrates (Batzner and Resh 1992, Kirkman and Sharitz 1994, de Szalay et al. 1996, de Szalay and Resh 1997).

Adamus et al. (2001) conclude from their literature review that the removal of vegetation:

- Removes substrates that would otherwise provide additional vertical space in the water column for invertebrates to colonize
- Removes shade, thus increasing water temperature and causing stress for invertebrates
- Increases the circulation and perhaps the velocity of water, with accompanying increases in dissolved oxygen and possible resuspension of sediments; this may result in changes to the habitats that favor different species of invertebrates
- Reduces inputs of leaf litter that provide food to some invertebrate taxa
- Reduces structures that otherwise shelter invertebrates from predators (Jordan et al. 1994)

Complete removal of vegetation generally reduces the richness of the wetland invertebrate community, but patchy removal or moderate grazing sometimes increases richness (McLaughlin and Harris 1990, Gray et al. 1999).

4.3.5 Impacts on Amphibians and Reptiles of Changing the Physical Structure of the Habitat

The information on the impacts of direct disturbances to the physical structure of a wetland on amphibians is ambiguous for Washington and the impacts cannot be predicted. In the Puget Sound Basin of Washington, surveys of 19 wetlands found no correlations that were statistically significant between amphibian richness and vegetation form (i.e., structure of plants) (Richter and Azous 1995). Plant stem diameter is apparently more important than plant species (Richter 1997).

Removing dense emergent vegetation, however, may impact populations of amphibians. A survey of 40 wetlands in the Puget Sound area found more native species of amphibians among wetlands containing dense emergent vegetation (Adams et al. 1998). Dense vegetation may help protect the larvae of native aquatic amphibians from larger predators. It can be hypothesized, therefore, that removing dense emergent vegetation would probably impact the populations of amphibians.

Other studies have focused on the impacts of grazing. Based on personal observations, Maxell (2000) asserts that livestock grazing can impact amphibians through:

- Trampling of vegetation that results in loss of habitat and reduces insect populations that are food sources for amphibians
- Changes in substrate composition and bank structure
- Increased sedimentation

These observations have been confirmed by Knutson et al. (2004) who reported a statistically significant negative effect of grazing and direct access of livestock to ponds on the reproduction of amphibians.

However, a study of the Columbia spotted frog in 127 ponds in northeastern Oregon does not support these findings. Bull and Hayes (2000) found no significant differences between grazed and ungrazed ponds in terms of the numbers of frog egg masses and the abundance of recently metamorphosed frogs. The volume of egg masses was larger at grazed sites, possibly due to a greater presence of adults or an older population (older, larger females lay bigger egg masses). Six of the eight most productive ponds (those with 20 or more egg masses) were grazed, indicating that grazing had no detrimental effect on this frog in these wetlands.

The differences in the conclusions between these studies may be a result of different intensities of grazing in the wetland. Jansen and Healy (2003) found a clear relationship (statistically significant) between the condition of a grazed wetland (as measured by vegetation and water quality) and the species richness of frogs. They also found a direct correlation between the intensity of grazing and the condition of a wetland.

4.3.6 Impacts on Fish from Changing the Physical Structure of the Habitat

Information in the literature did not differentiate between the responses of resident and anadromous fish to changes in the physical structure in wetlands. The information available addresses impacts to fish in general. For example, the removal of vegetation can have a significant impact on the fish present in a wetland as a result of (Adamus et al. 2001):

- Increased water temperature that may go above the tolerance limits of certain species
- Decreased cover and thereby increased susceptibility to predation
- Changes in foods and their availability

Woody material is especially important as a source of cover for fish in off-channel wetlands such as oxbows and sloughs and in lakes (Leitman et al. 1991, Dewey and Jennings 1992, Fausch and Northcote 1992, McIntosh et al. 1994).

In wetlands along the fringes of lakes, submerged plants are particularly important and their removal can change the habitat for fish. For example, declines in plants resulting from introductions of grass carp (Bain 1993) have been linked to an increase in the proportion of fish species found in limnetic areas (open water) (Bettoli et al. 1991, Maceina et al. 1991, Martin et al. 1992). However, intentional thinning of plant beds can sometimes result in higher growth rates of some age classes of lake fish, presumably by giving them better access to invertebrates that are their food source (Olson et al. 1998).

One impact that has been hypothesized in situations where the physical structure of wetlands is changed is the “stranding of fish (R. Friesz, K. March, B. Zeigler, Washington State Department of Fish and Wildlife, personal communications 2000-2004). Changing the shape or drainage of wetlands can create situations where shallow surface water is connected to streams such as during flood events or high precipitation and then isolated as water levels drop. This may result in the stranding of fish in these shallow pools, and their subsequent demise as the temperatures rise and oxygen levels decrease.

4.3.7 Impacts on Birds of Changing the Physical Structure of the Habitat

Many guilds of birds are sensitive to the presence and type of vegetation and its location in relationship to open water (Kauffman et al. 2001). The removal of vegetation can, therefore, be expected to change the distribution and abundance of birds in wetlands. For example, the rearing success of waterfowl in wetlands is reduced by removing herbaceous cover because it exposes the young to predation (Skovlin 1984).

Grazing has also been found to change the distribution of birds. In a study in southeastern Oregon on the effects of grazing on birds, researchers used exclosures to remove livestock from portions of riparian meadows (Dobkin et al. 1998). They found that the richness and abundance of bird species increased within the exclosures in comparison to the plots that

remained available for livestock grazing. Moreover, the exclosures were dominated by wetland-associated birds while the open plots were dominated by upland bird species.

The changes in physical structure of wetlands that result from grazing can have both positive and negative impacts on shorebirds that use freshwater wetlands (Buchanan, 2004). The negative impacts he reported include the direct trampling that destroyed eggs and nests, the compacting of soil that reduce populations of invertebrate prey, and an increased erosion that reduced populations of invertebrate prey in semi-arid regions.

The changes in the structure of vegetation that result from the conversion of forested wetlands to emergent and open water wetlands can alter species composition and richness of breeding birds. For example, 53% of the bird species that formerly used forested wetlands no longer occur regularly where such forests have been logged and converted to emergent wetlands (Doherty 2000 as reported in Adamus et al. 2001). In the Columbia Basin, where forests are not present, changes in the vegetation of the buffer also had impacts. Heavy grazing next to wetlands removed buffer vegetation and reduced waterfowl production by 50% (Foster et al. 1984).

4.3.8 Impacts on Mammals from Changing the Physical Structure of the Habitat

Many mammals are sensitive to the presence and type of vegetation and its location in relationship to open water. The removal of vegetation is therefore expected to change the distribution and abundance of mammals in wetlands (Adamus and Brandt 1990).

Adamus and Brandt (1990) created a synthesis of the literature on mammal habitat which serves as the basis for the following discussion.

The species richness of small mammals in wetlands has been correlated with the complexity of vegetation structure (Arner et al. 1976, Searls 1974, Landin 1985, Nordquist and Birney 1980, Stockwell 1985, Simons 1985). Removal of vegetation and associated long-term destruction of den sites in both wooded and emergent wetlands have caused changes in furbearer populations and small-mammal communities (Krapu et al. 1970, Malecki and Sullivan 1987). In contrast, restoration of riparian vegetation has led to increases in use by mink (Burgess and Bider 1980).

Grazing at levels recommended by the Natural Resources Conservation Service had no significant effect on the abundance or distribution patterns of small mammals in a cottonwood floodplain in Colorado (Samson et al. 1988). Based on this study, controlled grazing that does not contribute to structural changes in vegetation, appears to have no significant effect on the abundance and distribution of small mammals.

4.3.9 Summary of Key Points

- Filling or draining a wetland can so alter the water regime that the land can no longer support wetland vegetation and maintain hydric soils. If a wetland is lost, most if not all of its functions are also lost.
- Some direct disturbances of wetlands, such as removal of vegetation, grazing, and alteration of the soil, change the wetland functions but do not result in the complete loss of functions.
- Impacts of removing vegetation on the habitat functions in wetlands have been documented for invertebrates, fish, birds, and mammals. Impacts on amphibians, however, are ambiguous. Impacts to the hydrologic and water quality functions resulting from vegetation removal can only be hypothesized since no information was found in the literature.
- Impacts of grazing on habitat functions have been documented for invertebrates and birds and are somewhat conflicting for amphibians. The one study of mammals suggests that low levels of grazing in a floodplain may have minimal impacts on the habitat of this group. No information was found on impacts of grazing on the hydrologic and water quality functions.
- No information was found on the impacts of soil alterations (through tilling and compaction) on any of the functions performed by wetlands.

4.4 Impacts from Changing the Amount of Water in a Wetland

The quantity of water in the landscape is a critical factor in controlling how wetlands function. Many human land uses change the amount of water flowing into and out of wetlands, thereby creating a disturbance that affects the performance of functions in wetlands. The literature is quite clear that the frequency, timing, and duration of water in the landscape determine the presence of a wetland and the functions that it provides (see Chapter 2). How water enters a wetland, how long it is present, and the depths to which it is impounded all influence the functions that a wetland can provide or perform (Brinson 1993b, Mitsch and Gosselink 2000).

The movement and routing of water above and below the surface is the primary force in transporting nutrients, sediment, salts, and contaminants, and this in turn affects the functions provided by wetlands (Naiman et al. 1992). Water moves (or carries) sediment, nutrients, and energy throughout a watershed (Naiman et al. 1992). Changes in the amount of water and thereby the depth of inundation in a wetland, can alter how sediments, nutrients, and toxic contaminants come into a wetland and how they are “processed” within the wetland.

4.4.1 Impacts on Hydrologic Functions from Changing the Amount of Water

Specific documentation was lacking on how increasing or decreasing amounts of water may affect wetland functions in reducing flooding or erosion or recharging groundwater. It can be hypothesized, however, that the storage capacity of a wetland in a depression that drains to areas prone to flooding will be reduced if water levels increase. The volume that would have been available to store floodwaters is used instead to store the increased volumes coming into the wetland. This suggests that the functions related to reducing flooding would also decline because storage is a large component of flood reduction. On the other hand, wetlands in which water is deeper or covers more of the wetland may provide better recharge of groundwater because infiltration depends on the depth of water in the wetland (hydraulic head) and the area that is submerged (Hruby et al. 1999).

The converse can be hypothesized if water levels in wetlands decrease. The potential amount of water that can be stored in a wetland will increase as it becomes drier, thereby increasing the “flood reduction” functions. The function of recharging groundwater would decrease because less water would be present and it would be shallower.

4.4.2 Impacts on Functions that Improve Water Quality from Changing the Amount of Water

Increasing the amount of water in a wetland brings a greater volume of surface water in contact with wetland plants, soils, and the chemical processes that lead to water quality improvement. Increased flooding in wetlands can change residence time, the distribution of aerobic and anaerobic environments, and a variety of microbial and non-microbial chemical processes (Kadlec and Knight 1996). These factors can all change how wetlands remove contaminants.

Because there are so many factors involved in removing individual contaminants it is not possible to generalize the response of a wetland to changes in water levels. Kadlec and Knight (1996) provide further discussion on the many different ways water levels affect the capacity of wetlands to remove toxic compounds. The discussion below provides only a few examples.

For example, the activity of microbes potentially increases conversion of inorganic mercury to the much more toxic form, methyl mercury (Kelly et al. 1997). In this case flooding would reduce the effectiveness of a wetland at improving water quality because the wetland may become a source of this more toxic compound. We do not have specific data about mercury in Washington’s wetlands, although mercury is a water quality issue in some waters of the State (e.g., the high levels of mercury found in freshwater fish) (Ecology 2003). We can hypothesize, therefore, that mercury is present in some of the state’s wetlands and can be released under anaerobic conditions.

In addition, a change in the rate of nitrogen removal can be hypothesized to result from a shift in the amount of water present in a wetland. In Washington, the area that is seasonally

inundated was judged to be a critical factor in determining nitrogen removal by wetlands (Hruby et al. 1999). If the increase in water levels expands the area that is seasonally flooded, the rates of nitrogen removal will probably increase. If, however, increases in the amount of water in a wetland expand the amount of permanent water at the expense of the areas that were seasonally flooded, the rates of removal can be hypothesized to decrease. Thus, wetlands in which the water regime has been changed will probably have a different rate of nitrogen removal than they had previously.

4.4.3 Impacts on Plants from Changing the Amount of Water

Much of the literature on how changing amounts of water affect plant populations in wetlands of the Pacific Northwest is in terms of changes in the dynamics of water movement (hydroperiod). This concept combines both changes in water levels and changes in how water levels fluctuate (the latter is addressed as a separate disturbance in Section 4.5).

The composition and richness (number of species) of the plant community are influenced by the water in the root zones of wetland plants. This is influenced by:

- The **duration** of saturation (Dicke and Toliver 1990, Merendino and Smith 1991, David 1996, Vivian-Smith 1997, Silverton et al. 1999, Casanova and Brock 2000)
- The **timing** of saturation (Merendino et al. 1990, Squires and van der Valk 1992, Scott et al. 1996, 1997, Gladwin and Roelle 1998)
- The **frequency** of saturation (van der Valk 1994, Pezeshki et al. 1996, 1998, Smith 1996, Pollock et al. 1998, Casanova and Brock 2000)
- The **depth** of water (Casanova and Brock 2000).

Disturbances to any of these factors in a wetland can cause major changes in the distribution and richness of plant species. The response of an individual wetland to such changes, however, is difficult to predict. The existing information indicates that each plant species responds in a different way to changes in water levels. This means that overall the response of the plant community in a wetland will depend on the sum of the responses of the individual species. The following discussion summarizes some of the studies documenting how plant communities change with changes in water levels. It is beyond the scope of this document to provide detailed information on the response of individual plant species.

Responses of hundreds of plant species to specific hydrologic variables that have been studied are presented in a database at EPA's web site (Adamus and Gonyaw 2000). The database is available at <http://www.epa.gov/owow/wetlands/bawwg/publicat.html>

The changes in plant communities are linked to differences among plant species in their ability to resist drought and flooding. The life history and physical characteristics of plants play a role (Earnst 1990, Koncalova 1990, Voesecek et al. 1993, Kirkman and Sharitz 1993, Teutsch and Sulc 1997). The characteristics of seed dispersal and germination of plants

relative to water dynamics may have the greatest effect on the relative abundance of species, according to a simulation conducted by Ellison and Bedford (1995) using six years of data from a southern Wisconsin sedge meadow. Some species, such as cattail (*Typha* spp.), are able to keep pace with rising water levels because their stem tissue elongates rapidly and to a greater degree than other species (Waters and Shay 1992, Galatowitsch et al. 1999) or they sprout adventitious roots (Voesenek et al. 1993).

Increases in inundation may change the exposure of plants to competitors and herbivores (Wilson and Keddy 1991) and cause a shift in the location of plant communities within a wetland (van der Valk et al. 1992). The opposite extreme—dehydration—kills plants partly by removing the pathway for taking up nutrients and maintaining tissues. Dehydration may also increase or decrease competition and plant exposure to herbivores (Adamus et al. 2001).

Woody plants are particularly sensitive to prolonged inundation, especially for longer than 80 days (Niswander and Mitsch 1995, Toner and Keddy 1997, Sharitz and Gresham 1997). Their seedlings consequently are most affected during years when flooding occurs at or shortly after the beginning of the growing season, or when flooding persists for more than 40% of the growing season (Toner and Keddy 1997). Annual (as opposed to perennial) species tend to increase proportionately in response to drought and some other severe disturbances (Poiani and Johnson 1989).

Species with small, light seeds seem particularly adept at colonizing mudflats exposed during drawdowns and after disturbances (Poiani and Johnson 1989, Ellison and Bedford 1995). These species tend to emerge early in the season and may be more successful by taking advantage of greater light availability (Toner and Keddy 1997).

Successive years of annual drawdowns can favor the spread of many non-native plant species within wetlands (van der Valk 1994). Dominance of a wetland by just a few species is sometimes a sign that the wetland has experienced prolonged drought or drawdown (Wilcox 1995).

Many species have only a narrow “window” in which they can germinate. For example, there may be only a few weeks when favorable water levels or a temporary lack of competitors must coincide with favorable temperatures and acceptable water quality (Rood et al. 1998).

4.4.4 Impacts on Invertebrates from Changing the Amount of Water in the Habitat

Disturbances to the amount of water in a wetland can cause major changes in the distribution and richness of invertebrate species. Because each species responds in a different way to increases or decreases in water regime, the overall response of the invertebrate community in a wetland will depend on the sum of the responses of the individual species.

Responses of hundreds of invertebrate species to specific hydrologic variables that have been studied (Adamus and Gonyaw 2001) are presented in a database at EPA's web site. The database is available at <http://www.epa.gov/owow/wetlands/bawwg/publicat.html>

In general, the amounts of water in a wetland influence the distribution and richness of invertebrates by:

- Altering the amount and pattern of horizontal and vertical habitat space available for colonization (Adamus et al. 2001)
- Changing the types of algae and vascular plants that occur, the proportions of these two major food sources for invertebrates, and the seasons in which they occur (Murkin et al. 1992)
- Changing the extent of contact between plants and water, thus influencing attachment space, availability of detrital foods, shade, and shelter (Ross and Murkin et al. 1991, de Szalay et al. 1996)
- Influencing the access of predators (Reice 1991, Martin et al. 1991, Mallory et al. 1994, Johnson et al. 1995, Wellborn et al. 1996)
- Affecting the intensity of competition (Wissinger et al. 1999)
- Causing mortality if complete desiccation or freezing occurs (Layzer et al. 1993)

4.4.4.1 Impacts on Invertebrates from Reducing the Amount of Water in the Habitat

Some of the most dramatic changes to wetland invertebrate communities occur when wetlands that seldom or never dry out completely are subjected to drought or complete drawdown (Adamus et al. 2001). Less dramatic changes to invertebrate communities occur with slight alterations in the timing, duration, predictability, and depth of surface water (Eyre 1992, Giberson et al. 1992).

Drought and drawdown render the less mobile species of invertebrates more vulnerable to predation, as well as causing their direct loss due to desiccation and related factors (e.g., Stanley et al. 1994). Drought also seems to favor non-insect invertebrates, which can increase at the expense of the insect component of the invertebrate community (Hershey et al. 1999). References to drought and drawdown section are for a desert stream (Stanley et al. 1994) and Minnesota (Hershey et al. 1999), respectively. It is reasonable to extrapolate the findings of these studies to eastern Washington, which may have climates and conditions that are somewhat similar to those in the cited literature, but they may not apply to western Washington.

Coupled with the studies that show invertebrate richness increasing with longer periods of inundation, these observations indicate that removing water from a wetland may reduce the species richness of invertebrates.

4.4.4.2 Impacts on Invertebrates from Increasing the Amount of Water in the Habitat

An increase in the amount of water in a wetland seems to change the composition of the invertebrate community. Densities of swimming (nektonic) and bottom-dwelling (benthic) predatory invertebrates do not increase with flooding as much as the numbers of nektonic and benthic herbivores and detritivores. Predatory species can even decrease after flooding (Murkin et al. 1991), and they often increase as drought or drawdown progresses.

Although flooding generally increases the density and richness of invertebrates in wetlands, the increase may be short-lived. For example, flooding of Manitoba marshes (Murkin et al. 1991) to a level 3 feet (1 m) above normal caused a major increase in numbers of nektonic invertebrates in both vegetated and open water areas for only one year. Furthermore, densities of benthic invertebrates increased in flooded vegetation but not in open areas. The biomass of nektonic invertebrates increased only in the vegetated areas (Murkin et al. 1991).

Some researchers have observed that food webs become more complex and taxa numbers increase as wetlands become wetter, such as those that are ponded for longer periods. This has been observed in seasonal wetlands of eastern Washington (Lang 2000). Also, the use of emergence traps in 19 wetlands in King County yielded more taxa from permanently flooded than seasonally flooded wetlands (Ludwa and Richter 2001b), suggesting that wetlands in which the water levels fluctuate more often will have fewer invertebrate species.

These results suggest that disturbances that cause water to remain longer in a wetland will probably increase species richness at first. The long-term effects of such increases, however, are not well understood.

4.4.5 Impacts on Amphibians and Reptiles from Changing the Amount of Water in the Habitat

Most amphibians cannot tolerate prolonged dry periods. Drying of seasonal pools, especially when it occurs ahead of normal seasonal schedules, can greatly diminish the breeding success of amphibians (Rowe and Dunson 1993). This is partly because many amphibian species disperse only short distances (Berven and Grudzien 1990).

Amphibian populations scattered across wetlands of varying depth and water permanence can enable species to survive long-term droughts or floods. The availability of numerous, scattered wetlands can protect amphibians against effects of localized drought. Some frog and toad species living in relatively intact landscapes seem mostly unaffected, at the level of populations, by significant periods of drought (Dodd 1995).

In addition, both prolonged desiccation and extreme floods can increase opportunities for invasion of wetlands by exotic plant species. This change in water regime can impact the suitability of a wetland as habitat for amphibians by changing the structure of the wetland. Patterns of vegetation typically become more homogeneous, prey abundance may decline, and the habitat may become less suitable for amphibians (Ludwa 1994).

Changing the amount of water in wetlands can also impact the populations of reptiles. During a two-year drought in Washington, a local population of painted turtle (*Chrysemys picta belli*) suffered a 70% decline (Lindenman and Rabe 1990). This appeared to be due to both mortality and movement of turtles out of the wetland. Growth of the turtles was suppressed but it recovered as conditions improved. Drawing down the water level in the autumn to allow wetland management, flood control, or for other reasons can cause high mortality among juvenile turtles that are overwintering due to freezing. This occurs if the drawdowns follow abnormally high water levels in late summer that attracted turtles (Galat et al. 1998).

These results indicate that changing the amounts of water in a wetland affects both amphibians and reptiles. Impacts may occur both from lowering the water levels (for example, through ditching, draining, or pumping) or raising the levels through increased flooding as a watershed is developed.

4.4.6 Impacts on Fish from Changing the Amount of Water in the Habitat

Declines in the amounts of water alter the community structure of wetland fish. Fish experience a greater need to use overlapping resources and face an increased risk of predation when wetlands become drier (Adamus et al. 2001). Low water also increases the chance of fish freezing in winter or dying from thermal stress in summer (Adamus et al. 2001).

Sustained drawdowns can also reduce competition among fish that return to wetlands when water levels rise again by temporarily eliminating larval dragonflies and other large invertebrates that normally compete for food with the fish or prey on larval fish (Travnichek and Maceina 1994).

Impacts of increasing water levels on fish in wetlands were not documented in the literature.

4.4.7 Impacts on Birds from Changing the Amount of Water in the Habitat

Disturbances to the amounts of water in a wetland can cause major changes in the distribution and species of birds. As with plants and invertebrates, the overall response of the bird community in a wetland will depend on the sum of the responses of the individual species.

4.4.7.1 Impacts on Birds from Reducing the Amount of Water in the Habitat

Drainage and some other disturbances in the amounts of water in wetlands have been well documented as contributing to the decline of many wetland bird species (David 1994, DeAngelis et al. 1997). In Manitoba, for example, wetland drainage has made breeding and brood-rearing areas for waterfowl less available (Rotella and Ratti 1992). As wetlands are

drained or converted to other land cover types, local densities of wetlands decline and the average distances between individual wetlands increase.

Drought conditions also expose duck nests to greater predation. With drought, plants are less dense and vigorous, and islands that formerly were inaccessible gain new access points (Hallock and Hallock 1993, Jobin and Picman 1997).

Widespread drawdown of water tables reduces the number and perhaps the variety of wetlands and their vegetation communities. This in turn diminishes the richness, density, and breeding success of birds in many individual wetlands and wetland complexes (Higgins et al. 1992, Bethke and Nudds 1993, Bancroft et al. 1994, Greenwood et al. 1995, Dobkin et al. 1998).

4.4.7.2 Impacts on Birds from Increasing the Amount of Water in the Habitat

Increasing the duration of saturation or inundation can change the use of wetlands by a variety of birds. This change can occur when shallow ephemeral ponds are dredged to make areas with longer periods of standing water (such as stock ponds). In the Columbia Basin, Creighton et al. (1997) found an increase in use by several species of diving and dabbling ducks, coots, and terns when shallow, densely emergent wetlands were dredged to create deeper pools of open water. They also documented an increase in the biomass of zooplankton, a food source for several guilds of birds. However, there was a decrease in use by sora (*Porzana carolina*) and Virginia rails (*Rallus limicola*) as well as red-winged blackbirds (*Agelaius phoeniceus*). The use of the excavated habitats by rails was expected to increase over time as emergent vegetation became reestablished in the excavated pools because rails prefer vegetation that is a mix of robust and thin-stemmed species. An increase in use by shorebirds was one short-term benefit. The shorebirds fed on the moist, fresh dredge spoils and exposed unvegetated soils of the newly excavated basins. Once the soils became vegetated, use by shorebirds declined.

On the other hand, while construction of reservoirs raises water levels, this affects birds by eliminating many wetlands through flooding and destabilizing water levels in the remaining wetlands (Nilsson and Dynesius 1994). Associated changes in river morphology influence the species composition of wintering waterfowl (Johnson et al. 1996).

4.4.8 Impacts on Mammals from Changing the Amount of Water in the Habitat

Information on how disturbances to the amount of water in a wetland may affect their ability to provide habitat for mammals was not found. It is not possible at this stage to hypothesize either positive or negative impacts on habitat for mammals because no logical deductions could be made from the available information.

4.4.9 Summary of Key Points

- Impacts of reducing water levels on the habitat functions of wetlands have been documented for invertebrates, fish, birds, and amphibians. All these groups have reduced species richness and abundance when wetlands dry up.
- Impacts of increasing water levels in wetlands on its functions as habitat have been documented for invertebrates and birds. The species richness of invertebrates may increase for a short time if a wetland becomes wetter. The impacts on the populations of birds are mixed. In some cases the richness of birds increases and in some cases it decreases.
- Impacts to the suitability of wetlands as mammal habitat resulting from either increasing or reducing water levels have not been studied.
- Reducing the amount of water changes the distribution of plants in a wetland, but the studies did not address if species richness will increase or decrease. Data suggest that woody species will tend to be replaced by more grass-like species when water levels in a wetland increase.
- Impacts to the hydrologic and water quality functions from either increasing or reducing water levels can only be hypothesized since no information on these topics was found in the literature.

4.5 Impacts from Changing the Fluctuation of Water Levels within a Wetland

A major finding of the Puget Sound Wetlands and Stormwater Management Research Program was that fluctuations in water level are key in determining biological responses. There are different types of fluctuations in water levels in a wetland and these are described in the shaded box below. The researchers found a decline in the biotic diversity of wetlands associated with an increase in water level fluctuations caused by expanding impervious area within the contributing basin (Reinelt et al. 1998, Azous and Horner 2001).

Prolonged inundation (that is, less frequent water level fluctuations) resulting in a lack of oxygen in the soils has been indicated as a factor in changing the biota of wetlands. Although many hydric soils may be anaerobic, changing the length of time the soils are inundated results in prolonged anaerobic conditions and chemical changes in the soils. These changes in soil chemistry influence the survival of vegetation and microbes in the soil that were adapted to shorter periods of inundation (Thom et al. 2001).

Mechanisms for how fluctuations of water levels affect aquatic systems

Richter et al. (1996) developed a method to model “indicators of hydrologic alteration” based on assessing changes in 32 hydrologic parameters. They identified these parameters as being relevant to the biotic integrity of aquatic ecosystems. They divided the parameters into the following five fundamental factors that characterized how fluctuations in water levels influence biotic communities in aquatic systems:

Magnitude. A measure of the availability or suitability of aquatic habitat. It defines such habitat attributes as wetted area or habitat volume, or the position of a water table relative to the rooting zones of wetland or riparian areas.

Timing. The timing of occurrence of a particular water condition. It can determine whether certain life-cycle requirements are met. It can also influence the degree of stress or mortality associated with extreme water conditions such as floods or droughts.

Frequency. Refers to the frequency of occurrence of specific hydrologic conditions, such as droughts or floods. It may be tied to events such as the reproduction or mortality of various species, thereby influencing population dynamics.

Duration. The length of time over which a specific hydrologic condition exists. It may determine the success of the life cycle of a particular species or the accumulation of stressful effects.

Rate of change. In hydrologic conditions may be linked to stranding of individuals (in isolated pools or along a wetted edge). It may also be related to the ability of sensitive species to maintain root contact within the phreatic zone (the portion of the soil that is influenced by proximity to the groundwater table).

4.5.1 Impacts on Hydrologic Functions from Changing the Fluctuations in Water Levels

The literature did not provide explicit information on possible impacts of changes in water level fluctuations on factors within a wetland that affect its hydrologic functions. It is not possible at this stage to hypothesize either positive or negative impacts on hydrologic functions because no logical deductions could be made from the available information. The major questions that need to be addressed include:

- Will changes in the frequency or amplitude of water level fluctuations change the flood storage capacity of a wetland?
- Will changes in the frequency or amplitude of water level fluctuations change the way in which a wetland reduces water velocity?
- Will changes in the frequency or amplitude of water level fluctuations change the way in which a wetland recharges groundwater?

4.5.2 Impacts on Functions that Improve Water Quality from Changing the Fluctuations in Water Levels

How changing fluctuations in water levels impact the ability of wetlands to improve water quality was not detailed in the literature. It is not possible to hypothesize either positive or negative impacts on water quality functions because no logical deductions could be made from the available information. The major questions that need to be addressed include:

- Will changes in the frequency or amplitude of water level fluctuations change how a wetland traps sediment?
- Will changes in the frequency or amplitude of water level fluctuations change the way in which a wetland removes nitrogen?
- Will changes in the frequency or amplitude of water level fluctuations change the way in which a wetland captures or transforms toxic compounds?

4.5.3 Impacts on Plants from Changing the Fluctuations in Water Levels

In general, the amplitude and rate of water level fluctuations have been found to influence the species composition, biomass, and germination of plants (Hudon 1997, Shay et al. 1999). Furthermore, the timing of inundation and duration throughout the seasons also influences plant species richness and survival (Ewing 1996, Reinelt et al. 1998, Owen 1999, Azous et al. 2001). If these hydrologic factors change as a result of human activities as described in Chapter 3, one can then hypothesize changes in plant communities.

Researchers in the Puget Sound regions correlated a decline in plant species richness in urbanized watersheds where water level fluctuations had increased (Azous and Cooke 2001). Among 26 wetlands in the Seattle area, the degree of seasonal fluctuation in water level was negatively associated with richness found in emergent and shrub wetlands. However, it had no statistically significant effect on species richness in forested wetlands (Cooke and Azous 2001). These authors found that fluctuation during the early spring seemed to have an especially detrimental effect on plant richness in the emergent and shrub wetlands.

Reinelt et al. (1998) found that the development of plant communities in lowland wetlands of Puget Sound was related to water level fluctuations and depth of inundation during the early growing season. They noted that shifts in the “hydrologic profile” of the wetland caused a subsequent shift in the species composition of the wetland’s plants. The emergent and scrub-shrub communities of the wetland tended to have lower plant richness when average, annual water-level fluctuations increased to over 8 inches (20 cm).

Azous and Horner (2001) determined that the duration of flooding, as well as depth, also strongly influenced plant diversity. They noted greatest plant diversity when:

- Flooding events were less than 0.5 feet (0.2 m) above predevelopment levels
- Floods were limited to an annual average of three or fewer events per month
- The cumulative duration of flooding was less than six days per month above predevelopment averages

On the other hand, a lack of fluctuation in water level can be just as damaging as excessive fluctuation to some wetland plant species (Rood and Mahoney 1990). This is because many species need a period of desiccation in order to germinate. Furthermore, the loss of wet-dry cycles in floodplain wetlands that result from the construction of dams favor exotic species that replace the native plant community (Bunn and Arthington 2002).

On the other hand, evidence from some studies suggests that the relative tolerance to increases in water level fluctuations is greatest among several non-native or invasive species (Figiel et al. 1995, Haworth-Brockman and Murkin 1993, King and Grace 2000). Increases in water level fluctuations and duration of inundation favor generalist plants (plants that are found under a wide range of environmental conditions) in the Pacific Northwest (Azous et al. 2001).

These results indicate that changes to water level fluctuations in wetlands are likely to result in shifts in the composition, distribution, and abundance of plants, especially in situations where there is a relatively stable hydroperiod with low level fluctuations. Furthermore, either decreases or increases in water level fluctuations will probably facilitate the invasion of non-native or “aggressive” native species by increasing the level of disturbances to which plants are subject.

4.5.4 Impacts on Invertebrates from Changing the Water Level Fluctuations in the Habitat

In the Northwest, researchers have observed a decline in the number of invertebrate species in wetlands as the impervious area in the basin increases (Ludwa 1994, Hicks 1996, Ludwa and Richter 2001a, Thom et al. 2001). Since changes in the fluctuations of water levels are a major disturbance that results from an increase in impervious surface, it can be hypothesized that the decline in the Northwest is a result of this disturbance. Information from other parts of the United States seems to confirm this hypothesis.

The densities of some invertebrate species can be decimated by rapid water level fluctuations, especially when the fluctuations are more frequent and severe than historically encountered in the wetland. For example, Missouri floodplain pools that experience large fluctuations in water level during major floods tend to have lower invertebrate density (Magee et al. 1993). Repeated exposure to desiccation in a short period of time can lead to a marked reduction in the density of invertebrates. In an Arizona stream that experienced 12 flash floods between August and December of a single year, densities of all invertebrates

were reduced by 75% to 100% (Boulton et al. 1992). In particular, the numbers of water spiders, midges, and some caddisflies, mayflies, and snails declined.

A number of studies have found that reducing fluctuations in streams by maintaining minimum water levels (such as in reservoirs) can increase invertebrate densities in the part of an adjacent wetland that is not permanently inundated (Weisberg et al. 1990, Troelstrup and Hergenrader 1990).

4.5.5 Impacts on Amphibians and Reptiles from Changing the Water Level Fluctuations in the Habitat

In Puget Sound wetlands, amphibian species richness was negatively correlated with the percent of impervious cover in a contributing basin. The primary cause is increased water level fluctuation (Richter and Azous 2001a). The richness of amphibians declined to less than three species when water level fluctuations increased to over 8 inches (20 cm) (Richter and Azous 2001a, Thom et al. 2001). Chin (1996) concluded that the reduced richness of amphibians was correlated with a reduction in the diversity of wetland plants that resulted from increases in water level fluctuations.

Increases in fluctuation of water levels also affect amphibians by (1) stranding egg masses when water levels drop, and (2) reducing the thin-stemmed emergent plant species on which amphibians lay their eggs. Unpublished work by Richter (K. Richter, King County, personal communication 2002) in western Washington found that amphibians preferred thin-stemmed vegetation on which to lay their egg masses. Greater water level fluctuation directly affects amphibian egg survival and causes changes in plant species, reducing the thin-stemmed emergent species used by amphibians for egg laying (Chin 1996).

No correlations were found between the richness of amphibian species and a variety of other factors including wetland size, distance to breeding habitats, presence of predators, and number of vegetation classes (Richter and Azous 2001a). The most significant factor affecting species richness was mean water level fluctuation, with 8 inches (20 cm) mean annual fluctuation being a threshold for lentic breeding species (those that breed in stagnant or slow-moving waters such as ponds and wetlands). Lentic breeding amphibians appear to be affected by increases in the duration and frequency of flooding and increased discharge rates resulting from the greater frequency and magnitude of storm peaks in urban watersheds (Richter and Azous 2001a).

Amphibian populations in western Washington generally experience impacts in contributing basins with increasing amount of impervious surface (Booth and Reinelt 1993). A more recent study documented that watersheds with less than 15% total impervious area had three or more amphibian species, whereas most watersheds with more than 25% impervious area had less than three species (Chin 1996). Chin (1996) concludes that changes in water level fluctuations and maximum water levels during spring breeding and embryo development are the primary adverse effects of increased impervious surface.

4.5.6 Impacts on Fish from Changing the Water Level Fluctuations in the Habitat

No specific information was found on how changing fluctuations in water levels impact the ability of wetlands to provide habitat for fish. It is not possible to hypothesize either positive or negative impacts on habitat for fish because no logical deductions could be made from the available information.

4.5.7 Impacts on Birds from Changing the Water Level Fluctuations in the Habitat

General observations have indicated a decline in bird richness for wetlands located in a contributing basin that is developed or developing. Richness was not reduced in contributing basins that remained rural or relatively undeveloped over the course of the Puget Sound Wetlands and Stormwater Management Research Program (Richter and Azous 2001b, Thom et al. 2001). These observations have not specifically been correlated with changes in the fluctuation of water levels, although it can be hypothesized that some of the changes observed are a result of changes in water level fluctuations because this is one of the major disturbances caused by impervious surface (see Chapter 3).

4.5.8 Impacts on Mammals of Changing the Water Level Fluctuations in the Habitat

No explicit information on how changing fluctuations in water levels will impact mammal populations in wetlands was presented in the literature. It is not possible to hypothesize either positive or negative impacts on mammal populations because no logical deductions could be made from the available information.

4.5.9 Summary of Key Points

- No information was found on the impacts to the hydrologic and water quality functions of wetlands resulting from altered fluctuations in water levels.
- Impacts on habitat for invertebrates and amphibians resulting from changes in how water levels fluctuate in wetlands have been documented. Both groups of wildlife exhibit reduced species richness and abundance when wetlands are subject to increased fluctuations in water levels. Impacts to the suitability of wetlands as habitat for mammals, fish, and birds have not been documented.
- Increasing and decreasing fluctuations in water levels also reduce plant richness in wetlands.

4.6 Impacts from Changing the Amount of Sediment Coming into a Wetland

The sporadic movement of sediment in and out of wetlands is a disturbance that also occurs in the absence of human activities. For example, the persistence of some wetlands (i.e., certain riverine and lakeshore wetlands) depends on a sporadic deposition of sediment (Mistch and Gosslink 2000). On the other hand, depressional wetlands are natural sinks for sediments because they are the low points in the topography (Brinson 1993b), and this is a function they perform with or without the presence of human activities. Negative impacts to wetlands occur when the amount of sediment coming into a wetland either increases or decreases from the levels that are present in the absence of human activities (see Mistch and Gosslink 2000 for general references to this process).

4.6.1 Impacts on Hydrologic Functions from Changing the Amount of Sediment

Despite a lack of explicit information on impacts that sedimentation may have on hydrologic functions, it is possible to hypothesize that increases in sediment load to a wetland will reduce the amount of water it can store. For every cubic yard of sediment deposited in a wetland and not transported further, the storage capacity of water is reduced by a similar amount. This means that depressional wetlands along stream corridors with high inputs of sediment may lose much of their ability to store surface waters during floods. A similar hypothesis can be made for depressional wetlands with no surface outflow. Increases in sediment load to such wetlands can reduce the storage capacity.

4.6.2 Impacts on Functions that Improve Water Quality from Changing the Amount of Sediment

No information was found on how changing the sediment load to a wetland might change the water quality functions in wetlands. It is not possible to hypothesize either positive or negative impacts on the water quality functions because no logical deductions could be made from the available information.

4.6.3 Impacts on Plants from Changing the Amount of Sediment

Accelerated sediment deposition or erosion can tax the ability of plant communities to adapt (Kantrud et al. 1989, Jurik et al. 1994, Wang et al. 1994). Sediments have been found to impact plant communities in wetlands in several general ways:

- **Burying seeds, leaves, or plants.** Sedimentation can bury established vegetation and seed banks (Adamus et al. 2001). The burial of leaves prevents photosynthesis and restricts gas exchange through foliage (Ewing 1996). Buried plants expend energy

elongating their shoots in an attempt to outpace sedimentation, seeking oxygen and light, and consequently may be less robust.

- **Changing the depth of habitats.** Over the long term, sedimentation can shrink shallow wetlands or reduce the depth of ponds that previously were too deep to support many wetland plants. Such long-term changes in water depth or relative elevation also result in shifts in species composition, as has been documented in the Mississippi River floodplain (Adamus et al. 2001).
- **Inhibiting germination.** Seeds of the most sensitive species often fail to germinate when buried (Dittmar and Neely 1999). The addition of sediment has been found to reduce germination rates of herb species in wetlands by 34% (Neely and Wiler 1993), 80% (Jurik et al. 1994), and 90% (Wang et al. 1994) depending on the species involved. In general, the species with larger seeds appear to be better able to survive burial (Dittmar and Neely 1999, Jurik et al. 1994, Wang et al. 1994).

Less than 0.5 inch (1 cm) of sediment can inhibit germination of cattails (*Typha* sp.), barnyard grass (*Echinocloa crusgalli*), rice cutgrass (*Leersia oryzoides*), and sedges (*Carex* sp.) (Jurik et al. 1994). Sedimentation inhibits the germination of cattail (*Typha latifolia*) seeds more than seeds of bur-reed (*Sparganium eurycarpum*) (Neely and Wiler 1993). Germination of cattail (*Typha x glauca*) seeds decreased by 60% to 90% when sediment loads of less than 0.5 inch (0.2 to 0.4 cm) were applied to the surface of the soil (Wang et al. 1994).

In contrast, burial by 1 inch (2 cm) of sediment does not interfere with germination of several non-native plant species (Blackshaw 1992, Reddy and Singh 1992).

- **Reducing survival of seedlings.** Excessive sedimentation can reduce the survival of seedlings (Jurik et al. 1994). For example, the density of cattail seedlings and their biomass decreased as sediment loads increased from 0.08 to 0.5 inch (0.2 to 1.0 cm). One study found a fourfold greater density of annuals (vs. perennials) in some heavily sedimented sites (Neely and Wiler 1993). Older and larger seedlings were more tolerant of burial (Wang et al. 1994).
- **Favoring species more tolerant of sediment.** Sedimentation impacts individual wetland species in different ways. The composition of the plant community will therefore change as the most sensitive species are suppressed by the sediment while the more tolerant ones thrive. Effects of sedimentation on particular wetland plant species are not well documented (van der Valk and Jolly 1992) but findings relevant to wetland species found in Washington are discussed here.

Many mature plants, and especially woody species, apparently are not harmed by a small amount of sedimentation (Wang et al. 1994). Adult plants of wild celery (*Vallisneria americana*) tolerated burial to depths of up to 4 inches (10 cm) but none survived burial under sediment depths of 10 inches (25 cm) (Rybicki and Carter 1986). Among woody plants, saplings of red alder (*Alnus rubra*) tolerated burial less well than those of Oregon ash (*Fraxinus latifolia*) (Ewing 1996).

Growth of the invasive reed *Phragmites australis*, however, typically keeps pace with moderate rates of sedimentation (Pyke and Havens 1999). However, seeds, seedlings, and plants that have evolved in wetland types in which sedimentation is rare (such as bogs) may be highly sensitive to burial. The size of particles that are being deposited, not just their amount, may also influence plant survival (Dittmar and Neely 1999).

A recent study by Mahaney et al. (2004) found that the response of plants to increases in sedimentation depends on the hydrogeomorphic class of the wetland. Increases in sedimentation reduced the emergence of four species found in riparian depressions but only affected one species in slope wetlands and none in headwater floodplains.

4.6.4 Impacts on Invertebrates from Changing the Amount of Sediment in the Habitat

In general, increased amounts of sediment can reduce the richness and density of invertebrates and alter their species composition. Excessive sedimentation affects invertebrates through several mechanisms (reviewed in Adamus et al. 2001):

- Burial of detritus and algae, which are important food sources
- Increase in the time required for invertebrates to move through deposited sediment and collect scarce food items
- Reduced flow of water through soil particles, which is necessary to supplying invertebrates with adequate dissolved oxygen
- Mortality of plants that otherwise provide attachment structures and shelter to invertebrates

Some studies have linked changes in invertebrate communities to the development of watersheds (e.g., Hogg and Norris 1991, Ludwa 1994, Carlisle et al. 1998, Ludwa and Richter 2001a). Development often is accompanied by increased export of sediment to water bodies.

Many invertebrate communities in wetlands are adapted to occasional deposition of small amounts of sediment, whereas constant or severe deposition causes major changes. The following bullets summarize some of the studies that have documented impacts of sediment on individual invertebrate species, as well as groups of species, many of which are found in Washington.

- Once deposited, sediments can further damage wetland invertebrate communities if they are re-suspended by wind mixing or fish, making the water turbid. For example, bottom-feeding carp (*Cyprinus carpio*) noticeably increase turbidity, both directly (as they move along the bottom) and by consuming aquatic plants that otherwise would stabilize and trap sediments (Lougheed et al. 1998). The biomass of planktonic invertebrates declined in Utah ponds after introduction of carp (Huener and Kadlec 1992).

- In some instances, invertebrate density and perhaps richness can increase over the long term if sedimentation replaces coarser substrates with finer substrates that better support establishment of rooted plants. In temporarily flooded prairie pothole wetlands, only caddisflies seemed relatively unaffected by surrounding land use that generated sediments. Ostracods (seed shrimp), cladocerans (water fleas), and some snails (planorbiids, lymnaeids, physids) were diminished, presumably in part because of sedimentation (Euliss and Mushet 1999).
- Burrowing, tube-forming worms and midges commonly predominate where sediments accumulate (Magee et al. 1993). Filter-feeding species and those that graze on the bottom are most sensitive (Lougheed and Chow-Fraser 1998). However, invertebrate size and behavior also influence their tolerance to sediments (McClelland and Brusven 1980). On the other hand, substrates newly created by sedimentation may attract tolerant individuals and species that are poor competitors on older, more crowded substrates (Soster and McCall 1990).
- Severe and rapid sedimentation is inevitably lethal to nearly all aquatic invertebrates. In North Dakota, wetlands surrounded by cropland were virtually devoid of the resting eggs of zooplankton, whereas such eggs were abundant in wetlands surrounded by mostly natural grassland, which presumably minimized erosion and sedimentation (Euliss and Mushet 1999).
- Unionid mussels (mussels in the family Unionidae) are sensitive to increased sedimentation (Goudreau et al. 1993, Box and Mossa 1999). Numbers of the swamp fingernail clam (*Musculium partumeium*) and amphipods were reduced in willow wetlands in northeastern Missouri where 2 to 4 inches (5 to 10 cm) of sediment had been recently deposited (Magee et al. 1993).
- Sediments may clog the filter feeding mechanisms of some species and limit light penetration. This would adversely impact phytoplankton and other primary producers, with a subsequent adverse impact on food chains (Euliss and Mushet 1999).
- Sedimentation also potentially buries invertebrate eggs deposited in the substrates of wetlands (Euliss and Mushet 1999).

4.6.5 Impacts on Amphibians and Reptiles from Changing the Amount of Sediment in the Habitat

Few studies of the impacts of increases in the deposition of sediment on amphibians and reptiles have been conducted in wetlands. On one hand, some species require soft sediments as hibernation sites. For example, painted turtles (*Chrysemys picta*) used sediments 1.6 to 3 feet (0.50 to 0.95 m) thick in an Ontario pond (Taylor and Nol 1989). On the other hand, excessive sediments, when stirred, impair light penetration of the water column and thus can inhibit growth of algae and especially submersed aquatic plants, which provide cover and attachment sites for amphibian eggs.

4.6.6 Impacts on Fish from Changing the Amount of Sediment in the Habitat

No recent studies on the impacts of sediment on habitat for fish in North American wetlands or lakes were found. Most of the studies on the impacts of sediment on fish populations have been done in streams, especially as it concerns the growth and reproduction of salmonids in the Pacific Northwest. This information was reviewed and synthesized in Knutson and Naef (1997). The conclusion reached by Knutson and Naef quoted below can also apply to wetlands because streams are often considered a part of wetlands:

Sedimentation in fish-bearing waters affects habitat quality and fish survival in a number of ways. Stream bottoms covered with fine sediments are no longer suitable for spawning. Sediments cover and suffocate fish eggs and fry. High sediment deposits also block fish passage to upper spawning reaches. Suspended sediments clog the gills of fish, decrease dissolved oxygen levels, inhibit fish feeding and growth, and suppress macro-invertebrate food sources.

4.6.7 Impacts on Birds from Changing the Amount of Sediment in the Habitat

Little information was found on how sedimentation impacts the habitat that a wetland provides for bird communities. One can hypothesize, however, that sedimentation can impact birds by altering structure of vegetation (see Section 4.6.3) that provide food for herbivorous birds or those that prey on invertebrates (see Section 4.6.4). In one case, the densities of breeding dabbling ducks were positively correlated with wetland turbidity in ponds in the interior of British Columbia (Savard et al. 1994).

4.6.8 Impacts on Mammals from Changing the Amount of Sediment in the Habitat

No information was found on how sedimentation might change the habitat that a wetland provides for mammals. As with birds, however, one can hypothesize that sedimentation can impact mammals by altering habitat structure or changing the abundance or availability of prey items.

4.6.9 Summary of Key Points

- No information was found on possible impacts of sedimentation on the functions of wetlands that improve water quality.
- Increasing sedimentation will decrease plant richness and tends to favor the more invasive types that tolerate disturbance.

- Impacts of increased amounts of sediment on the habitat functions of wetlands have been documented for invertebrates, amphibians, and fish. All of these groups generally have reduced species richness and abundance when wetlands are subject to increased sedimentation. In some cases, however, where the sediments coming into a wetland are finer than existing sediments, the number of invertebrate species may increase. Impacts from sedimentation on the suitability of wetlands as habitat for mammals and birds have not been documented.

4.7 Impacts from Increasing the Amounts of Nutrients Coming into a Wetland

The major nutrients for plant growth, phosphates, nitrates, and ammonium, can be transported into aquatic systems and impact the functions performed by wetlands. These nutrients are carried in water in dissolved forms or adsorbed onto sediment. The element phosphorus is usually the limiting nutrient for plant growth in freshwater aquatic systems (Newton 1989, Mitsch and Gosselink 2000). Because it is the limiting factor, phosphorus in the presence of the other critical element, nitrogen, allows expansive growth of phytoplankton, algae, and larger plants in aquatic systems when it is available in higher quantities.

Excessive algal growth is unsustainable, and when the algae blooms die, their decomposition causes the available dissolved oxygen to be consumed. The undesirable growth of vegetation caused by high concentrations of plant nutrients in bodies of water is called *eutrophication*. Eutrophication is defined as the process by which a body of water becomes enriched in dissolved nutrients (as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen (Merriam Webster online <http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=eutrophication> accessed October 14, 2004).

Excess phosphorous and nitrogen, therefore, often leads to eutrophication with subsequent mortality of the aquatic organisms that require oxygen (Newton 1989, Mitsch and Gosselink 2000). Wetlands with areas of water on the surface can therefore become eutrophic if they receive excessive amounts of phosphorus and/or nitrogen.

4.7.1 Impacts on Hydrologic Functions from Increasing the Amounts of Nutrients

It is possible that the stimulation of plant growth by excess nutrients could increase the density of plants in the wetland. A thicker stand of vegetation can be expected to provide more resistance to flood flows than a thinner one (Adamus et al. 1991, Hruby et al. 1999). Therefore, excess nutrients might indirectly improve the reduction in velocity that a wetland provides during floods. The literature did not provide any other information on how nutrients might affect the hydrologic function of wetlands.

4.7.2 Impacts on Functions that Improve Water Quality from Increasing the Amounts of Nutrients

Some research indicates that excessive nutrients from agricultural operations may reduce the normal ability of wetland microbes to detoxify particular pesticides (Kazumi and Capone 1995, Chung et al. 1996, Entry and Emmingham 1996). Adding nitrogen to riparian wetlands may potentially compromise the long-term ability of the system to remove nitrogen via denitrification (Ettema et al. 1998). Other information on this topic was not documented in the literature.

However, several avenues of research could be combined to make some hypotheses about impacts. The addition of nutrients to acidic bogs results in changes in plant communities. The plant community that maintains the high acidity in the bog may change to one that maintains a more neutral pH. These changes might then alter several aspects of chemistry in the wetland that affect its ability to improve water quality. The rate of nitrification will probably increase because, as noted by Mitch and Gosselink (2000), low pH inhibits denitrifying bacteria. The change in pH will also probably change the ability of the wetland to bind different toxic metals and other compounds. (See the discussion in Chapter 2 on how pH is linked to the ability of a wetland to bind different pollutants.)

4.7.3 Impacts on Plants from Increasing the Amounts of Nutrients

Excessive nutrients can affect wetland plants in a variety of ways including:

- Shifting the species composition away from species that take up nutrients slowly, to those that are able to exploit nutrient pulses more rapidly or which have high nutrient requirements (Hough et al. 1989, Arts et al. 1990, Gopal and Chamanlal 1991, Wetzel and van der Valk 1998)
- Triggering algal blooms that can shade out many submersed herbaceous plants (Crowder and Painter 1991, Stevenson et al. 1993, Srivastava et al. 1995, Short and Burdick 1995)
- Causing dead plant material to accumulate faster than it can decompose completely, thus altering understory and soil structure (Neill 1990b, Craft and Richardson 1993)

Such changes usually result in long-term changes in the distribution and richness of plants within the wetland. Over the long term, nutrient additions to most wetlands tend to reduce species richness and increase the dominance of a few species. Often, non-native species are most capable of invading rapidly changing environments. Consequently they frequently come to dominate some nutrient-enriched wetlands (Adamus et al. 2001).

Increases in plant litter can smother other plants when the fast growing species die, thus helping maintain the dominance of species that exploit nutrients the most (Adamus et al. 2001). For example, the addition of nitrogen and phosphorus fertilizers to a marsh

dominated by cattail (*Typha glauca*) and the grass *Scolochloa festucacea* during two growing seasons resulted in increased biomass of both species. However, the biomass of *S. festucacea* declined in the second year due to accumulated litter of *T. glauca* (Neill 1990b).

The plants in bogs and other nutrient-poor wetlands are logically the most sensitive to nutrient additions (Moore et al. 1989). The increased availability of nutrients allows grasses and common opportunistic plants to out-compete rare plants (such as sundews, orchids, and pitcher plants) that are adapted to nutrient-poor conditions. For example, in Appalachian peat bogs, the spatial dominance of bristly dewberry (*Rubus hispidus*) was positively related to nutrient levels, but dominance of the Ericaceae shrubs was negatively related (Stewart and Nilsen 1993).

Many aquatic plant species respond to nutrient additions with increased growth, biomass, and productivity. Growth responses to enrichment have been documented for about 80 wetland-associated species in North America. Of these, most have tolerated enrichment or responded to enrichment with increased biomass or growth (Adamus and Gonyaw 2000).

Information on the response of many individual plant species to nutrients can be found in the National Database of Wetland Plant Tolerances at:
<http://www.epa.gov/owow/wetlands/bawwg/publicat.html#database1>

4.7.4 Impacts on Invertebrates from Increasing the Amounts of Nutrients in the Habitat

Excessive nutrients can cause long-term and short-term shifts in invertebrate communities. The information available suggests that excess nutrients can result in both decreases and increases in species richness as well as changes in the groups of invertebrates found. The direction of the change depends on how the nutrients impact the vegetation and soils that are the main habitat for invertebrates. Findings from the literature include:

- **Increased richness of invertebrates.** Up to some point, nutrient inputs to wetlands can lead to increased invertebrate richness, as more food sources become available to predatory invertebrates (Rader and Richardson 1992, Campeau et al. 1994, Cieminski and Flake 1995, Gernes and Helgen 1999).
- **Reduced richness of invertebrates.** Invertebrate richness in a series of highly enriched wastewater wetlands was found to be lower than in a less enriched reference wetland (Nelson et al. 2000).
- **Changes in the types of invertebrates.** In some cases excess nutrients result in the increased dominance of certain kinds of algae. Invertebrates that specialize in feeding on these algae, or that characteristically find shelter and attachment sites in the aquatic plants, then have an advantage and can become dominant (Murkin et al. 1991, Campeau et al. 1994). Exposure to organic enrichment and eutrophication frequently causes an increase in grazers (such as Tanypodinae midges), as well as

other herbivores, species that feed on detritus, predators, and “miners” that burrow into plants. These are groups that typically increase with increasing growth of algae growing on the bottom and emergent aquatic plants (Campeau et al. 1994). A study of four lacustrine wetlands bordering Lake Michigan also found that midge communities shifted across nutrient gradients (Murkin et al. 1992, Campeau et al. 1994).

- **Increased density of invertebrates.** Total invertebrate density increases with increased nutrients, as algal production becomes less of a limiting factor in the invertebrate community (Murkin et al. 1992, Campeau et al. 1994).
- **Changes in the bioaccumulation of metals by invertebrates.** Nutrients appear to influence the tendency of aquatic invertebrates to accumulate heavy metals and the type of metals that are accumulated. For instance, zinc, iron, and manganese concentrations were higher in midges from nutrient-rich wetlands, whereas high copper concentrations were found in midges from nutrient-poor wetlands (Bendell-Young et al. 2000). This may be due at least partly to the bioavailability of various metals being influenced by oxygen conditions in the sediment, which in turn are partly the result of decomposition of algal blooms triggered by high concentrations of nutrients (Adamus et al. 2001).

Information on the response of many individual invertebrate species to enrichment can be found in the National Database of Invertebrate Tolerances at:
<http://www.epa.gov/owow/wetlands/bawwg/publicat.html#database1>

4.7.5 Impacts on Amphibians and Reptiles from Increasing the Amounts of Nutrients in the Habitat

The review of the literature indicates that amphibians can be impacted by the input of nutrients. No studies were found on impacts on reptiles.

Amphibians in the Northwest can be directly impacted by the input of nitrates. Five amphibian species in Oregon showed both sublethal responses and mortality following laboratory applications of nitrate. These studies indicated that the EPA nitrate criteria for drinking water of 10 milligrams per liter (mg/l) and/or for protection of warmwater fish are inadequate to protect these amphibians (Marco et al. 1999). In Texas, playa wetlands receiving nutrient-laden effluent from feedlots were devoid of amphibians found in natural playas (Chavez et al. 1999). Experiments indicated that effluent had to be diluted to less than 3% strength in order to minimize adverse effects on the leopard frog (*Rana pipiens*).

Indirect impacts of excessive nutrients can also be important to amphibians. Shifts in seasonal timing and amount of nutrients that enter a wetland can, over a period of years, increase the relative dominance of algae and/or emergent plants at the expense of submersed plants. This in turn can reduce the availability of submersed plants as attachment substrates for amphibian eggs and as cover for larvae (Beebee 1996).

Excess nutrients can also diminish dissolved oxygen levels (Tattersall and Boutilier 1999), alter the abundance of aquatic predators, and shift the algal and invertebrate foods available to amphibians (Horne and Dunson 1995). As a result, species composition and sometimes species richness of amphibian communities can decline as eutrophication becomes severe. However, well designed studies of such effects are few.

4.7.6 Impacts on Fish from Increasing the Amounts of Nutrients in the Habitat

No information was found documenting direct impacts of excess nutrients on fish in wetlands. However, the secondary impacts of eutrophication such as oxygen depletion do affect fish. Much of the literature deals with impacts of low oxygen in streams (for a review see Knutson and Naef 1997), and it can be assumed that the impacts of low oxygen in wetlands will be similar.

As mentioned previously, the increased plant production that results from added nutrients often results in low oxygen levels when the plant material dies and starts to decompose. Many fish species suffer from reduced levels of dissolved oxygen, and feeding habits also may shift. To some degree, fish families can be grouped according to their susceptibility to oxygen deficiencies. Salmonids and coregonids (whitefish) require high levels of dissolved oxygen, whereas cyprinids (a large family that includes carp and goldfish) often tolerate low dissolved oxygen levels (Harper 1992). Thus the species composition and richness may change depending on the initial state of the wetland and the duration and magnitude of the eutrophication.

4.7.7 Impacts on Birds from Increasing the Amounts of Nutrients in the Habitat

Eutrophication can indirectly impact the composition of the wetland bird community by altering the vegetation structure and availability of prey. In general, moderately elevated nutrient levels also spur the growth of submersed plants that provide food for ducks, as well as supporting more aquatic insects that are especially important as food for ducklings and aerial foragers like swallows. However, excessive nutrients cause algal blooms that can kill fish eaten by birds, reduce the growth of plants growing on the bottom by blocking light, and reduce visibility of other food items under the water surface.

Studies that have documented changes in the bird community related to excess nutrients are summarized below:

- Excessive nitrates have been implicated in deaths of some frogs (see Section 4.7.5). Frogs are a significant prey item for some wetland birds (Adamus et al. 2001).
- Northern shoveler (*Anas clypeata*) and eared grebe (*Podiceps nigricollis*) were positively associated with phosphorus in a survey of wetlands in interior British Columbia (Savard et al. 1994).

- The abundance and biomass of water-birds were positively correlated in 46 Florida lakes with levels of phosphorus, nitrogen, and chlorophyll. There also was a positive correlation of water-bird richness with phosphorus, after accounting for nutrients contributed to the lakes by the birds themselves (Hoyer and Canfield 1994).
- Total density of dabbling ducks was correlated positively with total dissolved nitrogen (Savard et al. 1994).
- The parasitic nematode *Eustrongylides ignotus*, which has only been found in disturbed and enriched wetlands (Spaulding and Forester 1993), negatively affects the health of adult wading birds and the survival of their nestlings (Spaulding et al. 1993).

4.7.8 Impacts on Mammals from Increasing the Amounts of Nutrients in the Habitat

No information was found on impacts from increases in nutrients on the habitat of mammals in wetlands. It can be hypothesized, however, that, if eutrophication results in anoxic conditions that are lethal to the prey of mammals (e.g., fish and some amphibians), the community composition may shift from predator species (such as otter or mink) to vegetarian or invertebrate-eating species and opportunists (such as muskrat).

4.7.9 Summary of Key Points

- Some impacts to the hydrologic functions from increased nutrients can be hypothesized because the increased growth of plants resulting from increased nutrients may provide better resistance to the movement of flood waters.
- Some impacts to the functions of improving water quality have been reported. These include a potential reduction in the ability of wetlands to detoxify pesticides and to remove nitrogen as a pollutant. Impacts from increased nutrients can also be hypothesized for bogs. The ability of bogs to bind toxic metals may be reduced but their ability to remove nitrogen may be increased.
- Increasing nutrients will stimulate plant growth and may change the composition of the species present.
- Impacts of increased amounts of nutrients on the habitat wetlands provide have been documented for invertebrates, amphibians, and birds. Excess nutrients can result in both an improvement in the habitat through the production of food and a reduction in habitat through eutrophication. The actual impacts depend on local conditions in the wetland. Impacts to the habitat for fish and mammals can be inferred because eutrophication causes reductions in the levels of oxygen in the water with resultant impacts to both water quality and the food sources for these two groups.

4.8 Impacts from Introducing Toxic Contaminants to a Wetland

4.8.1 Impacts on Hydrologic Functions from Toxic Contaminants

Contaminants are chemical compounds, solutions, or particles introduced into the environment that change how the environment or the organisms living there function. Toxic contaminants are poisons that specifically impact the growth and reproduction of living organisms.

No explicit information was found in the literature on the possible impacts of toxicity from contaminants on the hydrologic functions provided by wetlands (storing flood waters, reducing erosion, and recharging groundwater). It is not possible at this stage to hypothesize either positive or negative impacts on hydrologic functions because no logical deductions could be made from the available information.

4.8.2 Impacts on Functions that Improve Water Quality from Toxic Contaminants

Information on how toxic compounds affect the function of wetlands to remove pollutants is sparse. It can be hypothesized, however, that an input of low levels of toxic compounds may stimulate the ability of a wetland to detoxify pollutants. Some microbial species biodegrade particular contaminants and their abundance is increased in the presence of low levels of the contaminants. These species can flourish in some wetlands that are only mildly or moderately contaminated.

Contaminants that can be processed by microbes when concentrations are low to moderate include copper (Farago and Mehra 1993), mercury (Marvin-Dipasquale and Oremland 1998), selenium (Steinberg and Oremland 1990, Azaizah et al. 1997), cadmium (Sharma et al. 2000), manganese (Sikora et al. 2000), and petroleum (Nyman 1999, Megharaj et al. 2000).

4.8.3 Impacts on Plants from Toxic Contaminants

Most plant species are relatively tolerant to toxic contaminants. Impacts usually result from the effects of contaminants on plant metabolic pathways, enzymatic reactions, and growth (Fitter and Hay 1987). Symptoms of toxicity can include reduced growth; small, discolored, or dying leaves; early leaf fall; and stunted or suppressed growth of roots (Pahlsson 1989, Rhoads et al. 1989, Vasquez et al. 1989).

Shifts in the composition of the plant community in response to contaminants have not been widely documented. Relevant studies include:

- Arsenic, cadmium, copper, lead, and zinc inhibited growth in hybrid poplar (*Populus*) and several other tree species (Lejeune et al. 1996).
- Iron and manganese, although not usually toxic to wetland plants, do affect species in some wetland types. For example, laboratory experiments revealed differences among 44 fen species with regard to the influence of iron on growth (Snowden and Wheeler 1993).
- Oil spills can have long-lasting effects on wetland plant communities (Obot et al. 1992). In a greenhouse experiment, oil and a detergent used to clean up oil spills were applied to broadleaf arrowhead (*Sagittaria lancifolia*), salt marsh sedge (*Scirpus olneyi*), and common cattail (*Typha latifolia*). The leaves on all of the study plants died following oiling, but new leaves soon developed on those plants subjected to oil and subsequent cleaning with the detergent. *S. olneyi* was the least sensitive of the three species, whereas *T. latifolia* appeared to be the most sensitive (Pezeshki et al. 1998).
- The herbicides Rodeo® and Garlan 3A®, applied to control purple loosestrife (*Lythrum salicaria*), also reduced the growth rates of non-target species such as duckweed (*Lemna gibba*) (Gardner and Grue 1996).

4.8.4 Impacts on Invertebrates from Toxic Contaminants in the Habitat

General studies on the impacts to invertebrates in wetlands of Puget Sound found that increased levels of contaminants and changes in the water regime correlated with declines in species richness among the scraper and shredder functional feeding groups and the Chironomidae family (small, mosquito-like flies) (Ludwa 1994). These authors found declines in richness and abundance of invertebrate groups whose presence is seen as an indicator of the general health or quality of a water body. Another study in Massachusetts also showed a direct and negative correlation between urbanization and the abundance and richness of macro-invertebrates (Hicks 1995) primarily through impacts to water quality.

The following sections first review the effects of metals on invertebrates and then describe the effects of organic and synthetic compounds such as pesticides. Much of the information on the impacts on invertebrates is based on studies in streams. These studies are probably applicable to wetlands because some of the species and many of the invertebrate families reported in the studies are also found in wetlands.

4.8.4.1 Impacts of Heavy Metals on Invertebrates

Heavy metals such as mercury, lead, zinc, copper, and cadmium can be directly toxic to wetland invertebrates. Metals can also impact invertebrate communities by altering the species composition and abundance of algae and aquatic plants upon which invertebrates

depend for food and shelter. Growth, larval development, and reproduction of invertebrates can also be harmed by long-term exposure to sublethal concentrations of trace metals (Timmermans 1993). Relatively little, however, is known about the sublethal effects of metal pollutants in freshwater wetlands or how metals are metabolized or accumulated.

The extent to which heavy metals are toxic to wetland invertebrates depends largely on the acidity of the wetland and the particular form of the metal involved. Acidic conditions can mobilize and increase the toxicity of some metals, such as cadmium (Wright and Welbourn 1994), and decrease the toxicity of others, such as aluminum (Wren and Stephenson 1991). On the other hand, some metals, such as iron and aluminum, can to some degree protect invertebrates from otherwise toxic effects of heavy metals in acid mine drainage (Whipple and Dunson 1992).

Specific studies documenting the impact of heavy metals on invertebrates are summarized below:

- Moderate recovery of invertebrates from metal contamination was demonstrated in the Coeur D'Alene River in Idaho. Over 22 years after contamination by zinc and other metals ceased, the number of species grew from zero to 18, while the proportion of mayflies, stoneflies, and caddisflies relative to the proportion of midges rose (Hoiland and Rabe 1992, Hoiland et al. 1994).
- Some studies show herbivores and detritivores as the most sensitive to additions of metals (Kiffney and Clements 1994a, Leland et al. 1989), whereas others have reported scrapers being the most sensitive group (Clements 1994).
- Mayflies and some stoneflies of western streams are sensitive to metals, whereas caddisflies and midges are relatively tolerant (Clements 1994, Kiffney and Clements 1994b, Leland et al. 1989).
- Agricultural drainage water containing arsenic, boron, lithium, and molybdenum entering the Stillwater Wildlife Management Area in Nevada proved acutely toxic to many wetland invertebrates (Hallock and Hallock 1993).
- Copper and some other heavy metals appear to be more damaging to aquatic communities in the spring and summer rather than in the fall (Leland et al. 1989). Summer exposure to metals may coincide more closely with hatching of many macro-invertebrates, and early periods in the development of the invertebrates may be more susceptible.

4.8.4.2 Impacts of Pesticides, Oil, and Other Contaminants on Invertebrates

Pesticides, oil, and other toxic contaminants represent a wide range of pollutants. In general, however, most have been shown to change the community structure (abundance, distribution, and richness) of invertebrates. Contaminants cause these effects through several mechanisms, including:

- Causing acute or chronic toxicity to invertebrates
- Altering algal communities and aquatic plants upon which some invertebrates depend for food and shelter
- Altering predation on invertebrates by decimating numbers of other crustaceans, fish, and amphibians
- Reducing rates of oxygen diffusion
- Changing the effects of other potential disturbances, such as acidity

The range of pesticides and organic pollutants used today is very large and it is not possible to generalize the impacts of this group of pollutants on invertebrates. Table 4-1 summarizes numerous studies that demonstrate the wide range of responses of invertebrates to contaminants.

Table 4-1. Summary of studies on effects of contaminants on invertebrates.

Reference	Contaminant Studied	Results
Eisler (1992)	diflubenzuron (insecticide)	In laboratory tests diflubenzuron was most toxic to crustaceans, followed by mayflies, midges, caddisflies. Larvae of corixids, dragonfly adults and larvae, spiders, dytiscids, and ostracods had moderate sensitivity
Eisler (1992)	paraquat, cyanide, fenvalerate, acrolein	These substances were lethal to invertebrates
Dieter et al. (1996)	phorate (pesticide)	In Prairie Pothole Region, macro-invertebrates that were particularly sensitive to phorate included hemipterans, mosquitoes, flies, mayflies, water mites, and water beetles. Less sensitive were leeches, snails, aquatic worms, ostracods
Lieffers (1990)	3-trifluoromethyl-4-nitrophenol (TFM) (lampricide)	TFM had a significant effect on invertebrates in a small stream
Fairchild and Eidt (1993)	fenithrothion (insecticide for forest insects)	Fenithrothion reduced emergence of aquatic insects for 6 to 12 weeks. Densities of most invertebrates (especially predatory species, midges, some other dipterans) were reduced by as much as 50% for more than one month after treatment. Wetland sediments became dominated by aquatic worms and water mites. Although in many streams and large lakes fenithrothion has transitory effects, residual toxicity remained in bog wetlands during winter and into the next year
Hachmoller et al. (1991)	various organic pollutants	Mayflies, stoneflies, caddisflies decreased in abundance in stream contaminated by various organic pollutants

Reference	Contaminant Studied	Results
Keller (1993), Metcalfe and Charlton (1990)	various contaminants	Mussels are especially sensitive to combined effects of pesticides, organic compounds, excessive nutrients
Kemp and Spotila (1996)	industrial pollutants, PCBs	Isopods, oligochaetes, crane flies were main survivors in a Pennsylvania stream with industrial pollution (including PCBs) compared with non-urbanized control segments
Crunkilton and Duchrow (1990)	oil	After 25 days, an oil spill in a Missouri stream reduced macro-invertebrate population to less than 0.1% of normal densities. Recovery of some species of stoneflies, mayflies, and caddisflies did not occur for at least nine months
Henry et al. (1994)	surfactant	In laboratory tests, a surfactant was approximately 100 times more toxic than the herbicide glyphosate, with which it is commonly applied
Wipfli and Merritt (1994), Kreutzweiser et al. (1994), Jackson et al. (1994), Waalwijk et al. (1992)	<i>Bacillus thuringiensis</i> var. <i>israelensis</i> (Bti) (biological control agent)	Bti appears to have minimal adverse effects on non-target insects in streams although mortality has been observed in Lepidoptera, some midges, crane flies, caddisflies, mayflies
Euliss and Mushet (1999)	agricultural contaminants	Direct adverse correlation found between aquatic invertebrate species richness and agricultural practices for seasonally inundated wetlands in prairie pothole region of North Dakota. Adverse effects on invertebrates could result from agrichemicals (shown to cause increased mortality of aquatic invertebrates in other studies). Tilling around wetlands could increase erosion, leading to suspended sediments and adsorbed metals that are toxic to some zooplankton and thus affect the food chain

4.8.5 Impacts on Amphibians and Reptiles from Toxic Contaminants in the Habitat

Studies of the effects of heavy metals, pesticides, and other toxins on amphibians and reptiles have been conducted mainly on species, not communities. A review of relevant literature was published by Sparling et al. (2000). Schuytema and Nebeker (1996) have compiled a database of toxicity information from published literature for 58 amphibian species as related to 135 chemicals.

Many different pollutants have been documented as toxic to species of amphibians and reptiles found in Washington's wetlands. The following references document the impact of toxic compounds on some species found in the Pacific Northwest:

- Toxic effects of aluminum and other metals on the embryos and tadpoles of the northern leopard frog (*Rana pipiens*) were found by Freda (1991), Freda and McDonald (1990), and Freda et al. (1990).

- Many synthetic organic compounds affect amphibians and aquatic reptiles. Northwestern salamander (*Ambystoma gracile*) egg mortality corresponded with levels of total petroleum hydrocarbons in western Washington (Platin 1994, Platin and Richter 1995).
- The pesticide esfenvalerate caused damaging sublethal effects on tadpoles of the northern leopard frog (Materna et al. 1995).
- Tests of three forest insecticides (fenitrothion, triclopyr, and hexazinone) on the northern leopard frog in Ontario suggested that tadpoles were sensitive to triclopyr and fenitrothion (Berrill et al. 1991).

4.8.6 Impacts on Fish from Toxic Contaminants in the Habitat

The response of fish communities and individual species to toxic compounds is varied and complicated by many environmental factors. Smaller fish may be the first to respond to contaminants (Matuszek et al. 1990).

The toxicity of copper and zinc to some fish species depends on other chemical characteristics of the water (Munkittrick and Dixon 1992, Welsh et al. 1993), as well as fish behavior (Pourang 1995). For example, dissolved organic matter from a marsh at a level of 5 mg carbon per liter kept copper from binding to the gills of small steelhead (*Oncorhynchus mykiss*), thereby reducing its toxicity. This occurred because copper formed a complex with dissolved organic carbon, making the copper unavailable (Hollis et al. 1997). In addition, some fish species may acclimate to moderately elevated levels of some metals (Klerks and Lentz 1998).

Selenium is not directly toxic to fish at concentrations usually found in soils but can become toxic once concentrated in fish food chains. This is especially true in some wetlands that receive effluents from irrigated fields or power plant reservoirs in some regions (Zilberman 1991, Lemly 1996).

Synthetic organics, including pesticides, can accumulate in wetland fish (Cooper 1993), often with adverse effects. In a Canadian wetland receiving effluent containing oily sand, fish had altered blood chemistry and died within fourteen days (Bendell-Young et al. 2000).

4.8.7 Impacts on Birds from Toxic Contaminants in the Habitat

The response of individual bird species and bird communities to toxic compounds is varied. Individual species are directly affected by many pollutants. Many pesticides, however, are more likely to impact bird populations by altering their habitat and foods rather than by direct toxicity. Studies that document such impacts are summarized below:

- Several instances have been documented of wetland birds being directly poisoned by insecticides applied at recommended rates (e.g., parathion, as documented by Flickinger et al. 1991).
- Herbicides have been applied to wetlands to change the structure of vegetation and the composition of plant species, with consequent shifts in the composition of bird species (Solberg and Higgins 1993, Linz et al. 1996). Information on pesticides in prairie wetlands has been compiled by Facemire (1992).
- Detrimental reproductive effects from dioxins have been documented for great blue herons (*Ardea herodias*) (Hart et al. 1991); for dioxins and furans for wood ducks (*Aix sponsa*) (White and Seginack 1994); for PCBs (polychlorinated biphenyls) in American kestrels (*Falco sparverius*); and for petroleum in mallards (*Anas platyrhynchos*) (Holmes and Cavannaugh 1990).
- Research has continued to focus on the effects of selenium on waterfowl in western states. Biogeochemical conditions favoring the release of selenium into wetlands are found throughout the arid regions of the western states and threaten bird communities in many wetlands along the Pacific and Central Flyways (Paveglio et al. 1992). Agricultural drainage, irrigation, and natural waters can leach selenium from many western soils. Subsurface irrigation is the most widespread and biologically important source of selenium toxicity for waterfowl, including the waterfowl in six national refuges (Ohlendorf et al. 1990, Feltz et al. 1991). Selenium is often accompanied by boron, which is toxic to ducklings (Stanley et al. 1996).

Lead shot as a source of toxic metal

The use of lead shot for hunting is banned in Washington State but its use is still allowed for target shooting. If target ranges are adjacent to wetlands the potential exists of lead entering these wetlands. The pathways for uptake of lead shot by aquatic birds would be the same whether the source is from active hunting or from target shooting.

Lead is toxic to aquatic biota (Eisler 1988). Waterborne lead is the most toxic form. The introduction of lead into the aquatic food chain via aquatic plants has been found in the roots and foliage of the pond weed *Potamogeton foliosus* and in the exoskeleton of crayfish (Eisler 1988, Knowlton et al. 1983). Elemental lead (lead shot), however, has been shown to be significantly less bioavailable to rooted aquatics than powdered lead (Behan et al. 1979).

Waterfowl are at risk from ingesting lead shot as they forage in wetlands. Because of the proximity of wetlands to shooting ranges, other aquatic organisms, including amphibians, and some bird species may be at risk from the spent lead. For example, Eisler (1988) found that lead in tadpoles might contribute to the lead levels reported in wildlife that eats tadpoles. Predatory animals that feed on amphibians include reptiles (such as the garter snake), birds such as the great blue heron and the marsh hawk, and mammals such as raccoons (Martin et al. 1951).

4.8.8 Impacts on Mammals from Toxic Contaminants in the Habitat

No explicit information was found in the literature on the possible impacts of toxicity from contaminants in wetlands on mammals using wetlands. It is not possible at this stage to hypothesize either positive or negative impacts on mammals because no logical deductions could be made from the available information.

4.8.9 Summary of Key Points

- No information was found on the impacts of contaminants on the hydrologic functions of wetlands, but it can be hypothesized that increases in sediment can reduce the storage of water in depressional wetlands.
- The rates at which wetlands remove toxic compounds may actually be increased under low levels of contamination because the specific microbes that detoxify the pollutants are stimulated.
- The impact of contaminants on plants has not been studied as extensively, but the information suggests that toxicity from contaminants can change the composition of the plant community.
- Impacts of increased contaminants on the habitat provided by wetlands have been documented for invertebrates, amphibians, fish, and birds. Many contaminants are toxic to these species and their presence in wetlands reduces the suitability of a wetland as habitat. Wetland-associated mammals are the only group of vertebrates for which no information was found.

4.9 Impacts from Changing the Acidity (pH) of Soils or Water in a Wetland

4.9.1 Impacts on Hydrologic Functions from Changing the Acidity

No information was found on the impacts that increasing acidity might have on the hydrologic functions performed by wetlands. In the absence of any information to the contrary, however, it is possible to hypothesize that decreasing pH will probably not change how wetlands perform these functions. Changes in the acidity of water are not expected to change how well wetlands store water, how well they slow it down during peak flows, or how well they recharge groundwater.

4.9.2 Impacts on Functions that Improve Water Quality from Changing the Acidity

Increased acidity (reduced pH) could change aspects of wetland chemistry that affect the ability to improve water quality. It can be hypothesized that the rate of nitrification will probably decrease because, as noted by Mitch and Gosselink (2000), low pH inhibits denitrifying bacteria. Changes in pH will also change the ability of the wetland to bind different toxic metals and other contaminants in the soils (Kadlec and Knight 1996). Each contaminant, however, has different chemical properties. Some are released when pH decreases (acidity increases) and some are more tightly bound when pH decreases. The impacts of changing the pH, will, therefore, depend on the contaminants coming into the wetland.

4.9.3 Impacts on Plants from Changing the Acidity

The pH is critical in determining the distribution of plants in wetlands. Changes in pH that result from human activities can, therefore, have major impacts. Studies described below have documented changes in plant populations that resulted from both decreases in pH (more acidic conditions) and increases in pH (less acidic conditions). However, the effects of acidification (or its reversal by liming) on the species composition of plants are not consistent among wetland types or even within individual wetlands (Farmer 1990, Baker and Christensen 1990, Mackun et al. 1994, Weiher et al. 1994).

For example, many plant species that inhabit bogs are adapted to acidity levels that would kill most wetland plants. Species whose decline or disappearance from a lacustrine wetland coincided with acidification include water lobelia (*Lobelia dortmanna*), shore quillwort (*Isoetes riparia*), water milfoil (*Myriophyllum tenellum*), yellow pond lily (*Nuphar* sp.), common bladderwort (*Utricularia vulgaris*), and ribbon leaf pondweed (*Potamogeton epihydrys*) (Farmer 1990). Species whose relative abundance increased included *Leptodictium riparium*, needle spike rush (*Eleocharis acicularis*), sphagnum moss (*Sphagnum* sp.), and pipe wort (*Eriocaulon septangulare*) (Farmer 1990).

In general, making wetlands more acidic can directly impact plants by limiting the availability of some inorganic nutrients and carbon (Farmer 1990). Acidic conditions also promote the conversion of nitrates into ammonium.

Acidic conditions can impact plants indirectly by reducing the densities of invertebrates that graze or process detritus. Acidic conditions in wetland soils increase the toxicity of aluminum and manganese (Rendig and Taylor 1989, Crowder and Painter 1991).

4.9.4 Impacts on Invertebrates from Changing Acidity in the Habitat

In general, changing the acidity in a wetland can alter the community structure of invertebrates by:

- Causing acute or chronic damage to tissues of invertebrates; the species that easily lose sodium ions when pH is reduced tend to be most sensitive (Steinberg and Wright 1992)
- Altering algal communities and aquatic plants upon which some invertebrates depend for food and shelter (see discussion in Section 4.9.3)
- Altering the populations that are predators of invertebrates such as other crustaceans, amphibian, and fish (see Sections 4.9.5, 4.9.6)

The impacts of acidification on aquatic invertebrate communities have been researched extensively. Table 4-2 categorizes invertebrate species as more or less tolerant of acidification based mainly on the North American literature. The list is included here because many of these species are probably found in Washington's wetlands. Few local studies, however, document the distribution of invertebrates in the state so it is not possible to identify the tolerance of species that are found here.

Some invertebrates are sensitive to pH increases (decreased acidity). For example, stormwater input to a Florida freshwater marsh increased phosphorus levels, lowered oxygen levels, and raised pH and hardness. This resulted in a shift of the macro-invertebrate population toward species that otherwise are intolerant of the acidic, nutrient-poor conditions typically found in the studied wetland (Graves et al. 1998).

Acidity often reduces the richness of macro-invertebrates in aquatic habitats (Schell and Kerekes 1989, Hall 1994). One study showed that with increased acidity, many aquatic invertebrates declined in numbers and biomass, especially in wetlands with pH below 5.0 (Parker and Wright 1992). Reductions in acid emissions from some Canadian smelters were followed by significant increases in richness of invertebrates in water bodies downwind of the smelters (Griffiths and Keller 1992).

Table 4-2. Summary of studies describing relative tolerance of invertebrates to acidification.

Taxonomic Group and Study Reference	More Tolerant to low pH (Less Sensitive)	Less Tolerant to low pH (More Sensitive)
Dragonflies and Damselflies (Odonata)		
Damselflies (Parker and Wright 1992, Baker and Christensen 1990)	X	
Beetles (Coleoptera)		
Some water beetles (Parker and Wright 1992), especially hydrophilid and dystiscid beetles (Baker and Christensen 1990)	X	
True Bugs (Hemiptera, Homoptera)		
Some water bugs, at least Notonectidae, Gerridae, Corixidae (Baker and Christensen 1990)	X	
Some water bugs (Parker and Wright 1992)		X

Taxonomic Group and Study Reference	More Tolerant to low pH (Less Sensitive)	Less Tolerant to low pH (More Sensitive)
Caddisflies (Trichoptera)		
Some caddisflies: <i>Cheumatopsyche pettiti</i> (Camargo and Ward 1992).	X	
Some caddisflies (Parker and Wright 1992) and some in the scraper and predator guilds (Williams 1991)		X
Flies, Midges, Mosquitoes (Diptera)		
Midges (Havens 1994a, Baker and Christensen 1990, Tuchman 1993)	X	
Some midges, such as <i>Tanytarsus</i> , <i>Microtendipes</i> , and <i>Nilothauma</i> (Griffiths and Keller 1992)		X
Stoneflies (Plecoptera)		
Some stoneflies (Tuchman 1993) such as <i>Amphinemura</i> and <i>Leuctra</i> (Griffith et al. 1995)	X	
Many stoneflies, e.g., <i>Peltoperla arcuata</i> (Griffith et al. 1995)		X
Mayflies (Ephemeroptera)		
The mayfly <i>Eurylophella funeralis</i> (Griffith et al. 1995)	X	
Some mayflies (Balding 1992)		X
Other Macro-invertebrates		
Planarian <i>Dugesia dorotocephala</i> (Camargo and Ward 1992)		X
Some water mites (Havens 1994a)	X	
Molluscs (Grapentine and Rosenberg 1992, Gibbons and Mackie 1991, Balding 1992), including clams (Schell and Kerekes 1989)		X
Mussels, snails, leeches (pH >5.0, Schell and Kerekes 1989)		X
The amphipod <i>Hyaella azteca</i> (Havens 1994a); pH must remain above 5.8 (Grapentine and Rosenberg 1992)		X
The amphipod <i>Gammarus minus</i> (Griffith et al. 1995)		X
Zooplankton		
Some zooplankters, such as <i>Daphnia galeata mendotae</i> , <i>D. retrocurva</i> , <i>Skistodiaptomus oregonensis</i> (Havens 1993)	X	
The rotifers <i>Gastropus stylifer</i> , <i>Keratella taurocephala</i> , <i>Polyarthra renata</i> , <i>Symchaeta</i> sp. (Fore et al. 1996)	X	
The water flea <i>Bosmina longirostris</i> (Havens 1993)		X

Taxonomic Group and Study Reference	More Tolerant to low pH (Less Sensitive)	Less Tolerant to low pH (More Sensitive)
The rotifers <i>Asplanchna priodonta</i> , <i>Collotheca mutabilis</i> , <i>Conochiloides</i> sp., <i>Conochilus unicornis</i> , <i>Gastropus hyptopus</i> , <i>Kellicota longispina</i> , <i>Keratella cochlearis</i> , <i>Keratella crassa</i> , <i>Polyarthra dolichoptera</i> , <i>Trichocera cylindrica</i> (Fore et al. 1996)		X
Functional Feeding Groups		
Scrapers and collectors (Smith et al. 1990)	X	
Shredders (Tuchman 1993)		X
Deposit feeders (Smith et al. 1990)		X

4.9.5 Impacts on Amphibians and Reptiles from Changing the Acidity in the Habitat

Increased acidity (lower pH) damages amphibians directly (Horne and Dunson 1994b). Acidity may also have direct impacts as a result of its capacity to mobilize toxic metals and perhaps by making sodium less available in some soil types (Wyman and Jancola 1991).

No studies were found describing the impact of increased acidity on amphibians and reptiles in Washington. Studies from other states, however, document these impacts. The information below summarizes some of the information for amphibian and reptile species that are found in the state, even if the studies were done elsewhere.

In Ontario, the acid-neutralizing capacity (alkalinity) of 38 wetlands positively influenced the probability of the northern leopard frog (*Rana pipiens*) being present (Glooschenko et al. 1992).

Embryos of the tiger salamander (*Ambystoma tigrinum*) had more than 70% survival at pH 4.5 and above but suffered much greater mortality at lower pH levels (Whiteman et al. 1995).

Concerns have been raised regarding the vulnerability to acidification of Montane wetlands in the West. Acidification makes aluminum and cadmium more mobile and increases their concentration in surface waters. Amphibians (e.g., Jefferson's and spotted salamanders) are known to be sensitive to acidity and elevated concentrations of aluminum found in some acidic ponds (Blancher 1991, Ireland 1991, Horne and Dunson 1995).

Aluminum released into Montane pools as a result of acidification sometimes has harmed embryos, reduced growth rates, and/or caused deformities and premature hatching of native amphibians (Bradford et al. 1991, Corn and Vertucci 1992).

4.9.6 Impacts on Fish from Changing the Acidity in the Habitat

No information was found on the impacts of acidity on fish in Washington's wetlands. In their review of the literature, Adamus et al. (2001) found that acidity can be directly toxic to fish, inhibit reproductive maturation, inhibit spawning behavior, induce emigration, and alter food availability. Furthermore, in areas where acid rain may be a problem, the increase in acidity induces aluminum toxicity in fish in many lakes and wetlands (Keller and Crisman 1990). Surveys of literature on effects of acidification on fish in lakes (and therefore potentially in wetlands along lake fringes) are provided by Baker and Christensen (1990) and Minns et al. (1990).

4.9.7 Impacts on Birds from Changing the Acidity in the Habitat

Acidification of wetlands affects birds primarily because it reduces the availability of calcium, which is important for egg development; potentially increases the availability of toxic metals; and alters the species composition and abundance of aquatic insects, submersed plants, amphibians, and fish that are important foods for waterfowl (see previous discussions in Sections 4.9.3, 4.9.4, 4.9.5, 4.9.6).

Changes in the types of available food, especially those rich in calcium, can diminish egg shell thickness and generally reduce the reproductive success of waterbirds in wetlands (Sparling 1990, 1991, Blancher and McNicol 1991, St. Louis et al. 1990, Albers and Camardese 1993). Overall, calcium deficiency appears to affect birds in acidified wetlands more than metal toxicity (Albers and Camardese 1993). Breeding pairs of 15 waterfowl species were more abundant in Ontario wetlands with over 40 parts per million (ppm) of total alkalinity than in less alkaline wetlands (Dennis et al. 1989, Merendino et al. 1992). In British Columbia as well, densities of several breeding duck species were greater in ponds with higher levels of conductivity and calcium (Savard et al. 1994).

4.9.8 Impacts on Mammals from Changing the Acidity in the Habitat

No information on the effects of acidification on the overall community structure of wetland mammals was located. It can be hypothesized, however, that where acidification becomes severe, community composition may shift from fish-eating species (e.g., otter) to vegetarian or invertebrate-eating species and opportunists (e.g., muskrat) (Adamus and Brandt 1990).

4.9.9 Summary of Key Points

- No information was found on the impacts of acidity on the hydrologic functions of wetlands, but it is possible to hypothesize that impacts, if any, are minor.
- The rates at which wetlands remove nitrogen are impacted by increasing acidity because denitrification is reduced.
- The rates at which toxic metals and other contaminants are removed by soils can change with acidity, but the actual changes depend on the chemical properties of the contaminant.
- Increasing the acidity in wetlands can also change the composition of the plant community.
- Impacts of increasing acidity on the habitat provided by wetlands have been documented for invertebrates, amphibians, fish, and birds. In general, increased acidity reduces the richness of invertebrates in wetlands and impacts amphibians either directly or by changing the chemistry of the water in the wetland, making it less suitable as a habitat. Acidic wetlands also become a less suitable habitat for birds because the amounts of calcium rich foods are reduced. Mammals are the only group of vertebrates for which no information exists.

4.10 Impacts from Increasing the Concentrations of Salt in a Wetland

Salt concentration in wetlands can increase as a result of (from Adamus et al. 2001):

- Isolating wetlands from some types of groundwater inflow
- Increasing water lost through evaporation
- Discharging effluents that contain salts (especially irrigation return water)
- Routing runoff that has relatively high conductivity into wetlands

Increased concentrations of salt (salinization) impact the functions of wetlands as described below.

4.10.1 Impacts on Hydrologic Functions from Increasing Concentrations of Salt

No information was found on how changes in salt content might affect the hydrologic functions of flood storage and flood desynchronization [the process by which peak flows are

delayed in their downstream movement (Adamus et al. 1991)]. However, it is possible to hypothesize that salinization will probably not change how wetlands in Washington perform these functions. Changes in the salt content of water coming into a wetland are not expected to change the physical structure of the wetland on which the hydrologic functions are based. Increasing salt concentrations are not expected to change how well wetlands store water, how well they slow it down during peak flows, or how well they recharge groundwater.

4.10.2 Impacts on Functions that Improve Water Quality from Increasing Concentrations of Salt

One relevant study found that salinities greater than about 300 grams per liter can inhibit the ability of microbes to detoxify toxic forms of selenium (Steinberg and Oremland 1990). This was the only literature found on how salinization might impact the ability of wetlands to remove pollutants.

As noted below, salinization has some impacts on plants, and thus it may affect nutrient uptake and transformation in a wetland. However, it is not possible to predict or hypothesize how such changes in these species might change other functions that improve water quality.

4.10.3 Impacts on Plants from Increasing Concentrations of Salt

In general, high concentrations of soluble salts are lethal to freshwater plants, and lower concentrations may impair growth (Rendig and Taylor 1989). Woody plants tend to be less tolerant than herbaceous plants because they do not have mechanisms for removing salt, other than accumulating salts in leaves and subsequently dropping them (Adamus et al. 2001).

Many plant species that inhabit inland saline wetlands are, of course, adapted to tolerating salt levels that would kill most other freshwater wetland plant species. A survey of inland lakes in western Canada which spanned a salinity gradient identified relative tolerance to salinity and specific salinity tolerance thresholds of many wetland species (Hammer and Heseltine 1988).

Individual plant species have different tolerances and reactions to increasing salinity. It can be expected that the plant community in a wetland will change to one dominated by salt-tolerant plants when additional salts are introduced. For example, wetlands in which salt has been present for some time, such as alkali wetlands, have a completely different plant community than that found in non-alkali wetlands. In eastern Washington a major change in plant communities was found when the conductivity (a measure of the amount of salts present in the water) increased to 2.0 milliSiemens and higher (Hruby et al. 2000).

A study by Hutchinson (1991) describes the tolerance of many wetland plants found in Washington. It can be used to predict how the plant species might change in Washington's wetlands as salt concentrations increase.

It can also be expected that wetlands subject to increases in salinity through agricultural practices or discharges of salt will also be subject to a change in plant populations. One wetland undergoing such a change was observed in the Richland area by the technical team calibrating the Washington State wetland rating systems in the summer of 2002. The conductivity of the wetland was measured at about 6.5 milliSiemens. About one-quarter of the area was still dominated by cattails (*Typha latifolia*), a wetland plant with a relatively low tolerance to salt (Hutchinson 1991), but this species was dying. Dead stalks of this species covered almost half the area of the wetland.

4.10.4 Impacts on Invertebrates from Increasing Concentrations of Salt in the Habitat

The review of the literature indicates that high levels of salinity can alter the structure of freshwater invertebrate communities in many ways. Adamus et al. (2001) have identified the following mechanisms by which the invertebrate community can be altered:

- Acute and chronic damage to tissues of invertebrates
- Changes in the species composition and structure of algal communities and aquatic plants upon which some invertebrates depend for food and shelter
- Changes in predation on invertebrates by decimating numbers of other crustaceans, fish, and amphibians
- Changes in the bioavailability of some other substances, such as heavy metals and nutrients

Even at low concentrations, increases in chloride (a correlate of salinity, and often associated with road salt applications) among twenty-seven Minnesota wetlands were significantly correlated with declines in species richness among the wetlands (Gernes and Helgen 1999). In Wyoming wetlands of fairly low salinity (0.8 to 30 milliSiemens per centimeter), the dominant macro-invertebrates were amphipods and epiphytic snails. Other recent species-specific data on the impacts of salinity in wetland invertebrates are presented in Parker and Wright (1992), and Lovvorn et al. (1999).

4.10.5 Impacts on Amphibians and Reptiles of Increasing Concentrations from Salt in the Habitat

In general, relatively little is known about amphibian tolerance to salinity in Washington. Three studies have reported a statistically significant negative correlation between conductivity of the water and amphibian species richness (Azous 1991, Platin 1994, Platin

and Richter 1995). However, the implications of these studies for understanding impacts on existing populations of amphibians in a wetland that is undergoing an increase in salt concentrations is not clear.

4.10.6 Impacts on Fish from Increasing Concentrations of Salt in the Habitat

No information was found on the tolerance of native fishes in Washington to salinity. Adamus et al. (2001) reported the following information relative to some of the introduced game fish that now are found in Washington's wetlands.

Laboratory trials consisting of 120-day exposure of freshwater largemouth bass (*Micropterus salmoides*) to four salinity levels (0, 4, 8, and 12 ppm) indicated a significant decrease in growth rate with increasing salinity up to 8 ppm.

In another experiment, juvenile bluegill (*Lepomis macrochirus*) from a freshwater pond in northeastern Mississippi and a brackish bayou in coastal Mississippi were held in a chamber with zero salinity but given access to chambers containing 0, 2, 4, 6, 8, and 10 ppm salinity (Peterson et al. 1993). Fish from neither habitat showed a clear preference for any of the salinity options. These data and data from previous studies suggest bluegills are better able to physiologically and behaviorally tolerate elevated salinity relative to other centrarchids (the family of fish containing bluegills, bass, crappies, etc.), particularly bass (Peterson et al. 1993).

4.10.7 Impacts on Birds from Increasing Concentrations of Salt in the Habitat

The impacts of increasing salinity on birds are highly dependent on the species in question. The following summarizes relevant studies:

- Highly saline or alkali conditions are detrimental to some invertebrate and plant foods used by many duck species. High salinity is directly toxic or impairs the growth of young ducklings (Clark and Nudds 1991, Moorman et al. 1991).
- Breeding densities of most duck and grebe species in interior British Columbia were greater in ponds with higher conductivity (higher salt content), but marsh nesting species were unaffected (Savard et al. 1994).
- Some species of water birds are very tolerant of high salt concentrations. They occur regularly at very high densities in alkali wetlands during the breeding season and/or migration. Examples include the American avocet (*Recurvirostra americana*), snowy plover (*Charadrius alexandrinus*), phalaropes, killdeer (*Charadrius vociferus*), horned grebe (*Podiceps auritus*), tundra swan (*Cygnus columbianus*), and white-rumped, semipalmated, and Baird's sandpipers (*Calidris* spp.) (Jehl 1994, Savard et al. 1994, Oring and Reed 1997, Rubega and Robinson 1997, Warnock 1997).

4.10.8 Impacts on Mammals from Increasing Concentrations of Salt in the Habitat

No information was found on the impacts of salinization on the overall structure of mammal communities in wetlands and changes in the suitability of wetlands as habitat for mammals.

4.10.9 Summary of Key Points

- No information was found on the impacts of salinization on the hydrologic functions of wetlands, but it is possible to hypothesize that impacts, if any, are minor.
- Only one study was found that documents any impacts of salinization on the ability of wetlands to improve water quality. Very high salt concentrations inhibit the microbes that detoxify selenium.
- Increasing the salt concentrations in wetlands can change the composition of the plant community because specific species are more tolerant of saline conditions than others.
- Impacts of increased salt concentrations on the habitat provided by wetlands have been documented for invertebrates, fish, and birds. In general, increased salinity changes the composition of the invertebrate community in wetlands. Largemouth bass seem to be especially sensitive to increased salinity relative to other species. The young of some waterbird species may also be sensitive, but other species seem to prefer high salinities. No information exists on the impact of salinization on mammals and amphibians.

4.11 Impacts from Fragmenting Wetland Habitats

Fragmentation results directly from human conversion of land to other uses. As described in Chapter 3 fragmentation is a result of both the direct loss of wetland area that isolate populations of wildlife and from changes to the spatial configuration of the wetlands in the landscape. Wetland loss and isolation is seen as a major factor contributing to the loss of biological diversity in vertebrate populations that use wetlands (Harris 1988, Gibbs 2000).

In general, fragmentation of habitats affects biological diversity through (Harris 1988):

- Loss of the species less tolerant to disturbance or those that inhabit the interior parts of wetlands
- Loss of large species with broad ranges
- Loss of genetic integrity within populations
- Increase in numbers of habitat generalists that thrive in disturbed environments, such as parasites

Occasional migration between wetlands is vital in sustaining local populations of wetland-dependent organisms. Limiting the movements of these species reduces the exchange of genetic material among local populations and can result in population extinctions (Gibbs 2000). Three factors that impede movement among wetlands and other habitats include (Gibbs 2000):

- Greater distances between wetlands
- Degradation of upland habitats
- Increased road density

The effects of fragmentation on wildlife that use wetlands are most extensively documented for amphibians and birds. Little information is available for effects on macro-invertebrates, reptiles, and mammals. Several studies done in the Pacific Northwest are cited in the following discussion of how fragmentation impacts wetland functions.

4.11.1 Impacts on Hydrologic Functions from Fragmentation

No information was found on how fragmentation may impact the flood storage, flood desynchronization, and groundwater recharge performed by individual wetlands. It is possible, however, to hypothesize that fragmentation will probably not change how individual wetlands still remaining in the landscape perform these functions. Fragmentation at a landscape level is not expected to change how well the remaining individual wetlands store water or how well they slow it down during peak flows. On the other hand, fragmentation probably does impact the delivery and routing of water to wetlands as described in Chapter 3. This may change how much water gets to a wetland for storage but not how well the wetland can store it.

4.11.2 Impacts on Functions that Improve Water Quality from Fragmentation

No information was found on how fragmentation may impact the ability of wetlands to improve water quality. It is not possible to hypothesize precisely how such changes might affect these functions because related information was also not found.

4.11.3 Impacts on Plants from Fragmentation

The only information found on the response of wetland plant communities to fragmentation are the series of studies carried out by J. Lienert in fens of Switzerland (Lienert, Diemer and Schmid 2002; Lienert, Fischer et al. 2002; Lienert, Fischer, and Diemer 2002; Lienert and Fischer 2003). These studies on the populations of individual obligate wetland plants show that fragmentation can have the following impacts:

- Fragmentation can reduce the genetic variability in a population (Lienert, Fisher, et al. 2002)
- Fragmentation reduces the densities and size of a plant population (Lienert and Fischer 2003)
- Fragmentation reduces the viability of a plant population (Lienert, Diemer and Schmid 2002)
- Fragmentation can lead to the local extinction of a wetland species (Lienert, Fischer, and Diemer 2002)

4.11.4 Impacts on Invertebrates from Fragmentation

Few studies were found that documented the impact of decreasing connections on the suitability of wetlands as habitat for invertebrates. One study found that wetland isolation combined with the harshness of the surrounding upland landscape in more arid environments (such as much of eastern Washington) limit dispersal and colonization by aquatic invertebrates (Myers and Resh 1999).

Another study in New York comparing macro-invertebrate populations at restored wetlands and reference wetlands showed that less mobile invertebrates colonized new wetland sites very slowly or not at all, whereas insects that disperse aerially colonized the new sites rapidly (Brown et al. 1997). Therefore, wetland isolation may have greater effects on less mobile invertebrate species.

4.11.5 Impacts on Amphibians and Reptiles from Fragmentation

4.11.5.1 Amphibians

As early as the mid-1960s, researchers in various parts of the country documented the effects of fragmentation on amphibians. One author notes the disappearance of a number of species of frogs, toads, turtles, and snakes in an urbanizing area in the Midwest that he studied from 1949 to 1964 (Minton 1968).

The effects of increased wetland isolation have been extensively studied for amphibians since then. This is probably because amphibians:

- Are restricted to movement on the ground
- Do not typically have large migration ranges
- Often move between terrestrial and aquatic habitats
- Have experienced significant population declines throughout the world

The causes of declines in the populations of amphibians have been extensively studied and most researchers conclude that the problem is very complex and multiple factors are likely at work (Hayes and Jennings 1986, Pechmann et al. 1991, Pechmann and Wilbur 1994, Delis et al. 1996, Adams 1999a). Among these factors, there is evidence that increasing isolation of wetlands due to wetland loss may play a significant role in declining amphibian populations (Ostergaard 2000, Adams 1999a, Lehtinen et al. 1999, Semlitsch and Bodie 1998). This has significant implications for amphibians in Washington State because about 97% of amphibian species that occur here commonly use wetlands for at least one life cycle stage (Leonard et al. 1993).

Amphibians are not randomly distributed within acceptable habitats—they occur in higher abundance and species richness in habitats that are better connected to other desirable habitats (Lehtinen et al. 1999, Lehtinen and Galtowitsch 2001). A Minnesota study of 21 marshes noted that the two most important predictors of decreases in amphibian species richness in agricultural areas are the degree of wetland isolation and the road density (Lehtinen et al. 1999). The marshes in this study were located in both prairie and hardwood forest ecoregions in two primary land-use settings: urban and agricultural. The study noted some differences between ecoregions and land-use effects. In the agricultural prairie ecoregion, the amphibian assemblages observed appeared to be most influenced by:

- Road density
- Wetland isolation
- Biological interactions (presence of predators)

In deciduous forest areas that are urbanizing, amphibian richness was most closely related to upland land use and associated habitat fragmentation.

Other landscape-based studies also conclude that the distances between wetlands, as well as the suitability of terrestrial habitats, are key factors in amphibian distribution. Amphibian recolonization patterns are species and spatially dependent because not all species have the capacity to move beyond fragmented, isolated habitats (Lehtinen and Galatowitsch 2001).

Declines in the richness of amphibian species have also been documented as urban land use increases (Lehtinen et al. 1999, Knutson et al. 1999, Richter and Azous 2001a). A landscape analysis of habitats for anurans (frogs and toads) in Wisconsin and Iowa showed that anurans were positively associated with uplands, wetland forests, and emergent wetlands and negatively associated with urban land (Knutson et al. 1999). A positive association, in this study, means higher abundance and species richness. The negative association with urban land is attributed by the authors to:

- Conversion of habitat
- Roads acting as barriers
- Presence of exotic predators
- Chemical contamination
- Other factors

A study of the distribution of frogs in the Netherlands found that the likelihood of a pond being used by frogs depended on the density of ponds and the amount of suitable terrestrial habitat in the surrounding area (Vos and Stumpel 1995). A similar study in the Netherlands showed that frog use of ponds was negatively correlated with the degree of wetland isolation and road density in the surrounding landscape (Vos and Chardon 1998). Distances between breeding ponds and other life stage habitats, as well as the condition of the terrestrial habitats, were primary factors in determining frog distribution. Open fields were avoided by adults and newly metamorphosed juveniles. Roads increased the mortality of frogs and acted as barriers between wetlands, thus effectively increasing wetland isolation (Vos and Chardon 1998).

Similarly, an Indiana study concluded that amphibian distribution was influenced by (Kolozsary and Swihart 1999):

- Forest area and proximity
- Density of ponds
- Duration of ponding
- Density of vegetation

The importance of each factor varied for each species.

Using a simulation model, one author concluded that the amount of breeding habitat had a significantly greater effect on the likelihood of population extinction than the extent of habitat fragmentation (Fahrig 1997). Her model showed that if breeding habitat covers more than 20% of the landscape, population extinction is very unlikely no matter how fragmented the habitat. However, this work was based on a generalized model that made a number of assumptions that cannot be verified without targeting a selected species, as do the more empirical studies of amphibian distribution.

Other studies indicate that there is a threshold for wetland isolation or distance between wetlands for the movement of each amphibian species. Several studies of maximum distances of amphibian movement to breeding habitats indicate that amphibian reproductive success is affected by wetland isolation and terrestrial habitat condition:

- Richter and Azous (1995) suggest that upland forest habitat must lie within 3,280 feet (1,000 m) of breeding wetland habitat for it to be useful to lentic (pond) breeding amphibian species in the Pacific Northwest.
- Baker and Halliday (1999) found limits on the distance that species of newts, frogs, and toads would move to colonize new ponds in England (1,312 feet [400 m] for newts, 3,117 feet [950 m] for frogs and toads). The authors also found that, in contrast to other studies, the condition and nature of the adjacent upland habitats did not have a strong correlation to pond colonization. The study may not have been sensitive enough, or the mixed land uses within the agricultural settings may have actually supported amphibian populations.

- The ability of juveniles to move from one wetland to the next depends on the spacing between wetlands and the habitat conditions within the buffers. Distances between ponds directly affect the probability of recolonization and the chance to prevent extinction of amphibian populations. Most individual amphibians cannot migrate long distances and adults return to their home ponds, usually after migrating no more than 656 to 984 feet (200 to 300 m) (Semlitsch 2000).
- A similar study in the Netherlands showed that amphibians would colonize new ponds up to 3,280 feet (1,000 m) away (Laan and Verboom 1990). The authors concluded, however, that the probability of a species colonizing a wetland increases with proximity to the source wetland and increased connectivity by upland forest habitats between the wetlands.

4.11.5.2 Reptiles

No studies were found that specifically addressed the effects of fragmentation on reptiles. In one study in North Carolina, researchers evaluated the adequacy of federal and state wetland regulations in protecting the habitats that freshwater turtles need to complete their life cycles (Burke and Gibbons 1995). They determined that the area protected as wetland under federal guidelines did not include the area in which two critical life-cycle stages occurred: nesting and terrestrial hibernation. This means that some of the habitats needed for turtle success are vulnerable to loss due to conversion to other land uses. However, this study focused not on the effects of wetland loss but the effects of eliminating upland habitats adjacent to wetlands.

A study that modeled the effects of wetland loss in Maine showed that local populations of freshwater turtles faced a statistically significant risk of extinction following the loss of small wetlands (Gibbs 1993).

As with amphibians, the limited dispersal distances of reptiles, in comparison to birds and mammals, would logically make reptiles particularly vulnerable to habitat fragmentation. However, documentation of the effects of habitat fragmentation on reptiles that use wetlands is very sparse, and it appears to be completely lacking for Washington State. With the exception of the western pond turtle (*Clemmys marmorata*) and the painted turtle (*Chrysemys picta*), no reptile species in Washington are primarily dependent on aquatic habitats. The terrestrial western and common garter snakes (*Thamnophis* spp.), however, are both common near water bodies, including wetlands.

4.11.6 Impacts on Fish from Fragmentation

No information was found on the impacts of fragmentation on the suitability of wetlands as habitat for fish. Also, not enough related information was found to make any hypotheses.

4.11.7 Impacts on Birds from Fragmentation

The impacts of fragmentation have generally been studied in two types of fragmented landscapes: one fragmented by growing urbanization and one fragmented by agricultural practices. In general there are no studies or conclusions in the literature that would suggest the fragmentation from these two types of land use has significantly different impacts on populations of birds, and so both types of studies are reported below.

The extent of wetland isolation is known to be an important factor that influences bird use of wetland habitats:

- In a study of Puget Sound wetlands, researchers documented a positive association between bird species richness and the proximity of lakes and open water habitats, as well as the structural complexity of the vegetation in the wetlands (Richter and Azous 2001b). This implies that fragmentation results in a reduction in species richness.
- In northern prairie marshes, bird species richness declined with increased isolation of the wetland (Brown and Dinsmore 1986). Marshes that were part of wetland complexes showed higher species richness than isolated wetlands. Smaller marshes had occurrences of certain bird species only when the marshes were part of a wetland complex.
- These findings are supported by a more recent study of wetland complexes in prairie marshes in Iowa (Fairbairn and Dinsmore 2001). This study related bird species richness and densities of individual species to habitat variables within the wetland complexes and to area of wetland habitat in the surrounding landscape. For some bird species, presence and abundance in a wetland complex were clearly related to the amount of wetland habitat in a 1.9 mile (3 km) area surrounding the complex. A similar study also determined that unfragmented landscapes with prairie marsh supported more waterfowl species than isolated wetlands (Naugle et al. 2001).

The pattern of habitat use in, and around, wetlands varies between different bird species that depend on wetlands (Naugle et al. 1999):

- Some species are sedentary and rarely use resources beyond the nest vicinity
- Some use only larger wetlands regardless of the surrounding landscape
- Others require a mosaic of wetlands on the landscape

Therefore, the entire landscape must be assessed, rather than just individual wetlands in order to determine the habitat suitability of an area for many species.

A correlation has been found between the degree of urban development in an area (and the resultant fragmentation) and the extent of declines in native bird species richness. One study in Santa Clara County, California, looked at six sites representing a gradient of development ranging from biological preserve to business district (Blair 1996). Increasing proportions of invasive and exotic bird species were found in the more highly developed areas. The moderately developed sites were highest in species richness and bird biomass. They were, however, lower in native bird diversity than the lesser disturbed sites. The shift in species

was related to changes in total available habitat and in habitat structure across the gradient. This study concluded that even relatively minor habitat alterations resulted in loss of species.

Wetlands in the Puget Sound area showed a similar response to urbanization. Researchers found no correlation between total bird species richness and amount of impervious surface, but there was a correlation with native species richness (Richter and Azous 2001b). The rarer, more sensitive birds, all of which are native, tended to decrease with urbanization. The more adaptive species, including a higher percentage of non-natives (e.g., European starlings [*Sturnus vulgaris*]), tended to increase in urbanizing watersheds. Again, these changes are most likely due to loss of habitat, and therefore reduced connections between habitats, as well as habitat degradation.

One study conducted in eastern Canada examined the role that habitat heterogeneity plays in the use of wetlands by ducks (Patterson 1976). It concluded that breeding duck pairs spaced themselves based on the physical size of the wetland. The authors also observed that breeding can occur in relatively less productive wetlands. However, duck broods hatched in less productive wetlands often moved to more biologically productive wetlands where there was a greater food source and more refuge/escape habitat. These preferable wetlands were close to the breeding wetlands because young waterfowl cannot fly. This would suggest that heterogeneity in the types of wetlands in an area are important in maintaining populations of ducks.

As with amphibians, the presence of terrestrial habitats between wetlands can be an important factor in waterfowl distribution. A study conducted in an area of intensive wheat farming demonstrates the importance of maintaining connections among habitats for birds (Saunders and DeRebeira 1991). These researchers found that native bird species used corridors as narrow as 13 feet (4 m) to move between patches of preferred habitat. Corridor width was positively correlated with species richness.

A study of bird populations in forest interiors found that habitat fragmentation impairs reproduction and can result in population declines and extinctions (Temple and Cary 1988). Though not focused on wetlands, the study can reasonably be applied to forested wetlands. The authors modeled the effects of habitat fragmentation. They predicted that success rates for nests for forest-interior birds would drop from 70% when nests are greater than 656 feet (200 m) from the forest edge, to only 18% when nests are less than 328 feet (100 m) from the edge. This indicates that fragmentation of forested wetlands through such activities as logging could have significant effects on species that are not tolerant of edge habitats.

In Minnesota, Mensing et al. (1998) assessed the implications of fragmentation at various landscape scales for birds. They found that:

- Diversity and richness of bird species increased with an increase in the extent of forest and wetland within the surrounding landscape.
- Habitats that were in good condition in the areas surrounding wetlands strongly influenced the biotic diversity, with positive correlations shown for birds within 1,640 feet (500 m) of the wetland edge.

4.11.8 Impacts on Mammals from Fragmentation

Information on the effects of fragmentation on mammals that depend on wetlands is sparse, even though many of the mammal species in Washington State are known to commonly use wetlands (beaver, muskrat, mink, otter, water vole, deer mouse, and others). Most of the literature on mammals in wetlands addresses the effects of beaver dams on wetland systems.

One study from the Pacific Northwest documented that fragmentation of wetlands and the elimination of surrounding upland habitats can have significant effects on small mammals that use wetlands (many of which are not, however, closely associated with wetlands). Richter and Azous (2001c) found that the total area of undeveloped land adjacent to a wetland (including forest, shrub, agricultural fields, and meadows) was weakly associated with mammal richness. A stronger correlation, however, was found between the percent of adjacent forest land (within 1,640 feet [500 m] of a wetland) and mammal richness. The highest small-mammal richness was observed in wetlands with at least 60% of the first 1,640 feet (500 m) surrounding the wetland in forest. The authors noted that richness of mammal species in Puget Sound wetlands has no correlation with area of impervious surface in the watershed.

Roads are an important factor in habitat fragmentation for mammals. For example, a major highway in Massachusetts increased wetland isolation and blocked major travel corridors between suitable habitat patches for mammals (Forman 1998). See Section 4.12.2 for additional discussion of effects of roads on wildlife.

4.11.9 Summary of Key Points

- No information was found on the impacts of fragmentation on the hydrologic functions or the functions that improve water quality.
- Increased isolation of wetlands appears to be a major factor in reducing species richness and abundance for most taxonomic groups. One author states that “modifications to the environment that preclude movement between component subsystems may be as devastating to vertebrates in the long run as are forces that actually destroy the wetland” (Harris 1988).
- Impacts of fragmentation on the habitat provided by wetlands have been documented for plants, invertebrates, amphibians, reptiles, birds, and mammals. No information was found on impacts to fish in wetlands.
- The impacts of habitat fragmentation are not as well documented for birds and mammals as they are for other taxonomic groups. There are different patterns of habitat use between groups of birds and mammals that can influence how they respond to fragmentation (Johnson and O’Neil 2001).

4.12 Impacts from Other Human Disturbances

There are many different human activities on the land which create disturbances that can impact wetland functions and values. The previous discussion addressed only impacts from disturbances caused by activities that have been extensively studied. The following sections review some of the impacts of other types of activities and disturbances that have been documented to a lesser extent. The discussions in these sections are not separated by wetland function because all of the impacts address either plants or wildlife, and the information is not extensive enough to warrant subdividing by functions.

4.12.1 Impacts on Plant Communities from Altering Soils

Physically disturbing wetland soils during the dry season, through tillage, compaction, excavation, or other means, can allow invasion by non-native plant species (Morin et al. 1989, Sutton 1996, David 1999, Galatowitsch et al. 1999). It can also destroy much of the viable seed bank (Lee 1991). Tilling the soil often reduces diversity, including both richness and evenness, as documented in a Carolina bay wetland (Kirkman and Sharitz 1994). The tillage treatment disrupted the roots of perennials more than burning, and it encouraged germination of annuals in the seed bank and colonization by several invasive species.

Invasive plants, especially non-native plants, significantly alter the species composition of many wetlands, sometimes even forming nearly monotypic stands. Among the most widespread invaders in North America are cattail (*Typha*), reed canarygrass (*Phalaris* sp.), purple loosestrife (*Lythrum salicaria*), giant reed (*Phragmites* sp.), milfoil (*Myriophyllum spicatum*), and hydrilla (*Hydrilla verticillata*). Their increased dominance is frequently attributed in part to the physical disturbance of soils or water levels within a wetland and/or the surrounding landscape, including accelerated sedimentation, eutrophication, and the construction of mitigation wetlands (Confer and Niering 1992, Magee et al. 1999).

Continuously disturbing the soil, for example through compaction and road building, can alter species composition. These disturbed conditions can lead to a decline in both the biomass of native species and a change in the soil conditions that support them (Ehrenfeld and Schneider 1991). Use of all-terrain vehicles also impacted wetlands on the Atlantic coastal plain, reducing the density of seed in wetland seed banks and allowing common rushes to displace rare species (Wisheu and Keddy 1991). Excavation and clearing of gas pipeline rights-of-way through forested wetlands in Florida resulted in increased species richness within the wetland clearings but an increased percent cover of non-native species (Van Dyke et al. 1993).

4.12.2 Impacts on Wildlife from Roads

Roads have been found to contribute to lower species richness for a variety of wildlife groups through the factors listed below. While most of the studies cited in this section were conducted in other regions of the country, much of the information is likely to pertain to effects on Pacific Northwest wildlife because the types of impacts described are inherent to

roads regardless of region, and many of the species impacted are also found in the Northwest. Furthermore, Findlay and Bourdages (2000) note that there may be long time lags between road construction and the time when effects on wildlife are perceptible. Impacts may be undetectable in some species for decades.

It is theorized that roads cause the loss of biodiversity by (Findlay and Bourdages 2000):

- Restricting movement between populations of wildlife
- Increasing mortality from road kills
- Fragmenting habitat
- Increasing edge habitat that increase the habitat for “generalist” species
- Facilitating invasion by exotic species
- Increasing human access to wildlife habitats

The following studies have documented the impacts of roads on different species of wildlife.

- In wetlands of southeast Ontario, the species richness of mammals, amphibians, reptiles, and birds was seen to decline with increased road density and forest removal (Findlay and Houlihan 1997).
- The numbers of frog and toads decreased with increasing traffic in a study by Fahrig et al. (1995). This study concluded that increased road density can contribute to a decline in the abundance of amphibians in urbanizing areas.
- A study of amphibians using small isolated wetlands in Florida found high mortality during migration between upland terrestrial habitats and temporary pond breeding habitats (Means 1996). The author attributes much of this to direct road mortality.
- A study of the “road-effect zone” of a four-lane suburban highway in Massachusetts was undertaken to determine the distance from a road that impacts can be measured (Forman 1998). This study concluded that the road blocks migration routes for salamanders up to several hundred meters from wetlands. The study also showed that the effect of the road on blocking major travel corridors between suitable habitat patches for small mammals could be measured to several kilometers from the road. The effects of traffic noise on birds could be measured up to 2,132 feet (650 m) from the road in forested areas and 3,051 feet (930 m) in open areas.
- A related study of the same Massachusetts highway showed that impacts on populations extended out at least 328 feet (100 m) from the highway. Forman and Deblinger (2000) studied nine ecological factors relating to, among other things, wetlands, streams, and amphibians. Assessing all factors, this study concluded that the “road-effect zone” averaged approximately 1,969 feet (600 m) wide, though it was quite variable in width at specific locations.
- In a study within the Columbia Basin, roads were found to increase human access and disturbance to fish and wildlife habitats, and this may reduce the number of waterfowl

using easily-accessed wetlands by an order of magnitude during the late-fall and winter months (Foster et al. 1984).

4.12.3 Impacts on Wildlife from Noise

The impacts of noise on wildlife are a topic of growing concern. The frequency of the sound waves and the duration of the sounds influence how noise affects wildlife species. Although many of the studies discussed below do not address wetlands specifically, the impacts of noise are not expected to change whether the species in question is in a wetland or another type of habitat.

Frequency is the pitch of a sound, and different animals show different sensitivities to the same range of frequencies. Generally, smaller mammals such as rodents, shrews, and bats have a greater sensitivity to higher frequencies—often within ranges exceeding 20,000 Hertz (Hz), the upper limit of human sound perception. Larger mammals show sensitivity to low frequencies and may be able to detect sound at or below 10 Hz. While most birds show a sensitivity to sound that is similar to humans (20 to 20,000 Hz), certain birds (such as rock doves) can also perceive low-frequency sounds, often with much greater sensitivity than their larger mammalian counterparts (Kreithen and Quine 1979). Some frogs and toads also show low-frequency sensitivity and even some small mammals are capable of discerning sounds of only a few Hertz (Plassman and Kadel 1991).

Sound duration may be divided into two classifications: continuous sounds which last for a long time with little or no interruption, and impulse sounds lasting for only short durations (Larkin et al. 1996). Impulse sound and continuous sound appear to have different physiological and behavioral effects. Generally, impulse noise appears to be more stressful to wildlife, at least in part due to the unpredictability of such noise (Larkin et al. 1996).

Overall, the literature suggests that species differ widely in their physiological response to various types, durations, and sources of noise (Manci et al. 1988). However, noise effects on wildlife may be broadly classified as primary, secondary, and tertiary:

- **Primary effects.** Are direct, physiological changes, such as stress and hypertension, to the auditory system and may be considered to include the “masking” of auditory signals. Masking is the inability of an individual to hear important environmental signals such as calls from mates or noises of predators or prey.
- **Secondary effects.** May include behavioral modifications that include interference with mating or reproduction and impaired ability to obtain adequate food, cover, or water.
- **Tertiary effects.** Are the direct result of primary and secondary effects at a population level and include population decline and habitat degradation. Most of the effects of noise are mild enough that they may never be detectable as variables of change in population size or population growth against the background of normal variation (Bowles 1995).

The behavioral responses of wildlife to noise show a high degree of variation depending on the species, the type of noise, and the habituation of the individuals to the source of noise. For example, some bald eagles can be very tolerant of auditory stimuli when the sources are screened from view (Stalmaster 1987), but other raptor species such as prairie falcons flush from perches and nests at sudden loud noises (Harmata et al. 1978).

Animals may become tolerant of repeated noises. Krausman et al. (1986) studied desert ungulates exposed to aircraft noise and noted that short-term habituation to aircraft noise occurred with repeated exposure. Sandhill cranes nesting meters away from a Florida highway showed no response to passing traffic (Dwyer and Tanner 1992). The effects of noise vary not only with the type of noise in question, but with an individual animal's experience, time of day (Herbold et al. 1992, Gese et al. 1989), and reproductive cycle (Platt 1977).

Research on the effects of traffic noise on breeding birds was conducted by Reijnen et al. (1995, 1996) who studied woodland and grassland bird populations in the vicinity of roadways. Ambient noise up to a given level resulted in no reduction in the density of bird populations. However, once an ambient noise threshold level was exceeded, densities decreased exponentially with increased noise. Threshold levels were found to range from 36 to 58 decibels, depending upon species, and the zones of decreased breeding densities surrounding the roadways ranged up to 2,670 feet (810 m) for particularly sensitive species near busy roadways. They found habitat avoidance by individual birds in habitat that would otherwise have been suitable for breeding.

One study also found evidence that reproductive output may be diminished in frogs breeding near highways because of acoustic interference (Barass 1985 in Larkin et al. 1996).

4.12.4 Impacts on Wildlife and Plant Communities from Recreational Activities

Little information was found on the impacts of recreational activities in wetlands. Most of the available information is anecdotal and focused on the more evident impacts such as loss of vegetation from the use of off-road vehicles. There is less information on the effects on wildlife of such disturbances as noise, light, glare, and human presence caused by recreational activities, particularly with respect to wetlands. None of the studies described in this section were located in the Pacific Northwest.

A synthesis paper on management of amphibians in Montana notes that among the many factors that are likely to contribute to a decline in amphibian populations are trail development, on- and off-road vehicles use, and development and management of recreational facilities (Maxell 2000). Citing a number of studies from the 1980s, Klein (1993) notes that recreational uses in natural areas can disrupt:

- Wildlife foraging and social behavior
- Animals that are feeding

- Parent-offspring bonds
- Pair bonds

The author also cites several studies stating that increased predation of nests and decreased densities of wildlife result from greater human recreational use of natural areas.

A study of flooded gravel pits in Britain examined the abundance and distribution of one species of wintering waterfowl with regard to recreational disturbance (Fox et al. 1994). The authors found that water-based recreational activity, such as boating, reduced the number of birds on the ponds to the greatest extent of all the observed activities. Ponds where fishing, walking, or other bank-side activities were allowed also showed reduced numbers of birds in comparison to the ponds that were designated reserves with restricted access. They were, however, not as reduced in abundance as those ponds that also allowed water-based activities.

The effects of recreational use on waterfowl were also studied in areas near the shore on Lake Erie (Knapton et al. 2000). Excessive human disturbance reduced the foraging efficiency and body fat acquisition for waterfowl and can result in decreased bird densities. Diving ducks appeared to be the most sensitive to disturbance.

In another study on recreation impacts on birds, Klein (1993) studied the specific behaviors of humans that disturb wildlife on a subtropical barrier island that is a National Wildlife Refuge off the coast of Florida. Her study sites were primarily in mudflat and mangrove wetland habitats. She tested a variety of treatments such as driving by without stopping, stopping the vehicle with and without getting out, approaching the birds on foot, and playing noise tapes. The author found that most of the bird species present were disturbed by the noise tape. Some species such as great blue heron consistently flew away when approached by a person, whereas other species tolerated human presence until closely approached.

Klein (1993) concludes that car traffic is less disruptive to wildlife than out-of-vehicle activity. Frequent human approaches may cause some bird species to forage in areas with fewer intrusions. Wildlife photographers were the most likely visitors to approach birds. Visitors who spoke with refuge staff and volunteers were the least likely to disturb birds, possibly due to an increased awareness of the habitat needs of wildlife. While this study involved a very different ecosystem, it is useful because it generated data on the Great Blue Heron, a bird species that also occurs in Washington. It also is one of the few studies that examined the effects of specific human behaviors on wildlife.

Recreational activity is believed to be one of the main factors in lakeshore deterioration and decline in reed-dominated wetlands in a study of Central European lakes (Ostendorp et al. 1995). It is likely that trampling of bank-side vegetation by recreational users is causing bank erosion and excessive siltation in wetlands near the shore.

Although recreation often occurs in more rural habitats, urbanization also brings increased intensity of recreational uses within remaining greenbelts and open spaces. A study in Western Australia examined the trend in smaller lot size relative to the owners' use of nearby open spaces (Syme et al. 2001). Smaller lot size resulted in an increase in recreational visits

by the homeowners to nearby wetlands. Increased access to and recreational use of wetlands is clearly one of the impacts that accompany urban development.

4.12.5 Introduction of Invasive and Exotic Species in Wetlands

Human activities increase the likelihood of introducing exotic animal and plant species to wetlands because they cause disturbances that favor the establishment of exotic species (Mack et al. 2000). The following factors have been found to favor the establishment of exotic species (Houck 1996, Dale et al. 2000, Mack et al. 2000, Gelbard and Belnap 2003, Maurer et al. 2003):

- Increased movement of seed and animals through higher road densities
- Greater fragmentation of the landscape that limit re-colonization of native species
- Higher densities of human land use
- Alterations of water regimes
- Direct disturbance of soils

The studies cited in the following discussion implicate disease, predation, and competition as major factors in limiting the success of native species when exotic, invasive species come in. Many of the relationships between invasive species and native species are not well understood because many environmental and biological factors play a role (Mack et al. 2000).

In Washington and Oregon, about 42 exotic vertebrate species have established populations (Witmer and Lewis 2001). These include species of 18 birds, 19 mammals, three reptiles, and two amphibians. The birds were mainly introduced for hunting or aesthetic purposes, while the mammals mostly escaped from commercial or domestic settings. The amphibians and reptiles were released pets or were introduced for food or aesthetic purposes. About 30% of these exotic species are restricted to freshwater and riparian systems, although others among this group will commonly use these habitats (Witmer and Lewis 2001). No information, however, was found on the number of exotic plant species found in wetlands.

4.12.5.1 Impacts on Wetlands from Exotic and Invasive Plants

Invasive plants, especially non-native invaders, significantly alter the composition of plant communities in many wetlands, sometimes even forming nearly monotypic stands (Adamus et al. 2001). Changes in the plant community can be expected to result in changes to all the invertebrates and microscopic organisms that are associated with specific plant species.

Among the most geographically widespread invaders in Washington's wetlands are reed canarygrass (*Phalaris arundinaceae*), purple loosestrife (*Lythrum salicaria*), giant reed (*Phragmites* sp.), and European milfoil (*Myriophyllum spicatum*). Their increased

dominance is frequently considered to be a result of human disturbances such as the following:

- Changes in soils or water levels within a wetland and/or the surrounding landscape, including accelerated sedimentation, eutrophication, and the construction of mitigation wetlands (Confer and Niering 1992, Magee et al. 1999)
- Changes in hydroperiod following urbanization (Cooke and Azous 2001)
- Increased human access and mechanical disturbance of wetlands (e.g., a study in southern Australia showed that vegetation removal and site disturbance are major factors in plant invasions; Detenbeck et al. 1999)
- Increases in sediment and nutrients resulting from agriculture or urbanization (Maurer et al. 2003).

4.12.5.2 Impacts on Species Using Wetlands from Domestic Pets

No information on the impacts of domestic pets on specific wetland-associated species was found. However, general information on predation by pets, specifically cats, indicate they can impact populations of many different small species living adjacent to residential areas. Residential development typically brings increased access to wetlands by domestic pets, primarily cats and dogs because wetlands are not fenced off.

Several studies of predation by house cats indicate that small mammals and birds were the preferred prey of house cats, but cats also killed reptiles and amphibians (Barratt 1997, Lepczyk et al. 2003). Many of the mice and rats captured by the cats are exotic species themselves. The results, however, suggest that house cats may have significant impacts on native populations as well, particularly along the fringes of suburban expansion where native mammals and birds are more common.

A study of predation by house cats in Virginia determined that individual cats caught an average of 26 animals in urban areas and 83 animals in rural areas over an 11-month period (Mitchell and Beck 1992). In another study in Michigan, Lepczyk et al. (2003) found that cats preyed on about 1 bird per week. Extrapolating these numbers of prey to the total number of cats in a specific urban or suburban area would give an astonishingly high toll attributable to house cats.

4.12.5.3 Impacts on Species Using Wetlands from Exotic Mammals and Birds

Many introduced birds are known to usurp nests of native birds or to compete with them for nest sites. European starlings (*Sturnus vulgaris*) are known to displace wood ducks, woodpeckers, and other species from their nests, often destroying the eggs and young (Witmer and Lewis 2001). Starlings also out-compete many native species for nest cavities, overwhelming them with their large numbers and aggressive behavior. Transmission of

disease, particularly from exotic birds and rodents from Europe, is also a major problem that threatens native wildlife (Witmer and Lewis 2001).

Introduced mammals affect native wildlife and plants through predation and herbivory (Witmer and Lewis 2001). For example, nutria (*Myocaster coypus*), which were introduced from South America for fur production, have tremendous impacts on wetland vegetation, uprooting plants as they dig for rhizomes and denuding vast areas (Mitsch and Gosselink 2000, Witmer and Lewis 2001). Nutria may be implicated in population declines of muskrats (*Ondatra zibethicus*), probably due to competitive exclusion (Witmer and Lewis 2001).

4.12.5.4 Impacts on Native Invertebrates from Exotic Invertebrates in Wetlands

Humans have introduced a number of non-native invertebrates to wetlands. Native invertebrate communities seem ill-adapted to compete with or avoid these alien species, but data on long-term effects to wetland communities are mostly lacking.

The zebra mussel (*Dreissena polymorpha*) has invaded many aquatic systems throughout North America. Although the zebra mussel has not yet been found in Washington, some local populations of mussels that live in wetlands may be highly susceptible if an invasion occurs. Some mussels (of the family Unionidae which is found in Washington streams and rivers) are particularly susceptible to disruptions from introduced mussels because they are relatively immobile and have long life spans, often over 10 years (Mehlhop and Vaughn 1994). Furthermore, riverine wetlands with higher alkalinity tend to be more susceptible to invasions by zebra mussels (Whittier et al. 1995).

In areas in other parts of the country that have been invaded by Zebra mussels substrates can become totally carpeted, displacing native mussels (Tucker and Atwood 1995). Some midges, snails, and caddisflies can be outcompeted as well. The mussel has minimal or positive effects on amphipods and flatworms (Wisenden and Bailey 1995). They may also concentrate contaminants, making them more available to invertebrate food chains (Bruner et al. 1994).

The rapid spread of zebra mussels may have been made more possible by the preceding decline of native mussels as a result of pollution and changes in habitat (Roberts 1990, Nalepa and Schloesser 1993, Mackie 1991, Haag et al. 1993, Whittier et al. 1995).

4.12.5.5 Impacts on Native Amphibians from Exotic Species in Wetlands

The effects of exotic species of amphibians on native amphibians that use wetlands are particularly well studied, but not well understood. Predation and competition from introduced amphibians has been suggested as one cause of population declines for native amphibian species (Witmer and Lewis 2001), but as described below the effects are complex.

Bullfrogs (*Rana catesbeiana*) are often cited as a factor in declining amphibian populations (Hecnar and M'Closkey 1996, Kiesecker and Blaustein 1998, Adams 1999a). Native to

eastern North America, bullfrogs were introduced to the Pacific Northwest in the early 1900s for hunting and food. Bullfrogs are suspected of causing amphibian declines because they prey on frogs and salamanders and are often so numerous in wetlands that they are thought to out-compete native species for space (Witmer and Lewis 2001). Studies of the role that bullfrogs play in declines of amphibian populations are, however, somewhat contradictory in their findings (Hecnar and M'Closkey 1996, Kiesecker and Blaustein 1998, Adams 1999a, Witmer and Lewis 2001). It is possible that the effects of bullfrogs may differ for various species, or their influence may be quite subtle and complex.

Several studies conducted in the Pacific Northwest have found either weak or no correlation between bullfrog presence and amphibian richness and abundance (Adams 1999a, Richter and Ostergaard 1999, Richter and Azous 1995). Data from a monitoring program of amphibians in wetlands in King County showed that bullfrogs are not causing competitive exclusion of native species (Richter and Ostergaard 1999). Native amphibian richness was not negatively correlated with bullfrog presence or with the presence of permanent water in the wetlands (Richter and Ostergaard 1999). Richter and Azous (1995) noted relatively high species richness for native amphibians in permanently ponded wetlands, the preferred habitat for bullfrogs.

Focusing on red-legged frogs (*Rana aurora*) in Puget Lowland wetlands, Adams (1999a) concluded that this species is not excluded from wetlands that also support bullfrogs. The study showed little to no negative correlation between red-legged frogs and bullfrogs. It noted that exotic fishes such as sunfish, yellow perch (*Perca flavescens*), and smallmouth bass (*Micropterus dolomieu*) had greater effect on amphibian richness in the wetlands studied. In a companion study Adams (1999b) found that habitat gradients or indirect effects of exotic vertebrates on native amphibians play major roles.

A study of red-legged frogs in the Willamette Valley in Oregon, however, stated their development was affected by both bullfrogs and exotic fishes (Kiesecker and Blaustein 1998). In this study, tadpoles showed decreased mass at metamorphosis and increased time to metamorphosis in the presence of larval and adult bullfrogs. Smallmouth bass alone had little effect on tadpole development, but red-legged frog tadpoles altered their use of microhabitats when both bullfrogs and smallmouth bass were present. Survival of tadpoles was affected only when both bullfrog adults and larvae were present, or when both bullfrog larvae and smallmouth bass were present.

4.12.5.6 Impacts on Wetland-associated Species from Exotic Fish

Non-native fish have been widely introduced into waters of the United States and Washington, both intentionally and by accident. Adamus et al. (2001) cite research showing that the effects of invading species on native fish communities are usually adverse (Baltz and Moyle 1993), especially when coupled with simultaneous impacts from other factors (Larimore and Bayley 1996, Marschall and Crowder 1996).

The presence of exotic fish has been implicated in reduced abundances and species richness of amphibians. A study in the Okanogan Highlands in northeast Washington showed that richness of pond-breeding amphibian and abundance were diminished by the presence of

exotic fish (Aker 1998). The non-native fish species observed in this study included largemouth bass, tench (*Tinca tinca*), brook trout (*Salvelinus fontinalis*), and perch. While there was lower amphibian richness in ponds with native fish than those with no fish, the data indicate that non-native fish had a greater impact on amphibian numbers and richness. Adams (1999a, 1999b) found that exotic, non-native, fish reduced survival of native amphibians to almost zero in the Puget Lowlands. Further studies by Adams (Adams et al. 2003) found that non-native fish facilitated the invasion of wetlands in Oregon by bullfrogs because they fed on invertebrate predators of bullfrog larvae.

Leonard et al. (1993) surveyed populations of the northern leopard frog (*Rana pipiens*) in Washington State. They found that the species had been extirpated from most of its historic range, with only small populations remaining in parts of eastern Washington. These authors noted that areas once inhabited by the northern leopard frog support exotic species such as largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), and brown bullhead (*Ameiurus nebulosus*). They hypothesized that these species may be implicated in the decline of the northern leopard frog but have no definitive data to support this hypothesis.

The introduction of carp has resulted in significant impacts on wetlands in eastern Washington. Large, herbivorous fish such as carp compete directly with birds for submerged aquatic plants (Bouffard and Hanson 1997). The fish also resuspend the sediments on the bottom of lakes and ponds. This has a significant impact on invertebrates as well as the submerged aquatic plants. Parkos et al. (2003) found that the presence of the common carp was positively correlated with increases of phosphorus (a nutrient that causes eutrophication), turbidity, suspended solids, and zooplankton biomass. Their presence was negatively correlated with the abundance of aquatic plants and invertebrates.

4.12.6 Summary of Key Points

- Alteration of soils can change the plant community in a wetland and allow invasion by exotic species.
- Noise creates stress for wildlife, but the impacts are very specific to individual species and to the type of noise generated.
- Recreational use of wetlands impacts the normal behavior of wildlife and reduces densities.
- Invasions by exotic species can alter the distributions of both plant and animal species in wetlands. The impacts of bullfrogs on other amphibians, however, seem to be ambiguous even though this question has been studied extensively.

4.13 Chapter Summary and Conclusions

Humans create many different types of disturbances that can affect the performance of wetland functions. The disturbances were reviewed in Chapter 3. Chapter 4 has reviewed the information available on how each type of human disturbance impacts wetlands and their functions. The disturbances that impact wetlands the most include:

- Direct changes to the physical structure of wetlands via filling, vegetation removal, tilling of soils, and compaction of soils
- Changes in the amount of water in wetlands
- Changes in how water levels fluctuate (frequency, amplitude, direction of flows)
- Changes in the amount of sediment
- Increases in the amount of nutrients
- Increases in the amount of toxic contaminants
- Changes in the amount of acidity
- Increasing the concentration of salts
- Increasing the fragmentation of habitat
- Other disturbances that are not as well documented including alteration of soils, construction of roads, noise, recreational use, and invasion by exotic species.

Table 4-3 reviews how various land-use practices create disturbances that can change the environmental factors that control wetland functions. Table 4-4 summarizes the effects of each of these disturbances in terms of the wetland functions they may impact. The rating of the impacts in the table represents a synthesis by the authors of all the information presented in this chapter. By combining the information in these two tables, it is possible to associate changes in functions of wetlands with general types of human land use, as shown in Table 4-5. The human land uses create various disturbances in the environment, and those disturbances in turn affect the factors that control wetland functions, ultimately leading to changes in those functions.

For example, Table 4-3 shows that urbanization creates significant disturbances that change the amount of water, the fluctuations of water levels, and input of sediments, nutrients, and contaminants to wetlands. Table 4-4 shows that these disturbances have a major impact on the wetland functions of providing habitat for plants, invertebrates and reptiles/amphibians. Table 4-5 synthesizes this information to show that urbanization impacts the habitat for plants, invertebrates, reptiles, and amphibians in wetlands.

The scientific information available indicates that human activities and uses of the land can have significant impacts on the functions in wetlands at both the larger, landscape scale and at the scale of the individual wetland itself. As a result many different approaches have been

developed to try to minimize these impacts. These include regulations to control human activities near wetlands, methods to replace the functions lost or altered including restoration, ways to protect the wetland resource through non-regulatory measures and incentives. The effectiveness of some of these tools at actually protecting wetland functions are discussed in Chapters 5 and 6.

Table 4-3. Summary of types of environmental disturbances created by some types of land use.

Disturbance	Scale of Disturbance	Agriculture	Urbanization	Mining
Changing the physical structure within wetlands (filling, vegetation removal, tilling of soils, compaction of soils)	Site scale	xx	xx	h
Changing the amounts of water	Landscape scale	xx	xx	?
	Site scale	xx	xx	h
Changing fluctuations of water levels (frequency, amplitude, direction of flows)	Landscape scale	xx	xx	?
	Site scale	xx	xx	h
Changing the amounts of sediment	Landscape scale	xx	xx	h
	Site scale	xx	xx	h
Increasing the amount of nutrients	Landscape scale	xx	xx	nm
	Site scale	xx	xx	nm
Increasing the amount of toxic contaminants	Landscape scale	xx	xx	x
	Site scale	xx	xx	xx
Changing the acidity	Landscape scale	nm	nm	x
	Site scale	nm	nm	xx
Increasing the concentrations of salt	Landscape scale	x	nm	nm
	Site scale	x	nm	nm
Fragmentation	Landscape scale	xx	xx	h
Other disturbances	Site scale	xx	xx	h
Key to symbols used in table: (xx) Land use creates a major disturbance of environmental factors (x) Land use creates a disturbance (nm) Studies on impacts of this land use do not mention this disturbance (h) Literature is lacking but disturbances can be hypothesized based on authors' experience (?) Information lacking				

Table 4-4. Synthesis of the information reported in the literature on the negative impacts of different human disturbances on wetland functions.

Disturbance Type	Functions							
	Hydrologic	Water Quality	Plants	Habitat for Invertebrates	Habitat for Amphibians and Reptiles	Habitat for Fish	Habitat for Birds	Habitat for Mammals
Changing the physical structure of wetlands	+	+	++	++	+	+	++	+
Changing the amount of water	+	+	++	++	++	+	+	?
Changing fluctuations of water levels	?	?	++	+	++	+	?	?
Changing amounts of sediment	+	?	++	++	?	?	?	?
Increasing amounts of nutrients	+	+	++	++	++	+	+	+
Increasing amounts of toxic contaminants	?	+	++	++	++	++	++	?
Changing acidity	0	+	+	++	++	+	+	+
Increasing concentrations of salt	0	?	++	++	?	?	+	?
Fragmentation	0	?	?	?	++	?	++	+
Other disturbances	?	?	++	+	++	++	++	++
Key to symbols used in table: ++ Major negative impacts on specific functions have been documented + Some data suggest impacts or impacts could be hypothesized 0 Data indicate that impacts are minimal ? Information is lacking								

Table 4-5. Synthesis of the negative impacts of some land uses on wetland functions.

Land Use	Functions							
	Hydrologic	Water Quality Improvement	Plants	Habitat for Invertebrates	Habitat for Reptiles and Amphibians	Habitat for Fish	Habitat for Birds	Habitat for Mammals
Agriculture	+	+	++	++	++	++	++	+?
Urbanization	+	+	++	++	++	++	++	+?
Mining	?	?	+	++	++	+	+	+?
Key to symbols used in table: ++ Major negative impacts on specific functions have been documented + Some data suggest impacts or impacts could be hypothesized ? Information is lacking +? Some impacts have been documented but more information is needed								

Chapter 5

The Science and Effectiveness of Wetland Management Tools

5.1 Reader's Guide to this Chapter

This chapter builds on the previous discussion of how wetlands function (Chapter 2), how human activities and changes in land use cause disturbances (across the landscape and at specific sites) that influence the factors that control wetland functions (Chapter 3), and how wetland functions are impacted by these disturbances (Chapter 4).

Chapter 5 presents a synthesis of what the current literature reports on four tools currently used to identify wetlands and to address impacts to wetlands and their functions: wetland definitions, wetland delineation methods, wetland ratings, and buffers. This chapter does not provide language or recommendations for regulatory or policy language—those will be provided in a separate volume on management options and recommendations (Volume 2).

5.1.1 Chapter Contents

Major sections of this chapter and the topics they cover include:

Section 5.2, Introduction and Background on Regulatory Tools introduces the key wetland management tools that are discussed in this chapter.

Section 5.3, How Wetlands Are Defined and Delineated describes similarities and differences in the way various agencies define *wetland*. It explains the critical difference between “biological wetlands” and “regulated wetlands.” It also discusses certain types of wetlands that are frequently exempted from regulation, such as isolated wetlands, small wetlands, or those designated as Prior Converted Croplands. The various manuals that have been developed to guide the delineation of wetland boundaries are also briefly discussed.

Section 5.4, Wetland Rating Systems discusses how rating systems have been developed to rapidly assess wetland characteristics in the field. These characterizations allow wetlands to be rated for regulatory or management purposes. This section introduces the reader to the Washington State wetland rating systems, which were briefly mentioned previously in a number of places in the document. It also includes discussion of certain wetland types that require particular attention under the Washington State wetland rating systems.

Section 5.5, Buffers comprises the bulk of this chapter. This section provides a synthesis of the literature on how buffers protect and maintain wetland functions. The section concludes by summarizing recommendations from the literature for establishing effective buffer widths.

Section 5.6, Chapter Summary and Conclusions ties together the major concepts presented in the chapter.

5.1.2 Where to Find Summary Information and Conclusions

Each major section of this chapter concludes with a brief summary of the major points resulting from the literature review on that topic in a bulleted list. The reader is encouraged to remember that a review of the entire section preceding the summary is necessary for an in-depth understanding of the topic.

For summaries of the information presented in this chapter, see the following sections:

- Section 5.3.6
- Section 5.4.2
- Section 5.5.3.5
- Section 5.5.4.4
- Section 5.5.5.4
- Section 5.5.6.1

In addition, Section 5.6 provides a summary and conclusions about the overarching themes gleaned from the literature and presented in this chapter.

5.1.3 Data Sources and Data Gaps

No literature review was conducted for the section on wetland definitions or delineations. Both of these management tools are currently established by state and federal statutes. It was determined that review of the previous discourse on these topics was not relevant to the current state of the science for Washington State.

Considerable research was published prior to 2000 on the role of small wetlands relative to wildlife in a landscape context. Since then, several synthesis documents on small and isolated wetlands have been published.

Papers on the adequacy or effectiveness of wetland rating systems were not found; instead, the literature concentrates on function assessment methods. This chapter does not attempt to assess the science on wetland function assessment because the Washington State Department of Ecology (Ecology) has evaluated and described different function assessment methods previously (see Volume 2, Appendix 5-B for more information). Additionally, Ecology completed function assessment methods for several different

wetland hydrogeomorphic types on both sides of the state within the last five years (see Chapter 2 for further information).

The subject of buffers is well documented in the scientific literature. Numerous studies from across the U.S. have been conducted for wetland and stream buffers. The results of buffer studies, completed here in the Pacific Northwest as well as other areas of the country, provide remarkably consistent findings related to the factors that are important in determining appropriate buffer widths. This consistency is particularly striking in the numerous buffer synthesis documents. Additionally, the results of many studies conducted in other parts of the U.S. have been replicated in studies in the Pacific Northwest.

Determining relevance to Washington, however, can be challenging, since the physical settings of the studies vary widely. Some, however, obviously do relate to Washington; for example, literature related to agricultural practices and vegetated filter strips from the north-central United States and south-central Canada is relevant to some agricultural practices in Washington, especially in areas east of the Cascades.

The majority of research on buffers tends to focus on how buffers influence water quality. Far fewer studies examine the influence of a buffer's physical characteristics on attenuating rates of surface water flow.

Most studies on buffers related to wildlife document the needs of a particular species or guild related to how far they travel from aquatic habitats to fulfill their life-needs. While there is substantial literature on the implications of habitat fragmentation, this literature does not specifically address the role of buffers in reducing fragmentation between wetlands and other parts of the landscape.

Numerous compilations and syntheses of the literature concerning buffers have been completed since 1990. These synthesis documents are used in this document as direct sources when no more recent research was found. This chapter also cites literature related to stream buffers and riparian areas when the findings are relevant to the functions or processes these areas provide to the adjacent aquatic resource.

A more detailed description of the types of literature used and any recognized gaps in the scientific literature are provided within each section on buffers as appropriate.

5.2 Introduction and Background on Regulatory Tools

The regulatory tools discussed in this chapter are components of “typical” wetland protection programs. The intent is not to analyze all elements of protection programs and their regulations but to focus on the key science-based elements relating directly to wetland protection and management. Therefore, this chapter focuses on the following four elements:

- Wetland definitions
- Wetland delineation methods
- Wetland ratings
- Buffers

The topic of compensatory mitigation, another key regulatory tool, is discussed separately in Chapter 6 because of the volume of information and literature available on this subject.

5.3 How Wetlands are Defined and Delineated

5.3.1 How Agencies Define Wetlands

Several definitions of wetlands have been developed and used by various federal, state, and local agencies and jurisdictions. The effectiveness of current federal or state wetland definitions was not evaluated as part of this synthesis. However, definitions are included here because how a wetland is defined is critical to determining what areas are subject to the provisions of a law or regulation.

For the purposes of most laws and regulations, wetlands are usually defined using one of the following two definitions:

Those areas that are saturated or inundated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. (U.S. Army Corps of Engineers 1987);

or

“Wetlands” or “wetland areas” means areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from nonwetland areas to mitigate the conversion of wetlands. (Washington Administrative Code 173-22-030.)

The Washington State definition is derived from the U.S. Army Corps of Engineers (Corps) definition, but it also includes clarifying language that identifies which common human-made or -induced features are not meant to be defined as wetland. The state definition is required by the Growth Management Act (RCW 36.70A.030 (20)) to be used in all local critical area regulations.

In addition, for the National Wetland Inventory, the U.S. Fish and Wildlife Service (USFWS) defined wetlands as follows:

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For the purpose of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. (Cowardin et al. 1979)

Note that the definition used by the USFWS allows the use of a single parameter to determine if an area is a wetland. The definition also includes areas that may not be vegetated, such as gravel bars and mudflats. In most cases, the Corps and Ecology definitions require the presence of all three parameters (vegetation, soil, and hydrology) for an area to be considered a wetland, and they both assume that wetlands generally are vegetated.

5.3.2 Biological vs. Regulated Wetlands

In some jurisdictions, all lands that meet the definition of *wetland* are regulated. However, it is not unusual for a jurisdiction to differentiate within its regulations between “wetlands” (i.e., biological wetlands) and “regulated wetlands” (i.e., wetlands that they intend to regulate). The definition of what constitutes a regulated wetland may vary from jurisdiction to jurisdiction.

In reviewing regulatory language from local wetland regulations, the three primary criteria used to differentiate between “wetland” and “regulated wetland” were:

- The category or rating of the wetland
- The size of the wetland
- The type of wetland (such as isolated wetlands and those designated as Prior Converted Croplands)

In general, a category or rating system has been used historically in regulatory language to differentiate between wetlands that need different degrees of protection. Rating systems are used by local jurisdictions to group wetlands based on physical characteristics and/or functions that the wetlands may provide and how those characteristics or functions are valued. Section 5.4 of this document describes the current

state of the science on wetland ratings and the wetland rating systems developed for eastern and western Washington.

The criterion of wetland size is usually a minimum below which the jurisdiction will not regulate a wetland. For example, the jurisdiction may allow no fill in wetlands larger than 10,000 square feet, or they may include language such as “Category 2 wetlands larger than 0.25 acre cannot be altered.” The historical rationale for the use of size as a regulatory criterion was the perception that “bigger is better,” and the belief that small wetlands were less important and did not provide significant functions. The scientific literature of the last 10 years has made it clear that size does matter but not in the way previously believed. In multiple studies, small wetlands have been shown to contain a significant diversity of plant and animal species (See Section 5.3.3 for more information).

Additionally, two other wetland types may be exempted from regulation: isolated wetlands and wetlands designated as Prior Converted Croplands.

In 2001, the U.S. Supreme Court determined that isolated wetlands are not subject to regulation under Section 404 of the federal Clean Water Act if the only basis for their regulation is their use by migratory birds. However, the Court did not define “isolated,” and the federal government has not issued any new guidance or regulations to clarify the situation. In general practice, the U.S. Army Corps of Engineers (Corps), the federal agency that administers the Clean Water Act, considers isolated wetlands to be those of any size that are not adjacent to or have no direct surface water connection to any navigable waters. However, recent lower court decisions have interpreted Corps jurisdiction over isolated waters differently, and the situation is in flux.

Washington State has determined that isolated wetlands are regulated by the Department of Ecology under the state Water Pollution Control Act (RCW 90.48). Since some local jurisdictions in Washington fashion their wetland regulations on the federal or state standards, it is important to consider the implications of not regulating isolated wetlands. Thus, scientific information on isolated wetlands is discussed in Section 5.3.4.

Wetlands that are designated as Prior Converted Croplands (PCC) are another type of wetland that are exempt from regulation by the federal government. PCC are those wetlands that were drained or otherwise manipulated prior to December 23, 1985, for the production of commodity crops. They are wetlands in which inundation (ponding) does not occur for more than 14 consecutive days during the growing season. These sites must produce an agricultural commodity that requires planting a crop that needs annual tilling. These areas are considered waters of the U.S. if they are abandoned (i.e., tilling and planting has not occurred for five consecutive years), and hydrophytic vegetation and wetland hydrology returns. However, even if they are not abandoned, many of the PCCs in Washington still meet the three criteria required for biological wetlands. As with isolated wetlands, the Department of Ecology regulates PCCs that are wetlands under state law.

No information on wetland areas meeting the definition of PCC was found in the scientific literature. However, many wetlands meeting the criteria for PCC would still be expected to provide important functions, given that the criteria for being designated “Prior Converted” require only that the wetland has been manipulated for production of commodity crops since 1985 and does not pond for more than 14 consecutive days during the growing season. The authors of Volume I have observed widespread flooding in PCC areas during the winter and have observed use of these areas by several species of overwintering waterfowl. One published study of waterfowl in Puget Sound documented significant use of farmlands by several duck species for feeding during the winter (Lovvorn and Baldwin 1996). This study found greater use by waterfowl of farm fields that were flooded in winter, but made no distinction between upland farm fields, farmed wetlands, and Prior Converted Croplands. In addition, the authors of Volume I have documented significant water quality and quantity functions provided by PCCs in projects reviewed and permitted by the Department of Ecology (This data has not been published).

If the agricultural activities were abandoned, PCCs could revert to a plant community characteristic of wetland; and, without maintenance of the hydrologic modifications, the wetland’s water regime may revert to a condition more like that which existed prior to the alteration. Further analysis of the functions of wetland areas designated as PCC is needed.

No literature was found that discussed the ecological consequences of the legal bifurcation between biological wetlands and regulated wetlands. However, literature was found that discusses the functions and values provided by small wetlands and isolated wetlands, as discussed below.

5.3.3 Small Wetlands

The elimination of small wetlands is an issue that has gained attention over the past 10 years. Many regulations have preferentially allowed filling of small wetlands. Many regulations completely exempt wetlands under a certain threshold. Also, size is one of the most common characteristics used in determining wetland ratings at the local level, and smaller wetlands typically receive lower levels of protection. Yet, the loss of small wetlands is one of the most common cumulative impacts on wetlands and wildlife (Weller 1988, Tiner et al. 2002).

No definition of *small* is provided here because what constitutes “small” varies between jurisdictions and scientific studies (see also Section 5.3.2). In some contexts, small is determined exclusively by size. Small may mean less than 0.10 acre; in others, it may mean less than 10 acres.

Some jurisdictions, however, also differentiate small wetlands using criteria that reflect function and values. Small wetlands can have outlets, be in a floodplain, or be otherwise associated with a larger aquatic system. These characteristics are often used in rating systems and, combined with size, determine what is considered a small wetland. For

example, a jurisdiction may include language in their regulations such as “Category 2 wetlands larger than 0.25 acre cannot be altered.” For each of the studies below, we have included the authors' definition of small.

In addition to the obvious loss of habitat for wildlife, fragmentation of habitat increases as small wetlands are eliminated, resulting in greater distances between wetland patches in the landscape. Semlitsch and Bodie (1998) found that creating greater distances between wetlands of 0.5 to 10 acres in size can have a significant effect on the ability of a landscape to support viable populations of amphibians, as juveniles dispersing from a source wetland may not be able to travel far enough to recolonize other surrounding (now distant) wetlands. Management priorities have focused on larger, semi-permanent wetlands, with the least emphasis on protecting the smaller, seasonal wetlands (< 1.2 acres) that are critical components of wetland complexes (Naugle et al. 2001).

The following sections describe studies of the use of small wetlands by wildlife, and the role that small wetlands play in maintaining connections between habitats. For each of these studies, the authors' definition of small is described.

Studies of the relationship between wetland size and wildlife distribution have mostly focused on amphibians and birds. Few studies have examined how use of wetlands by mammals relates to wetland size, and no studies of this relationship were found for macroinvertebrates or reptiles. No studies were found that documented the role that small wetlands play in providing water quality or hydrologic functions. However, the degree to which small wetlands perform water quality or hydrologic functions is likely to be determined by site-specific characteristics (see Chapter 2) and can be estimated on a per-acre basis using some of the available function assessment methods.

5.3.3.1 Amphibians and Small Wetlands

Snodgrass et al. (2000) undertook a study of amphibian use of wetlands to address three commonly held beliefs about small wetlands (0.7 acres - 3 acres):

- They have short hydroperiods
- They support few species
- They support species that are also found in larger wetlands

Snodgrass et al. (2000) determined that amphibian species richness increases with length of hydroperiod. They also concluded that short-hydroperiod wetlands (smaller temporarily ponded wetlands) are also important in maintaining biological diversity in that they support species not found in larger wetlands with longer hydroperiods. The species they found in small wetlands were not a subset of those in larger wetlands but rather a unique group of species.

Similarly, amphibian richness in Puget Sound wetlands was found to have no correlation with wetland size (1 - 30 acres). High richness occurred in some of the smallest wetlands (Richter and Azous 1995). The study indicates that small wetlands that are vegetatively

simple can serve adequately as breeding habitats as long as favorable nonbreeding habitat is present nearby. Species richness also was not related to persistence of ponding.

Gibbs (1993) conducted a simulation model in Maine from which he theorized that small wetlands may be most important for wetland organisms with low population growth rates and low densities. The model demonstrated that the loss of small freshwater wetlands (less than approximately 5 acres [2 ha]) would result in a decline of total wetland area by 19% and total wetland number by 62%, while the average distance between wetlands would increase by 67% (Gibbs 1993). The model showed that the loss of small wetlands would result in a change (from 90% to 54%) of the area that would lie within the maximum migration distance of terrestrial-dwelling and aquatic-breeding amphibians. The risk of extinction would significantly increase for local populations of turtles, small birds, and small mammals that are currently stable even though the model showed no change in the risk of metapopulation extinction for salamanders or frogs. Amphibian populations in the study were buffered from the risk of extinction due to high rates of population increase. The model demonstrated that dispersal ability for amphibians is a predictor of population growth rate and density, not sensitivity of a population to loss of small wetlands.

5.3.3.2 Birds and Small Wetlands

Bird use of wetlands appears to have a stronger relationship to wetland size than that of amphibians. Bird richness was positively correlated with larger wetland size in a Puget Sound study of palustrine wetlands (Richter and Azous 2001b). This is attributed to the fact that larger wetlands in the study generally had greater structural complexity and a greater number of habitat types.

Martin-Yanny (1992) also found that bird species richness and abundance in wetlands of the Pacific Northwest are positively correlated with wetland size. However, Martin-Yanny noted that habitat heterogeneity was a more important determining factor than wetland area in influencing bird species richness. Wetlands in highly urbanized watersheds had fewer neotropical migrant species, fewer ground-nesting birds, and more edge-tolerant (habitat generalist) species. This is because urbanizing watersheds tend to have smaller wetlands (less than 10 acres [4 ha]) with more edge habitat, making birds more susceptible to competition, predation, and nest parasitism. The author recommends preserving large wetlands or complexes of smaller wetlands that are connected by extensive upland buffers.

In northern prairie marshes, bird species richness was also seen to increase with marsh size and to decrease as the wetland became more isolated (Brown and Dinsmore 1986). Marshes that were part of wetland complexes showed higher species richness than isolated wetlands. Certain bird species used smaller marshes only when the marshes were part of a wetland complex. Large isolated marshes in the study often had lower species richness than smaller marshes that were part of wetland complexes. While bird species richness increased, the rate of increase slowed as the marshes became larger. In other words, they concluded that prairie marshes in the size range of 49 to 74 acres (20 to 30 ha) were more efficient in preserving bird species than larger marshes.

A study of agriculturally disturbed wetlands in western Oregon reached similar conclusions in finding that larger wetlands support more bird species (Budeau and Snow 1992). These authors also showed that wetlands of all sizes were important to water-birds.

However, in eastern Washington, Foster et al. (1984) found that waterfowl breeding use of wetlands in the Columbia Basin was greatest in smaller wetlands (less than 1 acre [0.4 ha]).

5.3.3.3 Mammals and Small Wetlands

The study that modeled the effects of the loss of small wetlands in Maine showed that local populations of small mammals faced a significant risk of extinction following the loss of small wetlands (<5 acres) (Gibbs 1993). However, in a study of Puget Sound wetlands, Richter and Azous (2001c) concluded that wetland size alone was not a significant factor in determining mammal richness or abundance. They noted that small-mammal richness was most closely affected by the combined factors of:

- Wetland size
- Extent of retention of forest adjacent to the wetland
- Quantity of large woody debris within wetland buffers

In conclusion, the literature suggests that size is not a significant factor in contributing to most wetland habitat functions. Rather, habitat structure, connectivity, and wetland hydroperiod are much more significant factors in determining habitat functions than size alone. The literature emphasizes that small wetlands are critically important to amphibians, particularly when connectivity between wetlands and with adjacent uplands is maintained. However, none of the studies evaluated the role of wetlands less than 0.5 acre, so the implications of exempting wetlands less than 0.25 acre, as is commonly done in local wetland regulations, are unknown.

The next section deals specifically with isolated wetlands. The following excerpt from Moler and Franz (1987) describes small, isolated wetlands and sheds some light on the attributes of both size and isolation.

To a great extent, the unique values and functions of small, isolated wetlands have been overlooked. This oversight derives from several factors, perhaps foremost being the general tendency to think of small wetlands as being little more than subsets of larger wetlands. So long as the uniqueness of small wetlands is unrecognized, then it is intuitive to think of wetlands as declining in value directly as function of size. Similarly, so long as the unique values of isolated wetlands are unrecognized, it is understandable that connected wetlands might be considered of greater value. In reality, small isolated wetlands are biologically unique systems. Because of their isolation and small size, they support a very different assemblage of species than that found in

larger, more permanently wet situations. The ephemeral nature of many small wetlands makes them unsuitable for species which require permanent water.

5.3.4 Isolated Wetlands

Isolated wetlands are being addressed in this document because of the recent Supreme Court decision to exclude many isolated wetlands from federal regulation. The Supreme Court decision regarding isolated wetlands was made based on a legal interpretation of jurisdiction under the federal Clean Water Act (Solid Waste of Northern Cook County v. United States Army Corps of Engineers). The key factor was the language in the Act that relates to navigable waters. The Court did not rule that isolated wetlands are less important than non-isolated wetlands, only that the intent of Congress in passing the Clean Water Act was to relate the protection of waters of the United States to navigability. The Court also did not provide any definition of what constitutes “isolation” for purposes of jurisdiction.

The Seattle District of the U.S. Army Corps of Engineers (Corps) does not have any national or regional guidance for making isolated wetland determinations. As of November 2004, if a wetland meets the test of "adjacency" (neighboring, bordering or contiguous) with any navigable water, or if the wetland has a surface outlet that drains to a navigable water, then the Corps does not consider it isolated (T.J. Stetz, U.S. Army Corps of Engineers, Seattle, personal communication 2004). Future court or administrative decisions may change how isolated wetlands are determined.

Much confusion has resulted from this decision, and some in the public have assumed that isolated wetlands are less important or less worthy of protection. Therefore, it is important to summarize some of the basic science on isolated wetlands, which is presented in the paragraphs that follow.

Much of the information comes from the work of Tiner et al. (2002) and a recent issue of *Wetlands* (Volume 23, #3, 2003) that includes numerous articles on isolated wetlands. Readers are directed to this work for more detailed information. Additionally, the work of Hruby et al. (1999, 2000) in developing assessment methods for wetland functions in Washington provides important scientific information on depressional wetlands in Washington, a wetland type that contains the majority of isolated wetlands in Washington.

Wetlands can be defined as isolated based on their geographic isolation, ecological isolation, or hydrologic isolation (Tiner et al. 2002). For this discussion, isolated wetlands are defined by a very specific type of hydrologic isolation—they do not have a surface outlet by which water leaves the wetland, even seasonally, to another water body. Although frequently described as closed depressions (Tiner et al. 2002, Winter and LaBaugh 2003), isolated wetlands can also be sloped wetlands where surface water, if present, re-enters the shallow groundwater zone at the base of the wetland and is not linked via surface flows to a downstream water body. Isolated wetlands are not

necessarily small. They can be large systems with substantial heterogeneity and diverse habitat types (Tiner et al. 2002, Leibowitz 2003).

Generally, isolated wetlands provide most of the same functions as non-isolated wetlands and do so for the same reasons: position in the landscape, hydrologic regime, and type of soils and vegetation present (Leibowitz 2003, Whigam and Jordan 2003, Liebowitz and Nadeau 2003). Basic functions of isolated wetlands as described by Hruby et al. (1999), Tiner et al. (2002), Leibowitz (2003), and Whigam and Jordan (2003) are presented below.

- **Water quantity (hydrologic functions).** Isolated wetlands have no surface outlet. Precipitation and local runoff entering the wetland must either return to the atmosphere by evapotranspiration or infiltrate into groundwater (Leibowitz 2003). As a result, their ability to retain surface water may be significant, depending upon the surrounding topography. This provides potential flood storage because no surface water leaves the wetland to cause potential flooding or erosion downgradient.
- **Water quality.** Because they lack an outlet, isolated wetlands function as sediment traps for contaminants that move into them. Isolated wetlands function as sinks for most dissolved and all sediment-associated nutrients and toxics because they have no outlets that allow materials to be transported downgradient (Hruby et al. 1999). A review of the literature by Whigam and Jordan (2003) concludes that isolated, depressional wetlands have been shown to improve water quality and to efficiently retain nutrients.
- **Wildlife habitat.** Isolated wetlands provide wildlife habitat functions similar to those of non-isolated wetlands (Liebowitz 2003), except in regard to habitat for migrating fish in Washington (Hruby et al. 1999). The habitat value of isolated wetlands is governed by the same factors as non-isolated wetlands (hydrologic regime, vegetation, habitat structure, connectivity to other habitats, etc.) (Liebowitz 2003, Gibbons 2003). Tiner et al. (2002) found that isolated wetlands provide essential habitat for a wide range of guilds and may be vital to maintaining viable, genetically diverse metapopulations. They state:

From an ecological standpoint, isolated wetlands are among the country's most significant biological resources. In some areas, isolation has led to the evolution of endemic species vital for the conservation of biodiversity. In other cases, their isolation and sheer numbers in a given locality have made these wetlands crucial habitats for amphibian breeding and survival (e.g., woodland vernal pools and cypress domes) or for waterfowl and waterbird breeding (e.g., potholes). In arid and semi-arid regions, many isolated wetlands are veritable oases – watering places and habitats vital to many wildlife that use them for breeding, feeding, and resting, or for their primary residence.

5.3.5 Delineation Methods

In addition to the definition of what constitutes a wetland, the U.S. Army Corps of Engineers (Corps) and Washington State Department of Ecology (Ecology) have provided guidance on how to determine the edge of a wetland (i.e., how to delineate the wetland boundary). Delineating a wetland's boundary is a necessary step in the regulatory process because it factors into calculations of potential wetland impacts and determines the starting point for buffers and setbacks.

The Corps published a federal manual to delineate wetlands in 1987 and another manual in 1989, jointly with the U.S. Environmental Protection Agency (EPA), Soil Conservation Service, and U.S. Fish and Wildlife Service. In subsequent years (1991, 1992, and with EPA in 1994) the Corps released updates to clarify questions and provide regional guidance.

In the early 1990s, there was substantial controversy over proposals to change the 1987 and 1989 federal delineation manuals. A substantial amount of literature was produced analyzing the effectiveness of the various delineation manuals for determining a wetland edge. In subsequent years, the use of the 1987 Federal Manual for Delineation of Wetland Areas became the required legal standard for the Corps.

As required by state legislation, Ecology issued the *Washington State Wetlands Identification and Delineation Manual* in 1996 (WAC 173-22-080, Ecology publication #96-94). Ecology's manual uses the original 1987 Corps of Engineers manual and incorporates changes in the manual made by the federal government since 1987. The state manual includes national guidance issued by the Corps in 1991 and 1992 (which is not present in the 1987 Corps manual), as well as regional guidance issued by the Corps and EPA in 1994. In addition, the state manual eliminated references and examples that were not relevant to Washington State and added examples and situations relevant to Washington. The 1996 state manual is required by statute (RCW 36.70A.175) to be used by local jurisdictions in implementing the Growth Management Act. Since the two manuals rely upon the same criteria and indicators for hydrology, soils, and vegetation, proper use of either manual should result in the same boundary.

5.3.6 Summary of Key Points

- Regulatory agencies define the term *wetland* in slightly different ways.
- Local jurisdictions often differentiate between “biological wetlands” and “regulated wetlands”. The distinction is often based on the wetland rating and/or wetland size.
- The studies of the correlation of wetland size to wildlife use conflict somewhat in their findings, but most generally conclude that small wetlands are important habitats (particularly where adjacent buffer habitats are available) and that elimination of small wetlands can negatively impact local populations.

- Small wetlands provide habitat for a range of species that are not a subset of the species found in larger, more permanently inundated wetlands. Small wetlands do not just provide a smaller area for the same array of amphibian species found in larger wetlands.
- Small wetlands are very important in reducing isolation among wetland habitat patches. Smaller wetlands provide significant habitat for wildlife and affect the habitat suitability of larger wetlands by reducing isolation on the landscape.
- The presence of small wetlands reduces the distance between wetlands and thus increases the probability of successful dispersal of organisms. This, in turn, likely increases the number of individuals dispersing among patches in a wetland mosaic, thereby reducing the chance of population extinction.
- Isolated wetlands provide the same range of wetland functions as non-isolated wetlands. Isolated wetlands provide important water quantity, water quality, and habitat functions.
- The U.S. Army Corps of Engineers 1987 wetland delineation manual and the 1996 *Washington State Wetlands Identification and Delineation Manual* are the current standards to be used in determining the boundary of a wetland. Correct use of these two manuals should result in the same wetland boundary.

5.4 Wetland Rating Systems

Wetland rating systems (or categorizations) are one of the numerous procedures that have been developed to analyze wetlands, providing ways to identify, characterize, or rate wetland characteristics, functions, and social benefits (values). Categorizations, as well as other procedures such as function assessment, are used by natural resource managers and regulators in a variety of contexts for regulating, planning, and managing the wetland resource (Bartoldus 1999). In the context of local regulations, rating systems are used to categorize wetlands based on different needs for protection. However, rating systems can often be used as one means to analyze wetlands.

Many different procedures to analyze wetlands have been developed in the last three decades. These range from detailed scientific evaluations that may require many years to complete, to the judgments of individual experts during one visit to a wetland. For example, Bartoldus (1999) summarized 40 different tools that were developed up to 1998, and that are used to meet the needs of regulating and managing wetlands.

Although many different rating-type tools have been developed, the literature search for this document did not uncover any analyses of the effectiveness of rating systems at protecting the wetland resource. It is assumed that better protection for wetlands is provided with improved understanding of wetland functions and values (e.g., Roth et al. 1993, National Research Council 1995).

Scientific rigor is often time consuming and costly. For regulatory use, tools are needed that provide some information on the functions and values of wetlands in a time- and cost-effective way. One way to accomplish this is with an analytical tool that categorizes wetlands by their important attributes or characteristics based on the collective judgment of regional experts. Categorization methods, such as rating systems, are relatively rapid but can still provide some scientific rigor (Hruby 1999).

The rapid method most commonly used for analyzing wetlands in eastern and western Washington has been Ecology's wetland rating systems (Ecology 1991, 1993, Hruby 2004a,b). This rating system or some modification of it has been incorporated in the wetland regulations of at least 20 counties in the state and many cities and towns as well (Chris Parsons, Washington State Department of Community, Trade and Economic Development (CTED), personal communications and survey 1999, data are available on request from CTED).

In the first editions of the Washington State wetland rating systems, the term *rating* was not used in a manner that is consistent with its definition in the dictionary, and this has caused some confusion. The method does not rate the wetland and generate a relative estimate of value (e.g., high, medium, low). Rather, it is a categorization of wetlands based on specific criteria, such as sensitivity to disturbance and rarity in the landscape.

The rating systems were designed to differentiate between wetlands based on their sensitivity to disturbance, their significance, their rarity, our ability to replace them, and the functions they provide. However, the rating systems were not intended to replace a full assessment that may be necessary to determine the levels of performance for numerous functions or to plan and monitor a compensatory mitigation project. As noted in the wetland rating system for eastern Washington:

The rating categories are intended to be used as the basis for developing standards for protecting and managing the wetlands to minimize further loss of their resource value. The management decisions that can be made based on the rating include the width of buffers necessary to protect the wetland from adjacent development, the ratios needed to compensate for impacts to the wetland, and permitted uses in the wetland. (Hruby 2004a)

The rating systems for both eastern and western Washington have been revised by Ecology in conjunction with teams of wetland experts and local planners in each region who provided technical input and field testing. The goal of the revisions is to reflect the best and most current science on wetlands and how they function (using three broad groups of functions—hydrologic, water quality, and habitat) while maintaining rapidity and ease of use. You can access the rating systems for eastern and western Washington at the following web site: <http://www.ecy.wa.gov/programs/sea/wetlan.html>.

Wetland rating systems used in other parts of the nation

Categorization systems have also been used in other parts of the United States to manage wetlands. Other states have wetland categorizations as part of their wetland laws and rules, and other jurisdictions have used them to help manage wetlands for specific projects. For example:

Vermont adopted a law (10 VSA Chapter 37, Section (a) (7-9)) mandating that rules be adopted to identify Vermont's significant wetlands. The rules categorize wetlands into three classes of which the first two are considered "significant" (Vermont Department of Environmental Conservation 1999).

New Jersey has a wetland categorization included directly in its law (NJAC 7:7A). Criteria are provided for categorizing wetlands into (1) freshwater wetlands of exceptional resource value, (2) wetlands of ordinary resource value, and (3) wetlands of intermediate resource value.

New York has adopted rules that categorize wetlands into four categories based on ecological associations, hydrologic features, pollution control features, cover types, and distribution and location (6 NYCRR Part 664.5).

West Eugene, Oregon developed a method for a plan based on "needs for protection" (City of Eugene 2002).

North Carolina created a GIS-based system that characterizes the "significance" of wetlands based on several landscape and function-based criteria (Gainey and Roise 1998).

5.4.1 Other Characteristics Used for Rating

Some wetlands in Washington are categorized in the Washington State wetland rating systems based on important characteristics that are not specifically related to functions. These characteristics include rarity on the landscape, sensitivity to disturbance, and difficulty in restoring or creating such wetlands through mitigation efforts (Ecology 1991, Hruby 2004a,b). The wetland types that have been defined for eastern and western Washington are listed below. Some of the types are unique to either eastern or western Washington (e.g., Wetlands in coastal lagoons are unique to western Washington):

- Bogs
- Alkali wetlands
- Mature and old-growth forested wetlands
- Vernal pools
- Wetlands identified by the Washington State Department of Natural Resources as "Natural Heritage" wetlands

- Wetlands in coastal lagoons
- Interdunal wetlands
- Estuarine wetlands

Each of these types is described in more detail below.

5.4.1.1 Bogs

Many of the scientific studies of bogs have been published in Europe and the northern parts of the United States, such as Minnesota and Maine. There has not been extensive research on bogs in Washington State. This summary of the literature is not intended to be a thorough synthesis but provides basic background information regarding characteristics of bogs requiring special consideration for management.

Predominance of Organic Soils

Bogs are peatlands (wetlands with organic soils) that have been classified according to their shape, chemistry, plant species, and vegetation structure (Gore 1983). The common factor in bogs is the presence of organic soils or peat, which result from the accumulation of poorly decomposed plant material. The optimum conditions for peat formation occur in cool, humid climates in a location with poorly drained soil.

The rate of peat accumulation is generally quite low, although it can vary with site-specific factors. Heathwaite and Gottlich (1993) report rates of accumulation ranging from 2 to 4 inches (5 to 10 cm) every 100 years. Durno (1961) lists a range of 0.5 to 4.3 inches (1.2 to 11 cm) accumulation every 100 years. In Washington, Rigg (1958) reports peat accumulation of 1 inch (2.5 cm) in 40 years for the west side of the Cascades and 1 inch in 50 years on the east side. Peat can be as little as 8 inches (20 cm) deep to over 45 feet (15 m) deep (Heathwaite and Gottlich 1993).

The three ways that peat is formed, described below, illustrate the lengthy process of peat and bog formation and help explain why bogs are almost impossible to recreate through compensatory mitigation (see below and in Chapter 6).

- In a **filled-lake sequence**, open water progresses to a sedge or moss community that gradually builds a mat over the water, evolving into a bog, bog forest, and then climax community (Conway 1949).
- **Paludification** occurs when bogs invade the surrounding forest. Sphagnum species cause a rise in the water table as peat layers compress and impede drainage (Heathwaite and Gottlich 1993).
- A **flow-through succession** occurs when surface flows are modified. Organic matter builds up to the point where surface flows are diverted around the peat mound. As it builds, the mound becomes isolated from groundwater, relying solely on precipitation as its water source (Klinger 1996).

Studies have shown, on the other hand, that many bogs remain very stable for thousands of years as a sphagnum moss/shrub community, even though succession to a forested community can occur (Klinger 1996).

Acidity and Poor Nutrients

Bogs have unusual hydrodynamics and chemistry for wetlands. They typically only receive precipitation and very localized surface runoff as their sources of water. As a result, many essential nutrients, such as nitrogen, occur in low concentrations. The upper layers of peat, formed by slowly decomposing sphagnum, are often strongly acidic, usually with a pH of 4 or less.

Bogs typically support plant species that are specially adapted to these harsh growing conditions. Sphagnum moss, as well as other mosses, usually dominate the vegetation near the ground. Ericaceous shrubs, such as Labrador tea (*Ledum gladulosum*), are also common in bogs.

Trees can grow in bogs but at a very slow rate due to the poor growing conditions. In studies in the Pacific Northwest, Rigg (1918) found tree growth in sphagnum peat soils was slow. Rigg determined that hemlock (*Tsuga heterophylla*) grew in sphagnum soils at a rate that was only 27% of its growth rate in productive upland soils, and that Douglas-fir (*Pseudotsuga menziesii*) grew in sphagnum at only 16% of its growth rate in upland soils. He measured the annual growth of western red cedar (*Thuja plicata*) as only 0.02 inches (0.6 mm).

Although persistent wet conditions, low soil oxygen, and high acidity are important factors, it is actually the lack of available nutrients, or the inability of plants to absorb nutrients because of acidity (Moore and Bellamy 1974), that most influences the flora of bogs. Most bog species have developed special adaptations to these conditions and out-compete more common wetland plants (Mitsch and Gosselink 2000). Therefore, this makes bog species susceptible to nutrient loading and changes in acidity (as well as alterations in water source that can precipitate these changes) that would enable other species to establish and dominate.

Bogs in Western and Eastern Washington

In western Washington, Kunze (1994) characterized numerous types of peatlands, including bogs and fens. She identified 10 types of sphagnum bog communities in the Puget Trough region and 14 in the Olympic Peninsula/southwest Washington. They occur in the lowlands of the Puget Trough in depressions, oxbows, and old lake beds. These typically have a raised center with a moat around the edge. Bogs and fens also occur on the Olympic Peninsula and in southwest Washington where they can occupy basins, slopes, and flat to rolling ground, as well as forming along low-gradient streams. Bogs in the foothills of the Cascades include sloping bogs, which are influenced by both mineral soil water and precipitation.

Peatlands in eastern Washington have not been classified to the extent of those in western Washington. However, 50 peatlands were identified by Rigg (1958). Forty-four of those

identified were located in the northeastern corner of the state. They included fens associated with flowing water, and bogs formed in depressions or along lake margins. Six peat systems were found in scabland channels and depressions on the Columbia Plateau.

Difficulty in Restoring Bogs

Researchers in Northern Europe and Canada have found that restoring bogs is difficult, specifically in regard to plant communities (Bolscher 1995, Grosvermier et al. 1995, Schouwenaars 1995, Schrautzer et al. 1996), water regime (Grootjans and van Diggelen 1995, Schouwenaars 1995), and/or water chemistry (Wind-Mulder and Vitt 2000). In fact, restoration may be impossible because of changes to the biotic and abiotic properties (Schouwenaars 1995, Schrautzer et al. 1996).

It is apparent that true restoration of a raised bog ecosystem is a long-term process. In *Restoration of Temperate Wetlands*, Joosten (1995) states:

Long term studies in bog regeneration indicate that restoration of bogs as self-regulating landscapes after severe anthropogenic damage is impossible within human time perspective, because the necessary massive re-establishment of bog key species and renewed accumulation of peat require centuries.

Refer to Chapter 6 for more information on the challenges in restoring bogs.

5.4.1.2 Alkali Wetlands

Alkali wetlands are characterized by the occurrence of non-tidal, shallow saline water. In eastern Washington, these wetlands contain surface water with specific conductance (a measure of salinity) that exceeds 3,000 micromhos per centimeter. These wetlands provide the primary habitat for several species of migratory shorebirds and are also heavily used by migrating waterfowl. They also have unique plants and animals that are not found anywhere else in eastern Washington. For example, the small alkali bee that is used to pollinate alfalfa and onion for seed production lives in alkali systems. This bee is a valuable natural resource for agriculture in the western United States and especially in eastern Washington (Delaplane and Mayer 2000). The “regular” bees which pollinate fruits and vegetables are generally too large to pollinate the small flowers of these commercially important plants.

The salt concentrations in alkali wetlands have resulted from a relatively long-term process of groundwater surfacing and evaporating. These conditions cannot be easily reproduced through compensatory mitigation because the balance of salts, evaporation, and water inflows is hard to reproduce, and no references were found suggesting this has ever been attempted. Alkali wetlands are also rare in the landscape of eastern Washington. Of several hundred wetlands that were surveyed and visited by wetland scientists during field work for the state’s function assessment methods and the rating system for eastern Washington (Hruby et al. 2000, Hruby 2004a), only nine could be classified as alkali.

5.4.1.3 Mature and Old-Growth Forested Wetlands

No mature or old-growth forested wetlands have ever been successfully created or restored through compensatory mitigation. A mature forested wetland may require 80 years or more to develop, and the full range of functions performed by these wetlands may take even longer (Stanturf et al. 2001). The actual time required to reconstruct old-growth forests and their soil properties (in contrast to mature forests) is unknown (Zedler and Callaway 1999). These forested wetlands provide important functions associated with wetlands as well as habitat functions associated with mature and old-growth forests. (Washington State Department of Fish and Wildlife 1999a).

5.4.1.4 Vernal Pools

Vernal pool wetlands occur in eastern Washington and are formed when small depressions in bedrock or in shallow soils fill with snowmelt or spring rains. They retain water until the late spring when reduced precipitation and increased evapotranspiration lead to a complete drying out. The wetlands hold water long enough throughout the year to allow some strictly aquatic organisms to flourish but not long enough for the development of a typical wetland environment (Zedler 1987). Vernal pools often contain upland species during the summer after they dry out and may be difficult to identify as jurisdictional wetlands during part of the year.

Vernal pools in the scablands are the first to melt in the early spring. This open water provides areas where migrating waterfowl can find food while other, larger bodies of water are still frozen. Furthermore, the open water provides areas for pair bonding of waterfowl (R. Friesz, Washington State Department of Fish and Wildlife, personal communications 2000-2004). Thus, vernal pools in a landscape with other wetlands provide a critical habitat function for waterfowl (Hruby 2004a).

5.4.1.5 “Natural Heritage” Wetlands

“Natural Heritage” wetlands are those that have been identified by scientists of the Washington State Natural Heritage Program as high-quality, relatively undisturbed wetlands, and wetlands that support state threatened, endangered, or sensitive plant species.

The Natural Heritage Program has identified important natural plant communities and species that are very sensitive to disturbance or threatened by human activities and maintains a database of these sites. The program’s web site states:

Some natural systems and species will survive in Washington only if we give them special attention. By focusing on species at risk and maintaining the diversity of natural ecosystems and native species, we can help assure our state's continued environmental and economic health.

(Washington State Department of Natural Resources No Date,
<http://www.dnr.wa.gov/nhp/about.html>)

5.4.1.6 Estuarine Wetlands

Estuaries, the areas where freshwater and salt water mix, are among the most highly productive and complex ecosystems. Here, tremendous quantities of sediments, nutrients, and organic matter are exchanged between terrestrial, freshwater, and marine communities. A large number of plants and animals benefit from estuarine wetlands. Fish, shellfish, birds, and plants are the most visible organisms that live in estuarine wetlands. However, a huge variety of other life forms also live in an estuarine wetland, including many kinds of diatoms, algae and invertebrates.

Estuaries, of which estuarine wetlands are a part, are a “priority habitat” as defined by the state Department of Fish and Wildlife. Estuaries have a high fish and wildlife density and species richness, important breeding habitat, important fish and wildlife seasonal ranges and movement corridors, limited availability, and high vulnerability to alteration of their habitat (Washington State Department of Fish and Wildlife, <http://www.wa.gov/wdfw/hab/phslist.htm> , accessed October 15, 2003).

Estuarine wetlands are not freshwater wetlands, and therefore, information about them was not reviewed in Volume 1. They are included in this compilation of wetlands with special characteristics because they are included in the wetland rating System for western Washington (Hruby 2004b). They are often found adjacent to freshwater wetlands and should be managed in conjunction with freshwater wetlands. The methods for identifying estuarine wetlands and the rationale for protecting them are described in more detail in the rating system (Hruby 2004b).

5.4.1.7 Wetlands in Coastal Lagoons

Coastal lagoons are shallow bodies of water, like a pond, partly or completely separated from the sea by a barrier beach. They may, or may not, be connected to the sea by an inlet, but they all receive periodic influxes of salt water. This can be either through storm surges overtopping the barrier beach or by flow through the porous sediments of the beach. Coastal lagoons often contain vegetated areas that are jurisdictional wetlands. The wetlands associated with coastal lagoons are, therefore, included in the rating system as wetlands with special characteristics.

Wetlands in coastal lagoons probably cannot be reproduced through compensatory mitigation, and they are relatively rare in the landscape. No information was found on any attempts to create or restore wetlands in coastal lagoons in Washington that would suggest this type of compensatory mitigation is possible. Any impacts to lagoons will, therefore, probably result in a net loss of their functions and values.

In addition, coastal lagoons and their associated wetlands are proving to be very important habitat for salmonids. Unpublished reports of ongoing research in the Puget Sound (Hirschi et al. 2003, Beamer et al. 2003) suggest coastal lagoons are heavily used by juvenile salmonids.

5.4.1.8 Interdunal Wetlands

As defined in the western Washington rating system (Hruby 2004b), any wetlands that are located to the west of the Boundary Line of Upland Ownership as determined in 1889 are considered interdunal. The boundary line is a legally defined line along the Pacific Coast. Interdunal wetlands form in the “deflation plains” and “swales” that are geomorphic features in areas of coastal dunes. These dunes are the result of the interaction between sand, wind, water, and plants. The dune system immediately behind the ocean beach (the primary dune system) and its associated wetlands is very dynamic and can change from storm to storm (Wiedemann 1984). This means that the location of the wetlands is not fixed and may change from year to year.

Interdunal wetlands provide critical habitat for many species in this ecosystem (Wiedemann 1984). Although important, these wetlands constitute only a small part of the total dune system (Wiedemann 1984). No methods have been developed to characterize how well interdunal wetlands function so these wetlands cannot be rated by a score for their functions. In the absence of direct methods for characterizing their functions, the rating of interdunal wetlands is based on their documented importance as habitat in the coastal dune ecosystem.

5.4.2 Summary of Key Points

- Wetland rating systems provide a rapid method to identify, characterize, categorize, or estimate relative wetland functions and values. This information is used in regulating and managing wetlands.
- The rapid method most commonly used for analyzing wetlands in eastern and western Washington has been the Washington State wetland rating systems. The rating system was designed to differentiate between wetlands based on a broad grouping of functions that they provide (hydrologic, water quality, and habitat), as well as other characteristics (listed in the next bullet). However, this rating system does not replace the more robust function assessment methods developed for Washington State. The latter may be necessary to determine the level of performance for specific functions (such as the potential to remove sediment) or to plan and monitor a compensatory mitigation project.
- In the rating system, some wetlands are categorized because of their rarity on the landscape, sensitivity to disturbance, or difficulty in restoration or creation through mitigation efforts, and not because of the functions these wetlands perform. The wetland types in Washington that are included in the rating system because they have these other characteristics include bogs, alkali wetlands, mature and old-growth forested wetlands, vernal pools, estuarine wetlands, wetlands in coastal lagoons, interdunal wetlands, and “Natural Heritage” wetlands.

5.5 Buffers

Buffers are another common element of wetland regulations. Buffers are vegetated areas adjacent to an aquatic resource that can, through various physical, chemical, and/or biological processes, reduce impacts from adjacent land uses. Buffers also provide the terrestrial habitats necessary for wildlife that use wetlands to meet their life-history needs. In this document, we collectively call these processes that buffers provide the *functions* of buffers. Buffers and other adjacent upland areas provide habitat for other wildlife species that do not commonly use wetlands. This document does not address those functions of upland habitats.

The primary purpose of buffers is to protect and maintain the wide variety of functions and values provided by wetlands (or other aquatic areas). The physical characteristics of buffers—slope, soils, vegetation, and width—determine how well buffers reduce the adverse impacts of human development and provide the habitat needed by wildlife species that use wetlands. These characteristics are discussed in detail in this section.

The subject of buffers is well documented in the scientific literature. The research on buffers has occurred worldwide, and this section includes literature from a variety of regions when it was found to be relevant. In particular, a variety of literature related to agricultural practices and vegetated filter strips from the north-central United States and south-central Canada is directly relevant to some agricultural practices in Washington State, especially east of the Cascades. In addition, studies on buffers in urban and suburban settings conducted in the Pacific Northwest region are clearly relevant. However, many of the buffer studies conducted elsewhere in the U.S. and the world, as well as the many buffer synthesis documents, provide information relevant to the state of Washington.

The majority of research on buffers tends to focus on the processes that buffers provide to filter sediment or take up nutrients (i.e., their influence on water quality). Far fewer studies look at the influence of a buffer's physical characteristics on attenuating surface water flow rates, except as it relates to water quality. The long-term effectiveness of buffers in providing such mechanical and biological processes is not well documented in the literature and may represent a critical need for future research.

The literature on buffers related to wildlife is, in general, less focused. Most studies document the needs of a particular species or guild relative to distances for breeding or other life-history needs within a radius from aquatic habitats. There is substantial literature on the implications of habitat fragmentation and connectivity, some of it related specifically to agricultural practices, forestry practices, or the impacts of urbanization. This literature does not specifically address the role of buffers in providing connectivity between wetlands and other parts of the landscape. It does, however, unequivocally support maintaining connectivity between wetlands in order to maintain viable populations of species that are closely associated with wetlands. The reader is referred to Section 4.11 in Chapter 4, which discussed the effects of habitat loss and fragmentation as well as Section 5.5.4.3.

Older research studied the tolerance limits of wetland wildlife for disturbance—how closely a disturbance can approach animals before they are flushed from wetlands—with particular emphasis on waterfowl. These studies tend to be older than 1990 and focus on the prairie pothole region of North America. Where the findings are germane and where they have not been superseded by more recent work, they are included.

In addition to papers on specific research studies, multiple compilations and syntheses of literature on buffers have been completed since 1990. Synthesis papers were compiled by Castelle and other authors (1992b, 1994, and 2000) and another was compiled by McMillan (2000) as a master's thesis. These compilations include literature that was published prior to 1990, but much of the work they rely on is considered seminal to the effectiveness of buffers in protecting wetlands and contributing to habitat. Therefore these synthesis documents are used in this document as direct sources when no more recent research was found to supersede the earlier findings.

This section also cites literature related to stream buffers and riparian areas when the findings are relevant to the influence these areas have on the adjacent aquatic resource. The literature on stream buffers related to microclimate, water quality influences, and some habitat characteristics is particularly relevant because the ways buffers protect and maintain these functions is similar whether they are adjacent to streams or wetlands.

5.5.1 Terms Used to Describe Buffers

The scientific literature varies widely on the terms used to denote the area that serves to reduce impacts to wetlands from adjacent land uses and provide habitat for parts of the life-cycle of many species. Common terms include:

- Buffer
- Wetland setback
- Vegetated filter strip
- Buffer strip
- Riparian area
- Riparian zone
- Riparian corridor

These terms can be differentiated as those that are a product of regulations or policy language and those that define or describe an ecological condition or location (Castelle et al. 1994). Terms such as *buffer*, *wetland setback*, or *vegetated filter strip* are most commonly applied in an administrative context to denote the landscape immediately adjacent to an aquatic resource, the dimensions of which are legally determined. The terms *buffer strip* or *vegetated filter strip* may imply a relatively undisturbed, vegetated

area that helps attenuate the adverse effects of land uses adjacent to a wetland. For example, Norman (1996) provides this definition:

Buffer strips are strips of vegetated land composed in many cases of natural ecotonal and upland plant communities which separate development from environmentally sensitive areas and lessen these adverse impacts of human disturbance.

The terms *riparian areas* or *riparian zones* are defined by many to denote ecologically discernable ecotones (transition zones) along aquatic resources where the presence or action of surface waters, or the presence and duration of shallow groundwater, influences the structure and composition of the vegetation community (Lowrance et al. 1995, Harper and MacDonald 2001). The term *riparian corridor* is defined by Naiman et al. (1993) as “encompass(ing) the stream channel and that portion of the terrestrial landscape from the high water mark towards the uplands where vegetation may be influenced by elevated water tables or flooding, and by the ability of the soils to hold water.”

5.5.2 Functions Provided by Buffers

The literature is broadly consistent on the ways in which buffers can provide for the protection and maintenance of wetland functions. These include:

- Removing sediment
- Removing excess nutrients (phosphorous and nitrogen)
- Removing toxics (bacteria, metals, pesticides)
- Influencing the microclimate
- Maintaining adjacent habitat critical for the life needs of many species that use wetlands
- Screening adjacent disturbances (noise, light, etc.)
- Maintaining habitat connectivity

As noted by Castelle and Johnson (2000), buffers can be both ecological sources and sinks. They can control or limit the effects of land uses upslope of the aquatic resource (act as a sink), and they can contribute biological benefits to the aquatic resource (act as a source). Naimen et al. (1992) summarize the range of functions provided by buffers along streams as follows:

It is well known that riparian vegetation regulates light and temperature regimes, provides nourishment to aquatic as well as terrestrial biota, acts as a source of large woody debris,...regulates the flow of water and nutrients from uplands to the stream, and maintains biodiversity by providing an unusually diverse array of habitat and ecological services.

These same functions can be attributed to wetland buffers (Castelle et al. 1992b, Desbonnet et al. 1994, McMillan 2000).

The literature also describes the physical, chemical, and/or biological characteristics of a buffer that determine the functions it provides. The most frequently cited physical characteristics that influence the effectiveness of a buffer are:

- Vegetation characteristics (composition, density, and roughness—for example, downed material)
- Percent slope
- Soils
- Buffer width and length (adjacent to the source of impacts)

Only two of the physical characteristics noted above can be easily managed (vegetation characteristics and buffer width/length), while the others are characteristics that do not lend themselves to manipulation.

By far the issue of greatest interest with respect to buffers is the question of how wide a buffer needs to be in order to be effective in protecting a wetland (or other aquatic resource). While the literature is unanimous that buffers provide important functions that protect wetlands and provide essential habitat for many species, there is wide-ranging discussion about how much buffer is necessary to be effective in providing a particular level of function (Young et al. 1980, Booth 1991, Castelle et al. 1994, Norman 1996, Dosskey 2000, McMillan 2000, Rickerl et al. 2000).

For ease of discussion as to the effective widths of buffers, the functions of buffers listed above are grouped into two major categories:

- Water quality (discussed in Section 5.5.3)
- Wildlife habitat (discussed in Section 5.5.4)

Buffers and their influence on wetland hydroperiod, as described in the few studies found on this subject, are summarized in the shaded box on the next page.

The following literature sources are generally consistent in describing what functions buffers provide to aquatic resources as well as the physical parameters that influence a buffer's ability to provide these functions: Budd et al. (1987), Phillips (1989), Castelle et al. (1992, 1994), Naiman et al. (1992), Belt and O'Laughlin (1994), Desbonnet et al. (1994), Norman (1996), Dillaha and Inamdar (1997), Dosskey (2000), Van der Kamp and Hayashi (1998), Liquori (2000), McMillan (2000), Todd (2000), Townsend and Robinson (2001), Dosskey (2001).

Buffers alone have limited influence on wetland hydroperiod

As described in detail in Chapter 3, human land uses, such as agricultural practices, clearing, and land development, alter the movement and storage of surface water and groundwater within a wetland's contributing basin. These changes can significantly affect the hydroperiod of wetlands and other aquatic resources, causing an adverse effect on many wetland functions (Azous and Horner 2001). There is little published literature on the effectiveness of buffers in ameliorating the effect of changes in land use within the contributing basin on wetland hydroperiod. Some of the literature indicates that wetland buffers are far less effective at maintaining wetland hydroperiod than other mechanisms, such as controlling impervious surfaces and utilizing effective stormwater management practices (Herson-Jones et al. 1995).

Research in the Puget Sound Basin has agreed that changes in the land cover type in the contributing basin have a stronger influence on the resulting hydroperiod of the wetland than the buffer does (Booth 1991, Azous and Horner 2001). An exception may be for wetlands that have a very small contributing basin. However, the rate and manner in which stormwater enters the wetland following land-use changes in the contributing basin will most often shift from sheet flow and interflow to one or more point sources, resulting in a potential change in hydroperiod. Based on hydroperiod models using the U.S. Environmental Protection Agency's Hydrologic Simulation Program Fortran (HSPF model) for areas west of the Cascades, the wetland will tend to receive more water more quickly in the fall and will receive less water for a shorter period in the spring, resulting in a shift in the seasonal hydroperiod.

Buffer width is usually not sufficient to counteract the influence of land-use changes and stormwater management facilities within the wetland's contributing basin.

5.5.3 Buffers and Protection of Water Quality

Buffers protect the water quality of wetlands through four basic mechanisms:

- They remove sediment (and attached pollutants) from surface water flowing across the buffer
- They biologically “treat” surface and shallow groundwater through plant uptake or by biological conversion of nutrients and bacteria into less harmful forms
- They bind dissolved pollutants by adsorption onto clay and humus particles in the soil
- They help maintain the water temperatures in the wetland through shading and blocking wind

Literature describing the different ways that buffers maintain and improve water quality in wetlands and other aquatic areas is abundant. There is also considerable research on the effective widths that provide a relative percentage of removal of sediments, nutrients, and some toxics emanating from various sources. Four categories of water quality improvement are discussed below:

- Removing sediment
- Removing nutrients
- Removing toxics and pathogens
- Maintaining microclimate

For each of these categories, a summary is provided on what the literature says about the relationship between buffer width (or other characteristics) and the buffer's effectiveness in providing that type of water quality improvement. A summary table is included that lists the range of buffer widths for each category and the literature references that substantiate those findings. However, the literature does not address the issue of "how much pollutant removal is acceptable." For each pollutant, there may be a maximum amount that a buffer can process before its ability to do so is overwhelmed. The literature does not provide any specific thresholds (See section 5.5.5.3 for more on this issue).

5.5.3.1 Removing Sediment

Characteristics that Influence a Buffer's Ability to Remove Sediment

A buffer's ability to remove sediment from surface water flows depends upon several physical characteristics of the buffer. Sediment removal occurs when (Castelle et al. 1992b, Dillaha and Inamdar 1997, Phillips 1989):

- Flows are slowed sufficiently to allow particles to settle out
- Physical filtering by vegetation and roots mechanically removes sediments from the water column
- The slope of the buffer is of a low enough gradient to preclude formation of rills and scouring
- There is large woody debris on the ground to create roughness
- The infiltration rate of the soils allows water to move through the soils rather than on the surface

The way sediment-laden water enters a buffer influences the ability of the buffer to slow the flows sufficiently to allow sediment deposition. Several studies noted that vegetated buffers are only effective at removing sediments if sediment-laden waters enter the buffer as sheet flow, rather than in channels or rivulets (Phillips 1989, Booth 1991, Castelle et

al. 1992b, Desbonnet et al. 1994, Belt and O’Laughlin 1994, Sheridan et al. 1999). Norman (1996) cites work conducted by Schueler in 1987 that found buffers in urban settings were most effective at removing sediments where slopes were less than 5%, and waters entered the buffer in shallow, dispersed sheet flow. Norman surmised that, “The rate of removal of pollutants appears to be a function of the width, slope, and soil permeability of the (buffer) strip, the size of the contributing runoff area, and the runoff velocity.”

In other research, Sheridan et al. (1999) found that the greatest reduction in sediment loading occurs in the initial “treatment” stages using a vegetated filter strip that is managed and mowed. Their research found the greatest removal of sediments (56 to 72%) and reduction in flow rates occurs in the outer portion of a vegetated filter strip (the strip closest to the source of sediment). Grass filter strips provided removal ranging from 78 to 83% of suspended sediments.

The ability of a buffer to provide physical filtering of sediments also depends on the condition of the vegetation and the surface roughness. Belt and O’Laughlin (1994) noted that when vegetation, rocks, or other obstructions were eliminated from the buffer surface, sediment-laden waters flowed further into (or through) a buffer. Buffers were found to be effective in removing sediments only if flows were shallow and broad, not narrow and incised. The presence of woody debris and vegetative obstructions on the ground surface (roughness) was found to slow flows, inhibit the formation of rills, and facilitate sediment deposition.

In contrast, hydrologic models created by Phillips (1989) estimated that surface roughness would be of minor concern, and buffer width was not critical, as long as a minimum 49-foot (15 m) buffer was maintained. This study was based on estimated models, whereas Belt and O’Laughlin’s work was based on field measurements.

Phillips (1989) also emphasized the importance of slope. He states, “Results show that where solid-phase pollutants transported as suspended or bed-load in overland flow are the major concern, slope gradient is the most critical factor, followed by soil hydraulic conductivity.” Slope gradient is critical because, on slopes greater than 5%, sheet flow can start to become channelized. Channelized flows have faster rates, more erosive powers, and less contact with vegetation (Norman 1996). Faster moving water has the capacity to carry fine sediment particles farther than slower flows, even moving through dense vegetation.

In his research in urbanizing settings, Booth (1991) notes that buffers adjacent to aquatic resources may have limited ability to filter and slow flows caused by stormwater. He found that (1) in some instances the buffers no longer existed in a natural vegetated condition, (2) once development occurred, and the buffer was subdivided into multiple private ownerships, maintaining an intact buffer was not possible, or (3) the increased volumes and rates of flows were too significant to be controlled by conditions within a vegetated buffer.

Buffers were found to facilitate reduction of sediment from active agricultural fields in several studies:

- Welsch (1991) found that a three-tiered buffer system on a shallow slope, with the first tier (closest to the source of sediment) composed of dense herbaceous vegetation, maximized sediment removal (See Section 5.5.6 for a discussion of the three-tiered system).
- Dosskey (2001) noted in agricultural settings that vegetated buffers retain pollutants by reducing the flow rates and filtering surface runoff from fields.
- Assessing management options to control non-point-source pollution (sediment, nitrogen, and phosphorus) in agricultural settings, Yocom et al. (1989) recommended the use of vegetated filter strips between actively cropped land and adjacent wetlands.

Buffer Width and Effectiveness in Removing Sediment

As noted above, the ability of a buffer to remove sediment is based on the condition of the buffer and its slope, as well as the characteristics of the incoming sediment. The following variables all contribute to the sediment removal effectiveness of a buffer:

- The velocity of sediment transport (in surface water)
- The size of sediment particles from the source materials
- The density of the vegetation present
- The presence and extent of large woody debris
- Surface roughness within the buffer

However, the relationship between the width of the buffer and its effectiveness is non-linear. The largest particles and the greatest percentage of particles are dropped in the outer portions of the buffer (closest to the source of sediment). In these outer areas, the rate of surface flow begins to diminish as the water is slowed by vegetation and woody debris. Slower water movement allows particles to drop out of the water column.

This is graphically illustrated in the graph below (Figure 5-1). This table is included here for illustrative purposes only, to depict the non-linear nature of buffers in removing sediments. This graph is based on data from the buffer synthesis by Desbonnet et al. (1994).

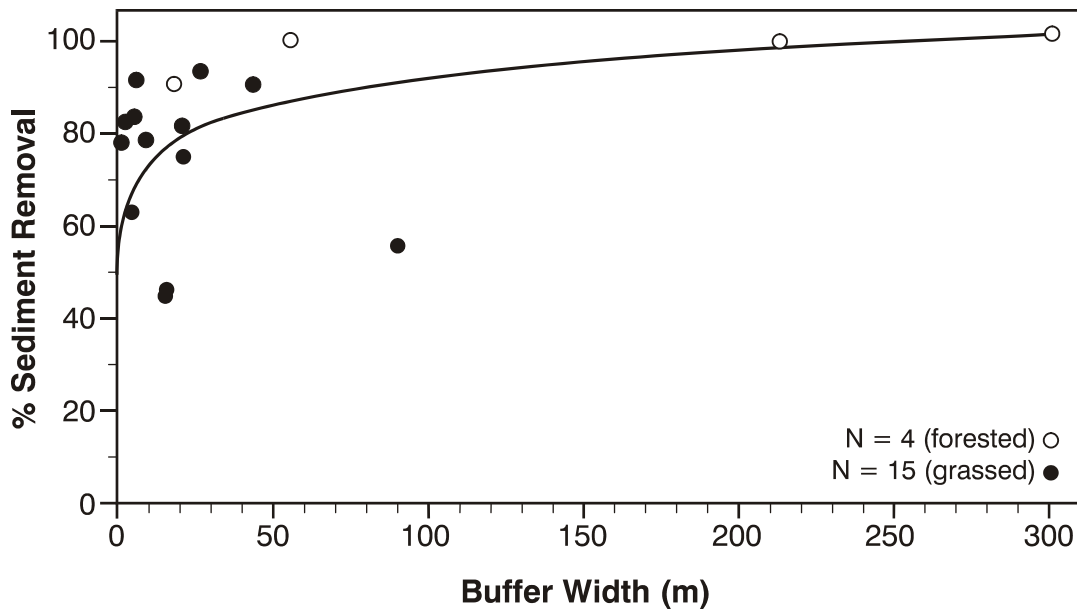


Figure 5-1. Relationship of percent removal to buffer width for the treatment of sediments contained in surface water runoff (Desbonnet et al. 1994).

In 1982, Wong and McCuen derived a formula to model a buffer's ability to remove sediments based on sediment particle size, the slope within the buffer, the rate of surface runoff, and the amount of vegetation and woody debris (roughness) in the buffer (Castelle et al. 1994). The model predicted that there would be a point of relative diminishing returns for function vs. width. For example, "If the sediment removal design criteria were increased from 90 to 95% on a 2% slope, then the buffer widths would have to be doubled from 30.5 to 61 m (100 to 200 ft)." In other words, the model predicted that the width of the buffer would have to double to achieve an additional 5% removal of sediment after 90% of it had already been removed from the water column. Desbonnet et al. (1994) determined that a small buffer (7 feet [2 m]) could effectively remove up to 60% of suspended sediment, while a buffer of up to 82 feet (25 m) would be needed to remove 80%.

These findings are consistent with others who have found that progressively larger buffer dimensions are required to filter out finer particles (Norman 1996). These and other studies are summarized in Table 5-1.

See Section 5.5.5 for discussion of the ability of buffers to continue providing sediment removal over the long term.

Table 5-1. Summary of studies on sediment control provided by buffers of various widths.

Author(s)	Date	Buffer Width	Comments
Broderson	1973	200 feet (61 m)	Effective sediment control “even on steep slopes”
Desbonnet et al.	1994	6.6 – 82 feet (2 – 25 m)	60% removal in 6.6 feet (2 m); 80% removal required 80 feet (25 m)
Desbonnet et al.	1994	16 – 49 feet (5 – 15 m)	On grassy buffers on slopes with less than 5% slope, removed all but the finest particles
Ghaffarzadeh et al.	1992	16 – 49 feet (5 – 15 m)	Found 85% removal in 30-foot (9.1 m) buffers
Horner and Mar	1982	200 feet (61 m)	80% of sediments. As cited by Castelle and Johnson (2000)
Lynch et al.	1985	98 feet (30 m)	75 to 80% removal of sediment from logging activities into wetlands
Norman	1996	9.8 feet (3 m): sands 49.9 feet (15.2 m): silts 400 feet (122 m): clays	Distances required for effective removal of progressively smaller particle sizes
Wong and McCuen	1982	100 – 200 feet (30.5 – 61 m)	90% at 100 feet (30 m), need 200 feet (61 m) to obtain 95% removal effectiveness
Young et al.	1980	80 feet (24.4 m)	92% sediment removal rate from feedlot through vegetated buffer strip

5.5.3.2 Removing Nutrients

Characteristics that Influence a Buffer’s Ability to Remove Nutrients

Nutrients are transported into wetlands via sediment-laden water or dissolved in surface or shallow subsurface flows. The primary nutrients of concern are nitrogen and phosphorous. Buffers remove nitrogen and phosphorous through a variety of mechanisms that are similar to the mechanisms present within the wetland itself, as described in Chapter 2.

As much as 85% of phosphorous in surface waters is bound to sediments (Karr and Schlosser 1977) and thus can be removed via sediment removal in buffers. Phosphorus and other nutrients may be effectively reduced in surface waters by filtering and uptake; however, dissolved forms of nitrogen are not affected by surface processes and can be more effectively removed in the buffer through subsurface contact with fine roots (Muscutt et al. 1993, Townsend and Robinson 2001). Lowrance et al. (1995) confirm that the areas where improvements in water quality are the most effective are where precipitation moves across, through, or near the rooting zone of a forested buffer. These

findings are similar to those of Phillips (1989), who found that longer contact of dissolved pollutants through wider vegetated buffers was the most important factor for effective removal.

Buffer Width and Effectiveness in Removing Nutrients

It is difficult to compare studies of buffer width and effectiveness at removing nutrients because the basic parameters of the studies differ greatly. Some studies were conducted in field settings while others occurred in experimentally designed plots. There were differences in the loading rate of nutrients, the types of soils, and the vegetation in the buffers. Some studies examined only nitrogen or phosphorous removal, whereas others combined different nutrients. The result is that reported effectiveness of buffer widths for removing nutrients ranges from a few meters to hundreds of meters. Studies are listed in Table 5-2.

In a synthesis of research on nitrogen removal, McMillan (2000) found nitrogen can be effectively removed in buffer strips ranging from 20 to 98 feet (6 to 30 m) wide. He cites work by two research groups (Patty et al. 1997, Daniels and Gilliam 1996) that 47 to 99% removal of nitrogen can be achieved in buffers ranging from 20 to 66 feet (6 to 20 m) wide. This is not totally consistent with synthesis results presented by Desbonnet et al. (1994) that “well configured” buffers (with ideal slope, soils, and vegetation) as small as 30 feet (9 m) could reduce as much as 60% of nitrogen, while 197-foot (60 m) buffers would be necessary for 80% nitrogen removal.

A recent study from Oregon documented the role of red alder forests in exporting nitrogen to streams (Compton et al. 2003). They found that the percent of alder forest in a watershed was positively correlated with nitrate concentrations in surface water. This has implications for assuming that buffers with alder forests will help reduce the input of nitrogen from adjacent land uses into wetlands and other surface water.

The literature also describes a range of buffer widths necessary for phosphorus removal. Studies of buffer widths as small as 13 feet (4 m) and as large as 279 feet (85 m) found phosphorus removal rates of 50% to over 90% (see Table 5-2).

Overall, a consistent pattern emerges from the literature. The largest relative percent removal of phosphorus occurs within the outer portions of the buffer (closest to the source), while larger buffers are required to remove increasingly more of the nutrients. This consistency substantiates the conclusions of many that initial contact causes sediment-associated nutrients to be deposited, while dissolved nutrients require longer residence time and prolonged contact with vegetation for effective uptake (removal from the water column) to occur.

Castelle and Johnson (2000) surmised in their literature review that nutrient removal may have a similar non-linear relationship to buffer width as sediment removal. However, Phillips (1989) found that buffer width was a more critical element for dissolved nutrients (especially nitrogen), because wider buffers provided more prolonged contact with the rooting zone and time for uptake and conversion. Phillips did not report widths of buffers related to a certain percent of removal or effectiveness.

Limited research has been done on the long-term effectiveness of buffers for nutrient removal when there is an ongoing nutrient source present on the outside edge of the buffer. See Section 5.5.5.3 for a discussion.

Table 5-2. Summary of studies on nutrient removal provided by buffers of various widths.

Author(s)	Date	Width	Comments
Daniels and Gilliam	1996	20 – 66 feet (6 – 20 m)	47-99% removal of nitrogen
Desbonnet et al.	1994	30 feet (9 m): 60% removal 197 feet (60 m): 80% removal	Small buffers could have effective removal rates for nitrogen; much larger buffers are necessary for a significant increase in effectiveness
Desbonnet et al.	1994	Averages: 39 feet (12 m): 60% 279 feet (85 m): 80%	When all the findings from the literature synthesis were averaged, the average removal efficiencies were non-linear: larger buffers were needed for increases in effectiveness
Dillaha	1993	15 feet (4.6 m): 70% 30 feet (9.1 m): 84 %	Percent removal of suspended solids and their associated nutrients with vegetated filter strips. As cited in Todd (2000)
Dillaha	1993	15 feet (4.6 m): 61 % 30 feet (9.1 m): 79 %	Removal of phosphorus with vegetated filter strips. As cited by Todd (2000)
Dillaha	1993	15 feet (4.6 m): 54% 30 feet (9.1 m): 73%	Removal of nitrogen with vegetated filter strips. As cited by Todd (2000)
Doyle et al.	1977	12.5 feet (3.8 m) forested 13.1 feet (4 m) grass	Reduced nitrogen, phosphorus, and potassium levels
Edwards et al.	1983	98 feet (30 m)	50% removal rate of phosphorus
Lowrance	1992	23 feet (7 m)	Forested buffer zones were effective at removing nitrate through plant uptake and microbial denitrification
Lynch et al.	1985	98 feet (30 m)	Forested buffers reduced soluble nutrient levels from logging activities to “appropriate” levels
Patty et al.	1997	20 – 66 feet (6 – 20 m)	47 - 99% removal of nitrogen
Shisler et al.	1987	62 feet (19 m)	Forested riparian buffers effectively removed up to 80% and 89% of phosphorus and nitrogen, respectively
Thompson et al.	1978	39 – 118 feet (12 – 36 m)	Found a range of removal effectiveness of 44 to 70%

Author(s)	Date	Width	Comments
Vanderholm and Dickey	1978	> 853 feet (260 m)	Removal of 80% of nutrients, solids, and BOD from feedlot runoff with shallow (<0.5%) buffer slopes. Cited in Castelle et al. (1992b)
Young et al.	1980	69 feet (21 m): 67% removal 89 feet (27 m): 88% removal	Removal of phosphorus
Xu et al.	1992	33 feet (10 m)	Significant reductions in nitrate through a mixed herbaceous and forested buffer strip (as cited by Castelle and Johnson 2000)

5.5.3.3 Removing Toxics and Pathogens

Characteristics that Influence a Buffer's Ability to Remove Toxics and Pathogens

A buffer's ability to remove toxicants and pathogens is one of the least thoroughly studied. At this time, it represents a significant data gap. Castelle and Johnson (2000) note the lack of research on pathogens, toxicants and fecal coliform bacteria (an indicator of the possible presence of pathogens). Many of the studies they examined are quite old, but little recent research was found to supplement these older studies. Therefore, the conclusions presented from the synthesis of the previous work are provided here.

Gilliam (1994) also confirms in his work that little to no research is available on the effective removal of fecal coliforms or various pesticides. Much of the work assessed the effectiveness of removal of nutrients and toxics, without identifying a dimension of width necessary to provide that removal.

Toxics (pesticides and metals) can be removed by buffers through sedimentation, biological uptake by vegetation, adsorption onto clay or humus particles in the soil of the buffer, or degradation of the toxics through biochemical processes (McMillan 2000, Patty et al. 1997).

As mentioned in the discussion of sediment removal, Welsch (1991) described the use of a three-tier buffering system for the most effective removal of sediments and their associated toxics. The outermost tier (closest to the source of impacts) was a densely vegetated filter strip, managed to ensure no erosion or rill formation. He found the most effective removal of sediments and the toxics adhered to sediment particles was through surface sheet flows through the vegetated filter strip. The middle tier was subject to some management activities (limited agriculture or limited tree harvest), while the innermost tier was undisturbed natural vegetation. Dissolved nutrients and some toxics were not affected by physical filtering unless there was prolonged contact with the rooting zone through the shallow groundwater table. See Section 5.5.6 for further discussion.

Castelle and Johnson (2000) note that the apparent effectiveness of small buffers in removing toxics is due to the adsorption of many toxics to sediment particles. When vegetated buffers are effective at filtering sediments, they will also be effective at filtering those toxics and nutrients adhered to the sediments.

One study in Saskatchewan (Donald et al. 1999) found that the concentrations of agricultural pesticides and herbicides in wetlands were influenced by the timing of precipitation relative to the applications of the chemicals. They noted that buffer width may influence exposure of the wetland to these chemicals, but they did not quantify what buffer widths related to the effectiveness of removing chemicals.

Neary et al. (1993) reviewed studies in the Southeastern U.S. on the use of buffers in reducing contamination of water by pesticides. They found that cases of high concentrations of pesticides in water only occurred when no buffer was present or when pesticides were applied within the buffer. Regular use of buffer strips kept concentrations of pesticide residue within water-quality standards. Neary concluded that, generally speaking, buffer strips of 15 m (49 ft) or larger are effective in minimizing contamination of streams by pesticide residue.

Table 5-3 summarizes studies on the effectiveness of toxicant and pathogen removal provided by buffers of various widths.

Table 5-3. Summary of studies on pathogen control provided by buffers of various widths.

Author(s)	Date	Width	Comments
Doyle et al.	1977	12.5-foot (3.8 m) forested buffers 13.1-foot (4 m) grass buffers	Reduction in fecal coliform bacteria levels.
Grismer	1981	98-foot (30 m) grass filter strip	Removal of 60% of fecal coliform bacteria.
Young et al.	1980	115-foot (35 m) grass buffer	Reduced microorganisms to acceptable levels.

5.5.3.4 Maintaining Microclimate

The influence of buffers on microclimate is most often thought of in the context of shading for maintaining water temperature. This is well documented in the literature in relation to the effects on streams (Lynch et al. 1985, Johnson and Stypula 1993, Belt and O’Laughlin 1994, Castelle and Johnson 2000,). In those documents, literature focused on streams and their buffers is almost exclusively relied upon to discuss the influences of buffers on water temperature. No literature was found that specifically examined the influence of buffers on the water temperatures and microclimates within wetlands.

It may be tempting to deduce that the benefit of forested shade in moderating water temperatures is the same in wetlands as in streams. However, it is not reasonable to

apply to wetlands the findings on the widths used for stream buffers for the purpose of shading. As with streams, there are many variables that can influence how shading affects the water temperature in a wetland. These variables relate to differences in water budgets (e.g., the relative influence of groundwater on a seasonal basis, whether the wetland has an inlet/outlet, etc.). In addition, the physical configurations of a large open-water wetland, a small fully vegetated wetland, and a linear stream corridor may not provide reasonable parallels. With these limitations in mind, some relevant findings are provided below.

Forests can create shade and also block the wind, which can help moderate temperatures in adjacent aquatic systems (Oke 1987). Stable water temperature helps maintain water quality because cooler water can carry higher loads of dissolved oxygen, which is important for many aquatic biota. Warmer water can also result in a looser bond between sediment particles and nutrients, which could result in an increase in nutrient loading in warmer aquatic systems (Karr and Schlosser 1977).

Microclimate influences can also extend from large wetlands into the adjacent forests. Harper and MacDonald (2001) conducted research on boreal forests near lakes and found a “distinct lake edge community” of about 131 feet (40 m) width. The lake edge community tended to have greater structural diversity, less canopy cover, fewer snags, greater amounts of coarse woody debris, and greater number of saplings and mid-canopy trees than the interior forest. Changes in the distribution of vegetation species were along a shade tolerance gradient, but the authors postulated that moisture gradient or water table depth also had an influence. Their research was conducted within forests adjacent to open water lakes, but it would be valid to extrapolate their findings to forested communities adjacent to permanent, large open wetlands that would create the same “light and shade” effect. The findings imply that large open aquatic systems influence the adjoining upland community for approximately 131 feet (40 m) distance into the interior of the forested buffer. Thus, buffers not only influence temperatures and wind effects in a wetland, but research identifies that large aquatic systems may have a reverse positive influence on the vegetation structure and species diversity of the buffer. This can thereby affect some of the habitat discussed later in this chapter.

Table 5-4. Summary of a study on the influence of microclimate provided by buffers of various widths.

Author(s)	Date	Width	Comments
Harper and MacDonald	2001	Approx. 131 feet (40 m)	Influence of large aquatic systems on adjacent upland forest composition and structural complexity

5.5.3.5 Summary of Key Points

- The use of buffers to protect and maintain water quality in wetlands (removing sediments, nutrients, and toxicants) is best accomplished by ensuring sheet flow across a well vegetated buffer with a flat slope (less than 5%).
- Significant reductions in some pollutants, especially coarse sediments and the pollutants adhered to them, can be accomplished in a relatively narrow buffer of 16 to 66 feet (5 to 20 m), but removal of fine sediments requires substantially wider buffers of 66 to 328 feet (20 to 100 m).
- Removal of dissolved nutrients requires long retention times (dense vegetation and/or very low slope) and, more importantly, contact with fine roots in the upper soil profile (i.e., soils that are permeable and not compacted). Distances for dissolved nutrient removal are quite variable, ranging in the literature from approximately 16 to 131 feet (5 to 40 m).
- The literature is consistent in finding that it takes a proportionally larger buffer to remove significantly more pollutants because coarse sediments and the pollutants associated with them drop out in the initial (outer) portions of a buffer. It takes a longer time for settling, filtering, and contact with biologically active root zones to remove fine particles and dissolved nutrients.
- The role of buffers in protecting the microclimate of streams is well documented and may be applicable to wetlands, but no specific data on buffers and wetland microclimate maintenance were found.

5.5.4 Buffers and Wildlife Habitat

Wetland buffers are essential to maintaining viable wildlife habitat because they perform three overlapping functions:

- Buffers can provide an ecologically rich and diverse transition zone between aquatic and terrestrial habitats. This includes necessary terrestrial habitats for many wildlife species that use and/or need wetlands but also need terrestrial habitats to meet critical life requirements.
- Buffers can screen wetland habitat from the disturbances of adjacent human development
- Buffers may provide connectivity between otherwise isolated habitat areas

In regard to wildlife, most of the scientific research is not directly focused on the effectiveness of buffers for maintaining individuals or populations of species that use wetlands. Some of the research simply documents use of upland habitats adjacent to wetlands by wildlife to meet their life-history needs. For example, a substantial body of

research identifies the distances that amphibians may be found away from a wetland edge. However, the implications to amphibian populations of providing buffers that are smaller than those identified ranges are not well documented.

The following discussion summarizes the literature on buffers related to wildlife that use wetlands for the three essential functions listed above. Several documents are cited that represent a synthesis of scientific literature on the effectiveness of buffers for protecting wildlife-related functions of wetlands. Even though these documents include some research conducted prior to 1990, they have been included where relevant.

There is substantial literature on the implications to wildlife populations from fragmenting habitats as a result of human activities. However, this research was not necessarily conducted to address the effectiveness of various buffer widths. The literature on this topic is mentioned because of the management implications for the long-term viability of species that are closely associated with wetlands. The reader is referred to Section 4.11 in Chapter 4 and Section 5.5.4.3 for a detailed discussion of habitat fragmentation.

5.5.4.1 Maintaining Terrestrial Habitat Adjacent to Wetlands

Buffers provide a transition between aquatic and terrestrial environments and are a critical component of the habitat of wildlife that use wetlands. The specific habitat functions provided by wetland buffers include:

- Sites for wildlife for foraging, breeding, and nesting
- Cover for escape from predators or adverse weather
- Source of woody debris and organic matter that provides habitat structure and food, as well as moderation of water temperatures within adjacent wetlands to support species that are sensitive to temperature (e.g., fish, amphibians).
- Areas for dispersal and migration related to both individuals and populations; buffers may connect or be part of corridors

As defined previously, buffers are predominantly upland habitat communities that lie adjacent to aquatic habitats. They are a different habitat type than the wetland and their presence increases habitat heterogeneity by providing niches for more species. First described by Leopold (1933) as the “edge effect,” and later by Odum (1959) as an “ecotone,” this phenomenon features higher use of transition zones by wildlife, particularly between aquatic and terrestrial habitats. It has been demonstrated in studies of birds (Beecher 1942, McElveen 1977), mammals (Bider 1968), and amphibians (Bury 1988). The same pattern has been demonstrated in the Pacific Northwest in studies by Oakley et al. (1985), Knight (1988), and Cross (1988). Recent research conducted in the Puget Sound lowlands found that the greatest species richness of birds and small mammals in 50 foot wetland buffers was found when an additional 1,640 feet (500 m) of relatively undisturbed habitat was adjacent to the wetland buffer (Richter and Azous 2001b, 2001c).

Protection of upland areas adjacent to wetlands is critical to helping ensure that wildlife populations that are closely associated with wetlands have access to the habitat features necessary to meet their survival requirements. Species that are closely associated with wetlands, such as many amphibians, aquatic invertebrates, waterfowl, and some mammals, require access to wetlands for critical stages of their life-history. Many more species use wetlands, as well as other aquatic systems such as streams, lakes, or rivers, to meet various life-history needs. Research shows that species that were assumed to be dependent upon wetlands also depend upon adequate and appropriate upland habitats to maintain viable populations (Foster et al. 1984, Bury 1988, Washington Department of Wildlife in Castelle et al. 1992b, Semlitsch 1998, Semlitsch 2000).

In addition, vegetated buffers protect habitat in wetlands by maintaining the microclimate (through temperature moderation), as discussed previously, and by providing a source of organic matter to aquatic systems. This includes both large organic debris (e.g., logs, root wads, limbs), which provides habitat structure in aquatic environments, and particulate and dissolved organic matter, which provides a source of food for invertebrates (Brown 1985, Groffman et al. 1991a).

In coastal wetlands in South Carolina, Braccia and Batzer (2001) found that large woody debris within wetlands was critical for both aquatic and terrestrial invertebrate populations. They identified that the source of the large woody debris within the wetlands was from the adjacent uplands. The forest conditions in adjacent uplands, therefore, can have a significant influence on wetland biota because the aquatic invertebrates form the foundation of many food chains in aquatic settings (Castelle et al. 1994).

Buffer Width and Effectiveness in Protecting Wetland Habitat and Providing Habitat in Adjacent Uplands

This section summarizes the literature that identified ranges of widths of uplands that protect wetland habitat and/or that provide adjacent upland habitat for wildlife species that use wetlands. The literature presents findings in a variety of ways. Some studies identify the distance that target species range from a wetland source, while other researchers identified the distances that species travel between wetlands. Synthesis documents outlined recommendations for buffer widths based on a review of research findings. Some of the literature identified use of habitats by broad categories of wildlife guilds, while other studies focused on limited guilds or even individual species.

It is important to understand that the range of buffer widths identified and discussed in the literature is a reflection of many variables including the objectives of the research, the species/guilds studied and their varied life-history needs, and the methods of the research. Thus, it is not appropriate to choose a single study or buffer dimension to justify a buffer dimension, whether large or small. It is critical to incorporate the life-history requirements of the range of targeted species when considering buffer dimensions. Synthesis documents clarify that a range of upland habitat buffer dimensions may be appropriate depending upon site considerations, landscape context, and targeted species.

For example, in summarizing the literature he reviewed on buffer effectiveness, McMillan (2000) concluded, “An appropriate buffer to maintain wildlife habitat functions for all but the most highly degraded wetlands would be comprised of native tree and/or shrub vegetation and range from 30 to 100 meters [98 to 328 feet].” Other authors have reached similar conclusions, with their buffer recommendations varying depending on the type of wildlife, life-history stage, intensity of adjacent land use, and surrounding landscape (Groffman et al. 1991a, Castelle et al. 1992b, Desbonnet et al. 1994, Semlitsch 1998). Because there is often substantial information on the needs for some specific wildlife groups, the research findings that are relevant for birds, amphibians, reptiles, and mammals are provided below. Following this discussion, Table 5-5 provides a summary of literature on general habitat needs in relation to buffer sizes.

One consideration not found for this synthesis was the implication of the condition of the upland buffer relative to its provision of wildlife habitat. In several studies on the use of upland buffers by native species, the study identified that the buffer was upland forest. However, no studies were reviewed for this synthesis that compared wildlife use of mature forested buffers with buffers composed of meadow, shrubland, harvest forest, or younger forests. Some research has identified the importance of intact forest habitat to wetland-related species (Azous and Horner 2001, Richter 1997), but a comparison study was not found for this synthesis.

Generally, wildlife-species have varying needs for different types of adjacent habitat for different life needs, such as breeding, foraging, and resting (Brown 1985). This makes it difficult to prescribe one particular type of habitat as best for wildlife. Habitat is very species specific. However, as a general rule, most researchers have recommended that buffers be maintained or restored to a forested condition if only for the screening function they provide. (Obviously, this has little relevance to the shrub-steppe ecoregion in Eastern Washington, where trees are rarely found.)

Birds

The research on birds ranges from studies in individual species to summaries on bird species richness. A tremendous amount of research on waterfowl exists, with the majority being conducted in the prairie pothole region of the United States. This section focuses on studies or syntheses that are relevant to the Pacific Northwest.

The Puget Sound Stormwater Management Research Program found that a distance of 1,640 feet (500 m) from a wetland edge was necessary to account for total species richness of birds (Richter and Azous 2001b). In a study of bird use of freshwater wetlands in urban King County, Washington, Milligan (1985) determined that bird species diversity was strongly correlated with the percentage of the wetland boundary that was buffered by at least 49 feet (15 m) of trees and shrubs.

In eastern Washington, Foster et al. (1984) determined that 68% of waterfowl nests were in upland areas within 98 feet (30 m) of the wetland edge, whereas it would take a 312-foot (95 m) buffer to encompass 95% of the nesting sites.

Temple and Cary (1988) created a computer model whose results may relate to the breeding success of forest birds using wetland buffers. Estimating the effects of habitat fragmentation on birds breeding in the interior of forests in Wisconsin, their model predicted that nesting success was strongly correlated to distance to the edge of a forest. The computer model predicted a success rate of 70% for nests greater than 656 feet (200 m) from the forest edge, 58% for a distance of 328 to 656 feet (100 to 200 m), and only 18% for nests less than 328 feet (100 m) from the forest edge. Applying these findings to wetland buffers, those less than 100 feet (30 m) in width might not be expected to support bird species that nest in forest interiors. The authors concluded that, without “recruits” (birds moving into appropriate habitat niches from farther afield), the continued fragmentation of forest habitats could lead to local extinction of populations of birds that use the interior of forests.

Amphibians

The research on amphibians and buffers in relation to their habitat needs comes both from studies in the Pacific Northwest and literature summaries from around the United States. Findings are rather consistent in that amphibians range substantial distances from breeding locations in a wetland to fulfill their life-history needs. On the west side of the Cascades, there appears to be a preference for forested habitats adjacent to breeding sites. Urban land uses near breeding sites seem to have a negative influence on amphibian abundance.

Detailed findings include:

- A study in the Puget Sound lowlands documented a decline in amphibian richness in wetlands where forest in the contributing watershed was diminishing. Results were not linked to buffer dimensions (Richter and Azous 2001a).
- In a study in King County by Ostergaard (2000), the greatest use of stormwater ponds by native breeding amphibians was found when 3,280 feet (1,000 m) of forested habitat was available adjacent to the pond.
- A study of pond-breeding salamanders in the eastern U.S. found that a buffer of 534 feet (164 m) would be needed to encompass 95% of adult and juvenile salamanders. This buffer range may apply to other similarly mobile species (Semlitsch 1998). Buffers of 98 to 328 feet (30 to 100 m) were recommended along riparian zones, depending upon slope, stream width, and adjacent use (Semlitsch 1998).
- Salamanders use upland habitats over 1,969 feet (600 m) from the edge of wetlands for non-breeding life-history stages. Sustaining viable amphibian species closely associated with wetlands requires maintaining the connection between wetlands and terrestrial habitats (Semlitsch 1998).

See Table 5-5 for further information on these studies.

In addition, in the Midwestern U.S., Knutson et al. (1999) found a positive correlation between the presence of forest around the perimeter of the wetland and amphibian abundance, and a negative correlation to urban land uses on the perimeter.

Reptiles

Western pond turtles are associated with a variety of aquatic habitats, including wetlands, streams, and rivers. In a California study, western pond turtles were found to overwinter as far as 1,650 feet (500m) from water (Reese and Welsh 1997). An unpublished study done in Washington for the Washington Department of Wildlife found nest sites as far as 615 feet (187m) from water, usually in open areas with good sun exposure (Holland 1991).

Research on freshwater turtles in North Carolina found that turtles used a wide area for nesting and terrestrial hibernation in uplands surrounding the ponds where breeding occurred (Burke and Gibbons 1995). They found that a 902-foot (275 m) buffer was required to protect 100% of the nest and hibernation sites. Protecting 90% of the sites required a 240-foot (73 m) buffer. The authors concluded that most buffer requirements are inadequate to protect turtle habitat for all stages of their life-history.

Mammals

Use of wetlands by mammals depends upon adjacent uplands. The literature indicates that even a mammal that is closely associated with wetlands, such as a beaver, uses upland habitats an average of 100 feet (30 m) from the wetland edge in eastern Washington and over 300 feet (100 m) distant in western Washington (Castelle et al. 1992b). Research on small mammals found the greatest concentration of species near riparian corridors, with some species found within that riparian corridor that were not found farther away in upland habitats (Cross 1985).

Dimensions of effective buffers for mammals are more difficult to discern from the literature because they depend upon the species' life-history. Also, as discussed in Section 4.11 of Chapter 4, habitat linkages and fragmentation may be more critical for the sustainability of some populations.

As part of the Puget Sound Stormwater Management Research Program, Richter and Azous (2001c) found that the highest richness of small mammals was in wetlands with at least 60% of the first 1,640 feet (500 m) of buffer in forest cover. Other findings of this program include:

- The preservation of large woody debris within the wetland and adjacent upland forest is important for maintaining small-mammal habitat.
- Small-mammal richness was best associated with the combined factors of wetland size, adjacent forest, and the quantity of large, coarse woody debris within the wetland and its buffer.

- In southwestern Oregon, Cross (1985) conducted research on small mammals in “leave-strips” adjacent to streams within zones of forest that had been harvested. He found that the richness of small-mammal species was highest in the riparian zone closest to the stream, intermediate in the transition zone, and lowest in the upland zone. (The zones were defined by vegetation composition, not by dimension.) Because riparian habitats provide more niches for species, it is expected that such habitats would maintain greater species richness (Cross 1985).

Cross also found no species in the upland zone that were not found in the riparian zone, but he found five species present in the riparian zone that were not present in the upland or transition zones. A strip averaging 220 feet (67 m) wide supports mammal communities at similar numbers and richness to the nearby undisturbed riparian corridor. This study focused on small mammals which, relative to large mammals, have small home ranges. Therefore, the study is not broadly applicable to appropriate leave-strip dimensions for larger species.

Table 5-5 presents a summary of literature on wildlife and buffer/upland habitat use that was relevant to this synthesis. As noted previously, some of the research is specific to individual species, some is focused on a particular guild or group of similar species, some looks at life-history patterns (nesting distances), and some sources represent synthesis documents of buffer effectiveness. These distances do not necessarily reflect the literature relative to human disturbance and/or habitat fragmentation, which are discussed in the next sections.

It is difficult to synthesize the findings of the research on wildlife and the width of buffers into simple generalizations that can be readily applied. When looking at life-history needs (e.g., nesting sites, foraging ranges, etc.), the distances presented in the literature range from 98 feet (30 m) (Foster et al. 1984, Castelle et al. 1992b) to 3,280 feet (1,000 m) (Richter 1997). These distances, measured in the field, represent the distance that species ranged, nested, or foraged from a wetland edge.

Other authors have presented their own synthesis or recommendations of effective buffer ranges based on review of the literature. These range from 49 feet (15 m) (Desbonnet et al. 1994) to 328 feet (100 m) (Groffman et al. 1991a, Castelle et al. 1992b, Desbonnet et al. 1994, McMillan 2000). Note that Desbonnet et al. (1994) recommends a range of buffer dimensions based on site conditions, species of interest, and proposed adjacent land uses; hence, their studies are cited at both ends of the distance spectrum.

Table 5-5. Summary of studies on wildlife habitat provided by buffers.

Author(s)	Date	Width	Comments
Allen	1982	328 – 590 feet (100 – 180 m)	Mink use: generally concentrated within 330 feet (100 m) of water but will use upland habitats up to 590 feet (180 m) distant
Burke and Gibbons	1995	240 feet (73 m): 90% 902 feet (275 m): 100%	Buffer to encompass % nesting and hibernation of turtles in North Carolina

Author(s)	Date	Width	Comments
Castelle et al.	1992b	197 – 295 feet (60 – 90 m): Western Washington 98 – 197 feet (30 – 60 m): Eastern Washington	Range for all species they noted Range for all species they noted
Castelle et al.	1992b	263 feet (80 m) avg. - 590 feet (180 m)	Wood duck nesting locations from wetland edge (non-Washington data)
Castelle et al.	1992b	98 feet (30 m): Eastern Washington 328 feet (100 m): Western Washington	Distance of beaver use of upland habitats from water edge
Chase et al.	1995	98 feet (30 m) or more	100 feet (30 m) would be “adequate”; buffers larger than 100 feet needed to meet habitat needs, including breeding for birds and some mammals
Cross	1985	220 feet (67 m)	Forested “leave-strips” for small mammal richness adjacent to streams in SW Oregon
Desbonnet et al.	1994	49 – 98 feet (15 – 30 m): low intensity 98 – 328 feet (30 – 100 m): high intensity	Variable buffer widths using adjacent land uses as decision-making criteria
Fischer et al.	2000	98 feet (30 m) minimum	Literature review; majority of literature cited recommends buffer widths of 330 feet (100 m) for reptiles, amphibians, birds, and mammals
Foster et al.	1984	98 feet (30 m): 68% of nests 312 feet (95 m): 95% of nests	Waterfowl breeding use of wetlands in the Columbia Basin greatest in smaller (<1 acre [0.4 ha]) wetlands; 68% of waterfowl nests within 100 feet (30 m) of wetland edge; to encompass 95% of waterfowl nests would require 310 feet (95 m) of buffer
Groffman et al.	1991a	197 - 328 feet (60 - 100 m)	For most wildlife needs
Groffman et al.	1991a	328 feet (100 m)	Neotropical migratory bird species
Howard and Allen	1989	197 feet (60 m)	For most wildlife needs
McMillan	2000	98 – 328 feet (30 – 100 m)	Based on a synthesis of literature
Milligan	1985	49 feet (15 m)	Bird species diversity strongly correlated with the percentage of the wetland boundary buffered by at least 50 feet (15 m) of tree and shrub vegetation
Norman	1996	164 feet (50 m)	To protect wetland functions; more buffer may be required for “sensitive wildlife species”

Author(s)	Date	Width	Comments
Ostergaard	2001	3,280 feet (1,000 m)	Forested habitat surrounding stormwater ponds, related to native amphibian richness
Richter	1996	3,280 feet (1,000 m)	Literature review and synthesis
Richter	1996	3,280 feet (1,000 m)	Native amphibian use
Richter and Azous	2001b	1,680 feet (512 m)	Distance from wetland edge necessary to include all bird richness in Puget Sound lowland wetlands
Richter and Azous	2001c	1,640 feet (500 m): 60%	Highest small-mammal richness when 60% of first 1,640 feet (500 m) of buffer was forest habitat
Semlitsch	1998	1,969 feet (600 m)	Salamanders
Semlitsch	1998	228 – 411 feet (69.6 - 125.3 m) 539 feet (164.3 m) for 95% of all species	Six species of adult salamanders and two species of juveniles; mean distance from wetland edge was 228 feet (juveniles) – 411 feet (adults). To incorporate 95% of all species, buffer mean would have to be 539 feet
Short and Cooper	1985	164 – 328 feet (50 – 100 m)	164 feet (50 m) for foraging
Temple and Cary	1988	> 656 feet (200 m): 70% success 328 – 656 feet (100 – 200 m): 58% success < 328 feet (100 m): 18% success	Nesting success rates for interior-dwelling forest birds related to distance into the interior of a forest from the forest edge

5.5.4.2 Screening Adjacent Disturbances

Wetland buffers screen wildlife from human activities. Disturbance from humans can come in the form of noise and light (indirect effects) or from human presence/movement (direct effects). Noise and light can disrupt feeding, breeding, and sleeping habits of wildlife. Many wildlife species in wetlands are disturbed by unscreened human activity within 200 feet (61 m) (Washington Department of Wildlife in Castelle et al. 1992b). Dense shrubs and trees in a wetland buffer can limit intrusion and screen out noise, light, and movement from adjacent human development (Castelle et al. 1992b).

In addition, domestic pets such as dogs and cats can adversely affect wetland wildlife by preying on some wildlife species and are particularly damaging to ground-nesting species (Churcher 1989). See Section 4.12.5 in Chapter 4 for further discussion.

The effect of noise on wildlife is a topic of growing concern. Little research exists on the effective buffer widths required to filter sounds for wildlife. See Section 4.12.3 in Chapter 4 for a discussion of current literature on the effects of noise on wildlife.

Groffman et al. (1991a) determined that 105 feet (32 m) of dense, forested buffer was necessary to reduce noise from commercial areas to background noise levels. Shisler et al. (1987) differentiated between the impacts of low-intensity land uses (agricultural, recreational, low-density housing) and high-intensity land uses (high-density residential, commercial/industrial). They found that low-intensity land uses could be effectively screened with vegetated buffers of 49 to 98 feet (15 to 30 m), while high-intensity land uses required buffers of 98 to 164 feet (30 to 50 m).

Direct sighting of humans approaching was found to disrupt birds (i.e., change their behavior or cause flushing) between 46 and 164 feet (14 to 50 m) (Shisler et al. 1987, Josselyn et al. 1989, Rodgers and Smith 1997). Looking specifically at great blue herons, Short and Cooper (1985) documented that they would flush from their nests if humans approached within 328 feet (100 m). Buffers between 46 and 164 feet (14 to 50 m) may be required to screen wildlife from direct observation of humans, while larger buffers (328 feet or 100 m) were documented as necessary to screen nesting herons.

Other researchers differentiated between the types of activities humans are engaged in and their effects on wildlife. Humans walking toward birds were studied to see how closely they could approach before birds flushed from perches or stopped foraging. In Florida, Rodgers and Smith (1997) found that humans could approach 46 to 112 feet (14 to 34 m) before flushing, but automobiles flushed birds at 61 to 78 feet (18.5 to 24 m). Interestingly, they found that bird-watching (as opposed to humans who were simply walking) had the greatest adverse impacts on birds. They surmised this was due to the human behavior of stopping and standing with binoculars at one point for a prolonged time.

Cooke (in Castelle et al. 1992b) analyzed 21 wetland sites in western Washington and concluded that buffers smaller than 50 feet (15 m) were generally ineffective in screening human disturbance from alterations such as noise, debris, and altered use of the buffer.

Table 5-6 summarizes the findings of the literature related to the disturbance limits or screening effects of a buffer for various wildlife species.

Table 5-6. Summary of studies on screening provided by buffers.

Author(s)	Date	Width	Comments
Castelle et al.	1992b	200 feet (61 m)	General wildlife considerations
Cooke	1992	50 feet (15 m)	Analyzed 21 sites in King County. Buffers less than 50 feet were often disturbed by human activities and were not effective at screening "human effects." Found in Castelle et al. (1992b)
Groffman et al.	1991a	105 feet (32 m)	Dense forest to filter sound from commercial land uses to natural background levels
Josselyn et al.	1989	49 – 164 feet (15 – 50 m)	Unscreened human activity within 50 – 164 feet was disruptive to waterbirds in San Francisco Bay area

Author(s)	Date	Width	Comments
Rodgers and Smith	1997	46 to 112 feet (14 – 34 m) 61 to 78 feet (18.5 – 24 m)	Waterbirds in Florida: flushing distance from walkers 46 – 112 feet; flushing distance from autos 61 – 78 feet. Nature observation had greatest impact if involving walking activities. Nesting birds tolerated closer human approach than birds that were perching/foraging
Shisler et al.	1987	50 - 100 feet (15 – 30 m) 100 – 164 feet (30 – 50 m)	Low-intensity land uses (agriculture, recreation, and low density residential): 50 - 100 feet High-density residential housing and commercial/industrial: 100 - 164 feet Most effective buffers had steep slopes, dense shrubs
Short and Cooper	1985	328 feet (100 m)	328 feet to buffer nesting great blue herons from human disturbance

5.5.4.3 Maintaining Habitat Connections

Converting habitats to other uses directly increases the isolation of wetlands and the fragmentation of habitats (See Section 4.11 in Chapter 4 for further discussion of the impacts of fragmentation). Buffers can play a role in reducing habitat fragmentation by serving as upland habitat directly adjacent to a wetland. They can also provide an area that can connect, or be part of a corridor that connects, wetlands with upland habitats or other water bodies (National Research Council 2001). However, buffers, as applied in a regulatory context, are rarely designed to provide these connections. Typical buffer widths generally are insufficient to link wetlands to other habitats. In addition, maintaining linkages from one habitat type to another on individual parcels is often not a consideration when properties are reviewed case by case. The authors of Volume I believe that maintaining habitat connectivity is best accomplished through landscape-scale planning and protection measures.

In general, the literature states that for terrestrial species with wide-ranging habits, it is important to maintain connections between sites used for breeding, feeding, and refuge. This is critical for maintaining population viability (Bedford and Preston 1988, Gibbs 1993, Semlitsch and Bodie 1998, National Research Council 2001). One may assume that this applies only to large terrestrial mammals. However, research has shown that many native amphibians on the west side of the Cascades can range 3,280 feet (1,000 m) from source wetlands into other wetlands or surrounding upland habitats (Richter 1997). Ostergaard (2001) found the greatest amphibian richness in sites that had upland forest habitat surrounding the site by 3,280 feet (1,000 m). Richter and Azous (2001b) found that a radius of 1,680 feet (512 m) surrounding a wetland was necessary to include all the bird richness of species utilizing the source wetland.

5.5.4.4 Summary of Key Points

- There is no simple, general answer for what constitutes an effective buffer width for wildlife considerations. The width of the buffer is dependent upon the species in question and its life-history needs, whether the goal is to maintain connectivity of habitats across a landscape, or whether one is simply trying to screen wildlife from human interactions.
- The majority of wildlife species in Washington use wetland habitats for some portion of their life-history needs. Many species that are closely associated with wetlands (those that depend upon wetlands for breeding, brood-raising, or feeding) depend upon surrounding upland habitats as well for some life-history stages.
- Many terrestrial species that are dependent upon wetlands have broad-ranging habits, some over 3,280 feet (1,000 m) from the source wetland. Although this might be expected for large mammals such as deer or black bears, it is also true for smaller species, such as salamanders and other amphibians.
- Human access and land uses adjacent to wetlands influence the use and habits of wildlife through noise and light intrusions, as well as elimination or degradation of appropriate upland habitats. Even “passive” activities, such as bird/nature-watching, have been shown to have effects on roosting and foraging birds.
- Synthesis documents that evaluated many studies discussing the protection of habitat provided by wetland buffers generally recommend buffer widths between 50 and 300 feet (15 to 100 m), depending on specific factors. These factors include the quality of the wetland habitat, the species needing protection, the quality of the buffer, and the surrounding land uses.

5.5.5 Buffer Maintenance and Effectiveness over Time

Buffers can help to protect wetlands for as long as the buffers themselves remain intact. Buffer areas can be altered over time by human disturbance and natural events, such as windstorms. In addition, some researchers have raised the issue of whether buffers have a long-term, carrying capacity with regard to filtration and binding of pollutants. In other words, is there a maximum amount that can be processed before the buffer’s ability is overwhelmed?

5.5.5.1 Human Alteration to Buffers

Human activities are the most common mechanism for altering buffers over time. Buffer functions can be reduced if vegetation is cut or trampled, soils are compacted, sediment loading surpasses the filtering capability of the vegetation, or surface-water flows create channels and subsequent erosion.

Cooke (in Castelle et al. 1992b) analyzed 21 wetland sites in western Washington and concluded that buffers less than 50 feet (15 m) wide were more susceptible to being reduced over time by human disturbance. Nearly all of the buffers they studied that were less than 50 feet (15 m) in width were significantly reduced in the few years the buffers had been present on the back of private lots. Some of the buffers were found to have been eliminated through complete clearing of native vegetation. Of the buffers wider than 50 feet (15 m), most still had some portion intact and, overall, showed fewer signs of human disturbance. Cooke also found that fencing buffers (without a gate allowing access) was effective at reducing the alteration of buffers by humans.

In a study in the Monterey Bay area of California, Dyste (1995) examined 15 wetlands with buffers. All of the buffers suffered from human alteration including cutting of vegetation, soil compaction, and dumping of garbage.

5.5.5.2 Loss of Trees to Blowdown

In the Pacific Northwest, forested buffers are often leave-strips around wetlands or along streams when the surrounding forest is cleared for land development. These forested strips are then exposed to winter windstorms, which are common, often resulting in substantial loss of large trees due to blowdown.

Pollock and Kennard (1998) concluded that trees in narrow forested buffers (less than 76 feet [23 m] wide) have a much higher probability of suffering significant mortality from windthrow and blowdown than trees in wider buffers. They conclude that buffers in the range of 76 to 115 feet (23 to 35 m), created when the surrounding forest is cut, are the minimum width that can be expected to withstand the effects of wind in the long term.

5.5.5.3 Reduced Capacity for Sediment/Nutrient Removal

Many of the studies described earlier assessed the effectiveness of buffers in removing sediments and nutrients for short durations (on the order of one to two years, if the time period was discernable in the methods sections of the literature). One study that assessed water quality improvement over longer periods found that effectiveness diminished as the outer margins of the buffers became saturated with sediment (Dillaha and Inamdar 1997). Their findings suggest that buffers have a limited carrying capacity for sediment removal (a maximum amount of sediment that can be removed) and that larger buffers and other methods may be required to ensure long-term control of sediment.

Similarly, Todd (2000) cites work by Dillaha in 1993 that found less than 10% of grass filter strips were effective after three to five years. The grass filter strips became channelized and surface flows were no longer passing through as sheet flow that would allow contact with vegetation to remove sediments and nutrients. Todd emphasizes that, for buffers to be effective, they have to be sustainable over time, and this must be a factor when determining buffer widths.

5.5.5.4 Summary of Key Points

- Human actions can reduce the effectiveness of buffers in the long term through removal of buffer vegetation, soil compaction, sediment loading, and dumping of garbage.
- Buffers may lose their effectiveness to disperse surface flows over time as flows create rills and channels, causing erosion within the buffer.
- Leaving narrow strips of trees can result in tree loss due to blowdown.
- Buffers may become saturated with sediment over time and become less effective at removing pollutants. The literature indicates that this should be considered when determining buffer widths.

5.5.6 Summary of Buffer Ranges and Characteristics from the Literature

The following discussion summarizes the many suggestions and recommendations in the literature for how buffer widths can be established. Many of these were found in synthesis documents that summarize scientific literature on buffers and then draw general conclusions. The recommendations in most of these syntheses are remarkably consistent. Taken together with the great number of site-specific studies cited in the syntheses, they present what should be considered "fundamental principles" for buffers.

At its most basic level, the science on wetland buffers identifies four criteria that should be considered in determining the width of a buffer (Castelle et al. 1992b, Desbonnet et al. 1994, Norman 1996, McMillan 2000, Todd 2000):

- The functions and values of the aquatic resource to be protected by the buffer
- The characteristics of the buffer itself and of the watershed contributing to the aquatic resource
- The intensity of the adjacent land use (or proposed land use) and the expected impacts that result from that land use
- The specific functions that the buffer is supposed to provide; for habitat functions this includes the targeted species to be managed and an understanding of its habitat requirements

The feasibility or possibility of incorporating those four considerations into determining buffer dimensions is dependent upon the jurisdiction in question. Ideally, buffer widths should be tailored to these four factors. However, the authors that recommend considering these factors also acknowledge that the scientific basis for determining the width of a buffer is often superseded by political expediency. Buffers are more often

determined administratively as standard or fixed dimensions that may, or may not, be correlated with the criteria listed above.

Table 5-7 presents a summary of the buffer ranges recommended by the authors who conducted literature reviews or syntheses on buffer effectiveness. Minimums ranged from 25 feet (8 m) to 197 feet (60 m). Maximums ranged from 98 feet (30 m) for some land uses to 350 feet (107 m).

Table 5-7. Summary of recommendations for buffer dimensions from the literature.

Author(s)	Date	Minimum Buffer	Maximum Buffer	Comments
Castelle et al.	1994	50 to 100 feet (15 - 30m)		“Minimum buffers necessary to protect wetlands and streams under most circumstances”
Fischer et al.	2000	98 feet (30 m)	328 feet (100 m)	Larger buffer for reptiles, amphibians, birds and mammals
Groffman et al.	1991a	197 feet (60 m)	328 feet (100 m)	For most wildlife needs
Howard and Allen	1989	197 feet (60 m)		For most wildlife needs
McMillan	2000	25 feet (8 m)	350 feet (107 m)	Case by case, using a rating system and the intensity of proposed or existing land use for protecting most wetland functions
Norman	1996	164 feet (50 m)		To protect wetland functions; more may be required to protect more “sensitive wildlife species”

Table 5-8 is taken from one of the most comprehensive buffer syntheses published (Desbonnet et al. 1994). The authors of the synthesis looked at several hundred articles and reports on buffers. This table presents the information in a format that outlines the general effectiveness of different buffer widths at removing pollutants and providing habitat.

Table 5-8. A summary of the effectiveness of pollutant removal and the value of the wildlife habitat of vegetated buffers according to buffer width (Desbonnet et al. 1994).

Buffer Width in Feet (Meters)	Pollutant Removal Effectiveness	Wildlife Habitat Value
16 feet (5 m)	Approximately 50% or greater sediment and pollutant removal	Poor habitat value; useful for temporary activities of wildlife
32 feet (10 m)	Approximately 60% or greater sediment and pollutant removal	Minimally protects stream habitat; poor habitat value; useful for temporary activities of wildlife
49 feet (15 m)	Greater than 60% sediment and pollutant removal	Minimal general wildlife and avian habitat value
66 feet (20 m)	Greater than 70% sediment and pollutant removal	Minimal wildlife habitat value; some value as avian habitat
98 feet (30 m)	Approximately 70% or greater sediment and pollutant removal	May have use as a wildlife travel corridor as well as general avian habitat
164 feet (50 m)	Approximately 75% or greater sediment and pollutant removal	Minimal general wildlife habitat value
246 feet (75 m)	Approximately 80% or greater sediment and pollutant removal	Fair to good general wildlife and avian habitat value
328 feet (100 m)	Approximately 80% or greater sediment and pollutant removal	Good general wildlife habitat value; may protect significant wildlife habitat
656 feet (200 m)	Approximately 90% or greater sediment and pollutant removal	Excellent general wildlife value; likely to support a diverse community
1,968 feet (600 m)	Approximately 99% or greater sediment and pollutant removal	Excellent general wildlife value; supports a diverse community; protection of significant species

Castelle et al. (1994), summarizing research conducted primarily before 1990, concluded “buffers necessary to protect wetlands and streams should be a minimum of 49 to 98 feet (15 to 30 m) in width under most circumstances.” They note that the lower end of the spectrum is the minimum necessary to maintain physical and chemical processes, while the upper end of the spectrum may be the minimum necessary to maintain biological processes. The Castelle et al. report of 1994 does not identify appropriate maximums. McMillan (2000) recommends an approach to determining buffers that attempts to balance predictability with flexibility by setting standard buffer widths that can be altered on a case-by-case basis to adapt to site-specific factors. This approach for determining buffer width incorporates a rating system for wetlands, plus an assessment of the intensity of proposed or existing adjacent land use, to establish buffer widths ranging from 25 to 350 feet (8 to 107 m). It is perhaps the method that is closest to fitting the four bulleted criteria outlined at the beginning of this section. It incorporates an understanding of the condition of the wetland, the buffer, and the proposed adjacent land use.

Several other authors also suggest that considering site-specific factors enhances the effectiveness of buffer strips over using fixed-width buffers (Steinblums et al. 1984,

Norman 1996, Todd 2000). Belt and O’Laughlin (1994) note that, “The fixed minimum-width approach enjoys the virtue of simplicity in application, but has the potential for providing either not enough or too much protection.”

Liquori (2000) also cautions against using fixed buffer widths to protect long-term ecological functioning of buffers and their associated aquatic resources. He notes that many of the functions that buffers provide are directly related to physical characteristics and biological processes within the buffers. Informed with site-specific information, a case-by-case argument could be made for establishing buffer widths. “The nature of the [functions a buffer provides] may significantly depend upon riparian structure both locally and as a mosaic over the watershed scale.”

In urban settings, larger buffer widths are often prescribed in anticipation of future impacts from adjacent land use and activity upstream in the watershed. The most important criterion for determining buffer width is identification of the various functions the buffer is expected to provide (Todd 2000).

In agricultural lands, Welsch (1991) identifies a three-zone approach for establishing buffers:

- **Zone 1** consists of riparian-type trees and shrubs immediately adjacent to the stream, water body, or wetland. It should be a minimum 13 feet (4 m) wide, or adjusted to include the entire riparian area (the area with year-long or seasonal soil-moisture regime influenced by the stream or water body). Minimum length should be the length of the proposed disturbance outside the riparian management zones, or “the longest distance possible.”
- **Zone 2** extends upslope from Zone 1 and consists of vegetation that may be periodically harvested as it matures. A minimum distance of 20 feet (6 m) should be allowed for this zone for small streams or water bodies; for larger streams or water bodies the total of Zones 1 and 2 can be increased up to 98 feet (30 m) or 30% of the geomorphic floodplain (whichever is less). Minimum length should match that of Zone 1. Zone 2 can be an active harvest zone, but trees and vegetation need to be left to provide soil holding and filtering capacity.
- **Zone 3** is added upslope of Zone 2 if adjacent land (away from the aquatic resource) is cultivated cropland or another land use with the potential for erosion or sediment production. Zone 3 is a vegetated filter strip and should be wide enough to control “concentrated flow erosion from cultivated cropland.” Zone 3 vegetation should be established prior to the establishment of Zones 1 and 2.

This zonal approach is recommended for active agricultural activities, which implies the regular creation of conditions with high erosion potential (grazing or tilling). It also allows more active use of the central portion of the buffer and active management of the outer area of the buffer.

Townsend and Robinson (2001) build on this zonal approach and recommend guidance on maintenance of canopy coverage and closure. They suggest using species that readily

resprout from stumps or roots in the areas nearest the stream channels (to allow the vegetation to respond to flood damage and/or beaver activity). They stress the need for ongoing maintenance, especially in Zone 3, to ensure that erosive flows are not causing rills or channelized flows into Zone 2. They also note that, while most of these buffers will be applied on an ownership basis, greater benefit would be realized if the concept of zoned buffers were applied on a watershed basis.

Other recommendations are based on wildlife species of particular interest. Based on their study of waterbirds in Florida, Rodgers and Smith (1997) recommend a buffer width of 328 feet (100 m) to ensure that birds will not be triggered into an “approach” response, a state which occurs prior to actual flushing. They derived this figure by analyzing the flushing distance from human approach for 16 species, then adding 131 feet (40 m) to that distance. The 131-foot (40 m) distance was derived from previous work which found that birds became alert (stopped their ongoing behavior and focused on the approaching human) in a range of 82 to 131 feet (25 to 40 m).

5.5.6.1 Summary of Key Points

- Many researchers have recommended using four basic criteria to determine the width of a buffer:
 - the functions and values of the aquatic resource to be protected by the buffer
 - the characteristics of the buffer itself and of the watershed contributing to the aquatic resource
 - the intensity of the adjacent land use (or proposed land use) and the expected impacts that result from that land use
 - the specific functions that the buffer is supposed to provide including the targeted species to be managed and an understanding of their habitat needs
- Protecting wildlife habitat functions of wetlands generally requires larger buffers than protecting water quality functions of wetlands
- Effective buffer widths should be based on the above factors. They generally should range from:
 - 25 to 75 feet (8 to 23 m) for wetlands with minimal habitat functions and low-intensity land uses adjacent to the wetland
 - 75 to 150 feet (15 to 46 m) for wetlands with moderate habitat functions and moderate or high-intensity land uses adjacent to the wetland
 - 150 to 300+ feet (46 to 92+ m) for wetlands with high habitat functions, regardless of the intensity of the land uses adjacent to the wetland
- Fixed-width buffers may not adequately address the issues of habitat fragmentation and population dynamics. Several researchers have recommended

a more flexible approach that allows buffer widths to be varied depending on site-specific conditions.

5.6 Chapter Summary and Conclusions

Wetlands are defined using well established language that is generally consistent between federal and state laws. However, certain wetland types are sometimes excluded from regulation. These include small wetlands, isolated wetlands, and wetlands that are designated as Prior Converted Croplands (PCC). The scientific literature makes clear that small wetlands and isolated wetlands provide important functions and does not provide any rationale for excluding these wetlands from regulation. Little scientific information is available on PCC, but there is no evidence to suggest that they are unimportant in providing wetland functions. They retain many of the characteristics necessary to provide multiple wetland functions.

Wetland delineation is conducted according to either the federal or state delineation manual. These manuals are consistent and, when applied correctly, will result in the same wetland boundary. Wetland rating systems are a useful tool for grouping wetlands based on their needs for protection. The most widely used method in Washington is the state's rating system which places wetlands in categories based on their rarity, sensitivity, irreplaceability, and functions.

Wetland buffers are a critical tool for protecting wetland functions. Findings regarding buffer functions and effectiveness are consistent in recommending that the width of a buffer should be related to the wetland functions that need protection, the land-use activities from which the wetland is being buffered, and the characteristics of the buffer itself. These factors, derived from the many studies of wetland buffers and other aquatic resources, can be thought of as the "fundamental principles" that are recommended to determine the widths and characteristics of buffers.

The literature confirms that for water quality improvement (e.g., sediment removal and nutrient uptake) there is a non-linear relationship between buffer width and increased effectiveness. Sediment removal and nutrient uptake are provided at the greatest rates within the immediate outer portions of a buffer (nearest the source of sediment/nutrient), with increasingly larger widths of buffers required to obtain measurable increases in those functions. Additionally, the long-term effectiveness of buffers in providing such mechanical and biological processes is not well documented in the literature. However, the literature suggests that buffers may have a carrying capacity or limit to their ability to remove pollutants. Future research on this topic is needed.

Compared to the widths needed for sediment removal and nutrient uptake, the literature has documented the need for significantly wider buffers to protect or maintain habitat functions for wildlife species that are closely associated with wetlands, as well as for populations that use wetlands. Research confirms that many wildlife species and guilds are dependent upon wetlands for only portions of their life cycles, and that they require upland habitats adjacent to the wetland to meet all their life needs. Without adequate

upland habitat adjacent to wetlands, these habitat functions are lost. Some species use upland habitats that are far from the source wetland. The literature documents that, without access to appropriate upland habitat and the opportunity to move between wetlands and other habitats across a landscape, it is not possible to maintain viable populations of many species. Beyond simply providing adequate upland habitat adjacent to a single wetland, the literature on the maintenance of wildlife populations finds that it is necessary to link habitat types, including wetlands and uplands, across a landscape in order to maintain genetically viable populations.

Several authors who suggested recommendations for buffer widths based on their own synthesis of the literature have recommended variable widths based on the conditions of the wetland, the conditions of the buffer, the proposed land uses adjacent to the buffer, and what functions are intended to be managed. For protection and maintenance of wildlife habitat functions of wetlands, these studies suggest that effective buffer widths should be based on the above factors and generally should range from: 25 to 75 feet (8 to 23 m) for wetlands with minimal habitat functions and low-intensity land uses adjacent to wetlands; 50 to 150 feet (15 to 46 m) for wetlands with moderate habitat functions and moderate or high-intensity land use that is adjacent; and 150 to 300+ feet (46 to 92+ m) for wetlands with high habitat functions depending on the intensity of the adjacent land use. However, several authors noted that protection and maintenance of viable wildlife populations for many species requires habitat connections via corridors and large habitat patches.

Chapter 6 continues the discussion of regulatory tools used to manage wetlands by discussing wetland compensatory mitigation and its effectiveness.

Chapter 6

The Science and Effectiveness of Wetland Mitigation

6.1 Reader's Guide to this Chapter

This chapter synthesizes the scientific literature regarding compensatory mitigation and its effectiveness at reducing the severity of activities that detrimentally affect wetlands. It also reports the suggestions made by various authors regarding ways to improve compensatory mitigation.

6.1.1 Chapter Contents

Major sections of this chapter and the topics they cover include:

Section 6.2, Introduction and Background to Wetland Mitigation describes wetland mitigation sequencing, which encompasses a series of actions that requires addressing each action, or step, in a particular order. Compensation for wetland impacts is just one of these steps.

Section 6.3, Success of Compensatory Mitigation Wetlands synthesizes the literature on the biological, ecological, or functional success of compensatory mitigation projects. This section does not specifically evaluate the successful compensation for wetland area; that is discussed in Section 6.7.

Section 6.4, Compliance with Permit Requirements describes studies that evaluated several aspects of how well compensatory mitigation projects met legal or permit requirements. These included whether projects were completed or installed according to plan, whether they attained the required wetland acreage, whether performance standards were achieved, whether the project was monitored or maintained, and whether the regulatory agencies followed-up on the project.

Section 6.5, Types of Compensatory Mitigation discusses the use and effectiveness of restoration, creation, enhancement/exchange, preservation, mixed compensatory mitigation, mitigation banking, and in-lieu fees.

Section 6.6, Replacement Ratios describes the rationale for the use of ratios in determining the acreage required as compensation for a given area of wetland impact. It synthesizes the literature on the ratios that were required and those actually achieved for numerous projects. This section also discusses approaches proposed in the literature to more effectively determine compensatory mitigation ratios.

Section 6.7, Replacement of Wetland Acreage summarizes the results of studies examining whether compensatory wetland mitigation is actually replacing the acreage of wetland losses authorized. This includes both evaluations of overall permitting programs and of specific compensation projects in compensating for wetland acreage.

Section 6.8, Functions and Characteristics Provided by Created, Restored, or Enhanced Wetlands describes the ability of mitigation wetlands to provide wildlife habitat, plant communities, adequate soil conditions, and water quality/quantity functions. Compensation wetlands were often compared with pre-existing or reference wetlands in these studies.

Section 6.9, Reproducibility of Particular Wetland Types summarizes the literature regarding whether and how easily certain wetland types, such as bogs, fens, vernal pools, alkali wetlands, and mature forested wetlands, can be reproduced or restored.

Section 6.10, Suggestions from the Literature for Improving Compensatory Mitigation summarizes numerous recommendations made by researchers to improve the success of compensation projects—ranging from improvements to regulations and site selection, to better performance standards, to a broader landscape approach, to mitigation banking.

Section 6.11, Chapter Summary and Conclusions ties together the major concepts presented in the chapter.

6.1.2 Where to Find Summary Information and Conclusions

Each major section of this chapter concludes with a brief summary of the key points resulting from the literature review on that topic in a bullet list format. The reader is encouraged to remember that a review of the entire section preceding the summary is necessary for an in-depth understanding of the topic.

For summaries of the information presented in this chapter, see the following sections:

- Section 6.3.2
- Section 6.4.9
- Section 6.5.8
- Section 6.6.4
- Section 6.7.3
- Section 6.8.6
- Section 6.9.5
- Section 6.10.7

In addition, Section 6.11 provides a summary of the chapter and conclusions about the overarching themes gleaned from the literature and presented in this chapter.

6.1.3 Sources and Gaps in Information

The synthesis in this chapter is based on more than 50 articles, government reports, and conference proceedings that have been published since about 1990 on the topic of compensatory mitigation. (The literature did not address the other types of mitigation listed in Section 6.2.1.)

The information resulted from studies conducted in various states and countries, including several studies from the Pacific Northwest. Environmental conditions may vary in other states and countries. However, the information resulting from these studies is relevant to compensatory wetland mitigation in Washington State for the following reasons:

- The general principals and techniques used to restore, create, and enhance wetlands are similar
- The regulatory approaches and requirements are similar
- Most importantly, the studies provide similar and consistent results

Geographic location of the studies cited in this chapter

The articles and reports that evaluated the effectiveness of individual compensatory mitigation projects focused on a variety of locations, including Washington, Oregon, California, Louisiana, Michigan, Indiana, Ohio, New Jersey, Massachusetts, Maryland, Tennessee, and Florida.

Studies that assessed specific functions performed by wetlands that were sites for compensatory mitigation and non-regulatory restoration were located in: Washington, Oregon, Wyoming, Iowa, Minnesota, Wisconsin, Illinois, Ohio, New York, Pennsylvania, Connecticut, West Virginia, South Carolina, Florida, Canada, Sweden, Spain, Austria, and central Europe.

The information synthesized in this chapter covers a range of topics and issues relating to compensatory wetland mitigation (refer to Chapter Contents, Section 6.1.1). Yet there are some topics and issues for which no scientific information was found. For example, studies were found that examined whether compensation projects had performance standards and whether the performance standards were met. However, no studies were found that explored why performance standards were not met. Other examples of data gaps include studies that:

- Determined the effectiveness of local critical area ordinances at replacing permitted wetland losses
- Examined the effect of construction inspections, monitoring, maintenance, or performance bonding on the success or level of compliance of projects
- Compared the level of success of newly installed versus more established compensation sites

- Looked specifically at the quality and effectiveness of preservation sites
- Focused specifically on wildlife habitat provided by restored, created, or enhanced wetlands in urban settings
- Examined the effects of mitigation decisions on a watershed scale
- Looked at the reproducibility of alkali wetlands

The articles and reports reviewed used a variety of terms to define what they were assessing or evaluating. For the purposes of this synthesis, *effectiveness* is used as a general term referring to how compensatory wetland mitigation was doing overall, including evaluations of success, compliance, and functions and characteristics. These terms will be defined more precisely in subsequent sections.

6.2 Introduction and Background to Wetland Mitigation

6.2.1 Wetland Mitigation Sequence

Mitigation is a series of actions that requires addressing each action, or step, in a particular order. This sequence of steps is used to reduce the severity of negative impacts from activities that potentially affect wetlands. When a change in land use has the potential to adversely affect a wetland, regulatory agencies require the applicant to illustrate how the project has considered the six sequential steps of mitigation. According to the rules implementing the Washington State Environmental Policy Act (Chapter 197.11 WAC), mitigation involves the following:

1. *Avoiding the impact altogether by not taking a certain action or parts of an action;*
2. *Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;*
3. *Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;*
4. *Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;*
5. *Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or*
6. *Monitoring the impact and taking appropriate corrective measures (WAC 197.11.768).*

The authors of Volume 1 provide a brief explanation and examples of the steps in the mitigation sequence in the following paragraphs.

Avoidance is the first step in the mitigation sequence. Avoidance of impacts means that there is no direct loss of wetland area and functions. Avoidance does not, however, eliminate indirect losses of wetland function. For example, consider a hypothetical proposal to develop a 5-acre parcel of land. The parcel contains 2 acres of wetland. The development is designed around the wetland and will therefore avoid any direct loss. Avoidance has occurred. Yet if buildings and parking lots surround the wetland, indirect impacts to wildlife habitat and hydrology may occur in the form of fragmentation and altered hydroperiod.

Minimization of adverse impacts is the second step. It can reduce the extent of wetland impacts when a project is redesigned to lessen wetland alteration. However, it does not eliminate the direct or indirect loss of area and/or functions.

Rectification, the third step, assumes that losses in wetland area and/or function at the impact site are temporary and can be restored. For example, projects such as installing or maintaining an underground pipeline that passes through a wetland typically use rectification as a mitigation measure. In the example of the underground pipeline, vegetation, soil, and water movement may be disturbed and altered. The wetland area and/or functions are temporarily changed or lost. Rectification would entail replacing the soil, restoring the water movement, and restoring the vegetation.

The fourth step of the mitigation sequence is not generally relevant to wetlands, and therefore, no examples of its application are provided.

Compensation for unavoidable adverse impacts, the fifth step, involves restoring, creating, enhancing, or preserving wetland area to replace or make-up for the wetland area and functions that were lost or altered. It is discussed in much greater detail in the following sections.

Monitoring, step 6, is used to address the potential impact to wetlands that may result from a project when specific impacts are not known. If impacts are observed during or after project completion, actions should be taken to address the loss of wetland functions. For example, if a bridge is built over a river fringed by wetlands, the bridge may shade portions of the wetlands. Though no wetlands would be filled during construction, the shading could alter the performance of functions, thereby resulting in impacts to wetlands. To address the potential risk of impacts to wetlands, the project could be monitored to determine the effect of shading on the riverine wetlands. If monitoring reveals that the functions of the riverine wetlands were adversely altered, then compensation might be required.

The scientific literature reviewed for this synthesis did not contain information on the use or effectiveness of any of the mitigation measures defined above, except compensatory mitigation, which is the focus of the remainder of this chapter.

6.2.2 The Emergence of Compensatory Wetland Mitigation

The term *compensatory mitigation* refers to the compensation stage of the mitigation sequence (number 5 in the list of steps described earlier). Compensatory wetland mitigation generally entails performing one or more of the following types of compensation:

- Restoring wetland conditions (and functions) to an area
- Creating new wetland area and functions
- Enhancing functions at an existing wetland
- Preserving an existing high-quality wetland to protect it from future development

The term **compensatory mitigation** refers to the compensation stage of the mitigation sequence (number 5 in the list of steps on the previous page). Because the regulatory requirements and policies tend to focus on the compensation stage, the term “mitigation” is often used to refer to compensation, which is just one part of the overall mitigation sequence.

The use of compensatory mitigation for wetland loss emerged in the 1980s (Roberts 1993, National Research Council 2001). The U.S. Army Corps of Engineers considered the process of mitigation as part of the National Environmental Policy Act of 1969. However, it wasn't until 1980 when the U.S. Environmental Protection Agency (EPA) issued new guidelines for Section 404(b)(1) of the Clean Water Act that mitigating for wetland losses by creating or restoring another wetland as compensation became widely acceptable (National Research Council 2001). Compensatory mitigation was seen as a way to speed up an arduous process of documenting avoidance and minimization efforts, while satisfying concerns about the loss of ecosystems and functions (Roberts 1993). Creating or restoring wetland area to compensate for permitted wetland losses was viewed and publicized as a way to allow development while preventing a net loss of wetland areas.

By the late 1980s, studies of the effectiveness of compensatory mitigation were emerging, with mixed results. The primary indication was that replacing or replicating an existing wetland was difficult, if not impossible (Kusler and Kentula 1990, National Research Council 2001). However, some wetland types and functions could be approximated given the proper conditions (Kusler and Kentula 1990, National Research Council 2001). This chapter focuses on studies published since 1990 that examined the effectiveness of compensatory mitigation.

6.3 Success of Compensatory Mitigation Wetlands

Compensatory mitigation “success” is poorly defined and often contentious (Kentula 2000). The literature refers to legal success, biological success, ecosystem success (Wilson and Mitsch 1996), functional success (Mockler et al. 1998), or some combination of these.

Compliance generally means the same as “legal success.” It is evaluated by comparing the actual on-the-ground, or as-built, conditions against what was required in the permit. Studies describing legal success are referred to as compliance in this document, and they are discussed in Section 6.4.

This section will focus on “biological, ecological, or functional success.” Therefore, when the term *success* is used in this chapter, it refers exclusively to biological, ecological, or functional success. Success involves an evaluation of the factors that characterize a wetland (e.g., hydroperiod, vegetation, soils), the performance of functions, or both. Best professional judgment and/or one of a variety of function assessment methods have been used by researchers to evaluate success.

The authors of Volume 1 have observed two main problems with evaluating the success of compensatory mitigation projects. First, success is often confused with compliance, and it is assumed that they must go hand in hand. In some cases, compliance and success may be separate considerations. For example, a compensation site may be in compliance with its permit requirements and not be considered a success because it does not replace the functions of the wetland that was lost. On the other hand, a site may fall short of meeting its permit requirements, perhaps because performance standards were unrealistic. The site is therefore not in compliance, yet it may still be determined a success because it compensates for the wetland functions lost.

The second problem involves time; when should a project be evaluated for success? For example, two years after installation a compensation site may not be meeting its performance standards, perhaps because the site has too much bare ground, percent aerial cover of native vegetation is too low, or cover by invasive plant species is too high. The site is, therefore, neither in compliance nor a success. However, looking at the same site five or six years after installation, the site may have experienced rapid growth of native shrubs and trees, native volunteer species may have colonized the bare ground, and maintenance activities may have controlled invasive plants. At this time, the site could be evaluated as a success and considered to be in compliance.

Rather than judging the success or failure of a compensatory wetland mitigation project at a single point in time, Zedler and Callaway (2000) proposed evaluating how a project progresses over time. The authors suggest that a focus on progress would encourage proponents to acknowledge problems occurring at a site and look for solutions. Zedler (2000) proposes that more compensation projects should be viewed as experiments without a specific desired outcome. In lieu of attaining a specific level of performance, projects would be monitored as experiments for at least 25 years. The regulatory framework currently in place, however, does not support this method of evaluation due to the relatively short timeframe allowed for monitoring and assessing the compliance of compensation projects (Breaux and Serefiddin 1999, Zedler 2000).

Refer to Section 6.10.4 for more information on performance standards. Specifically, Section 6.10.4.1 discusses shortcomings of existing performance standards, and Section 6.10.4.3 discusses the need for longer monitoring periods.

6.3.1 Results of Literature Studies

Several studies determined the level of success of compensatory mitigation projects (Table 6-1). Though the data indicated that some projects were successful and some projects were unsuccessful, most compensation projects had an intermediate level of success, meaning they were neither fully successful nor completely unsuccessful.

- 25 to 66% of projects were determined to have an intermediate level of success
- 3 to 43% of projects achieved full success
- 7 to 97% of projects were unsuccessful, though half of the studies found that at least 20% of projects were unsuccessful (Johnson et al. 2002, Michigan Department of Environmental Quality 2000, Mockler et al. 1998, Sudol and Ambrose 2002)

The methods used to evaluate the success of compensatory wetland mitigation projects varied from best professional judgment (Storm and Stellini 1994) to function assessments (Wilson and Mitsch 1996, Balzano et al. 2002), to quantitative measures of vegetation cover and survival (Allen and Feddema 1996), or some combination (Michigan Department of Environmental Quality 2000, Johnson et al. 2002). Though the methods of evaluation differed, most studies considered similar variables such as wetland area, hydrologic conditions, wildlife suitability, vegetation, and soils.

Table 6-1. Results of studies examining the success of compensatory mitigation.

Location of Study	No. of Projects Evaluated	Level of Success	Evaluation Criteria
Washington State (Johnson et al. 2002)	24	13% fully successful 33% moderately successful 33% minimally successful 21% not successful	Wetland acreage, performance standards, goals/objectives, contribution to functions, comparison with wetland lost
Washington/ King County (Mockler et al. 1998)	38	3% successful 97% not successful	Replacing the functions of the wetland lost. Examined vegetation survival and areal coverage, hydrology, soil, wetland and buffer condition assessment, wildlife habitat, and invasive species
Western Washington (Storm and Stellini 1994)	17	23% functioned well ecologically 65% functioned poorly 12% were not completed	Vegetation diversity, non-native plant dominance, structural diversity, wildlife use, adjacent land uses, vegetation cover vs. open water

Location of Study	No. of Projects Evaluated	Level of Success	Evaluation Criteria
Southern California (Allen and Feddema 1996)	75	32 successful 9 mostly successful 10 half successful 5 unsuccessful 8 under construction 5 not initiated 6 did not require mitigation	Project installed according to plan; percent cover of vegetation (dead, living, and invasive)
California/ Orange County (Sudol and Ambrose 2002)	55	16% successful 58% partially successful 26% failures	Qualitative evaluation based on habitat quality (e.g., vegetation density and diversity, invasive species, tree height)
Ohio (Wilson and Mitsch 1996)	5	1 high 2 medium to high 1 medium 1 medium to low	WETII evaluation (Adamus et al. 1989) - hydrology, soils, vegetation, wildlife, water quality
New Jersey (Balzano et al. 2002)	74	Wetland Mitigation Quality Assessment scores were indexed from 0 (low) to 1 (high). The average score was 0.51, and the range was 0.25 to 0.83	Hydrology, soils, vegetation, wildlife suitability, site characteristics, and landscape features
Michigan (Michigan Department of Environmental Quality 2000)	69	22% successful overall 78% unsuccessful overall	Project's legal rating (permit compliance) and biological rating (wetland acreage). Does not include enhancement

6.3.2 Summary of Key Points

- Success is defined as meeting biological or ecological criteria, which may include an assessment of functions.
- The majority of compensatory wetland mitigation projects were found to be neither fully successful nor completely unsuccessful, meaning that most projects had an intermediate level of success, relative to biological or ecological functions.
- Though the methods used to evaluate project success differed, the studies considered similar criteria, such as vegetation, soils, and hydrologic conditions.

6.4 Compliance with Permit Requirements

Regulatory agencies typically require wetland compensation for authorized, unavoidable wetland impacts. A wetland mitigation plan is reviewed and approved as part of the permit approval process. It outlines how wetland impacts will be compensated for. The mitigation plan identifies how the project will be designed. It addresses wetland acreage, hydroperiod, vegetation, goals, objectives, performance standards, monitoring, maintenance, contingency actions, and long-term protection. These are the parameters by which regulators often measure compliance.

According to the Merriam-Webster dictionary, compliance means “conformity in fulfilling official requirements.” Regarding compensatory wetland mitigation, compliance means that a project has satisfied or is satisfying the legal requirements and obligations identified in a permit.

Most studies that examined compliance investigated how well a compensatory wetland mitigation project complied overall (i.e., with all applicable permit requirements). Several of these studies only reported the results of the overall evaluations. Other studies evaluated how well projects complied with individual requirements, such as:

- Installation – whether the project was installed
- Installation according to plan – whether the project was constructed according to the approved mitigation plan and design
- Wetland area establishment – whether the project obtained the acreage of wetland that was required
- Performance standards/goals/objectives attainment – whether the project performed as anticipated
- Monitoring – whether the project was monitored as required (or was required to be monitored)
- Maintenance – whether project maintenance was performed (or required)

Studies also reviewed regulatory follow-up - whether any regulatory agencies made an attempt to track an individual project after the permit was issued.

Each of these types of evaluations is discussed in subsequent sections.

6.4.1 Compliance Overall

Several studies attempted to determine how well a project complied with several or all of its permit requirements. Because permit requirements vary by state and over time, not all compliance evaluations considered the same criteria or requirements. Where specified, the requirements evaluated by a given study are identified in Table 6-2.

Twelve studies evaluated overall compliance with regulatory requirements for compensatory wetland mitigation projects (Table 6-2). In Washington State four studies that evaluated compliance were conducted in the past decade (Storm and Stellini 1994, Mockler et al. 1998, Johnson et al. 2000, Johnson et al. 2002), and two studies were conducted in Oregon (Gwin and Kentula 1990, Shaich and Franklin 1995).

The studies in Washington found that 29% of compensation projects complied with their regulatory requirements. In Oregon, studies revealed that compliance of projects ranged from zero to 36%.

Studies from other states demonstrated more variability in levels of compliance. Results ranged from less than 20% to about 80% of projects in compliance (Holland and Bossert 1994, De Weese 1998, Morgan and Roberts 1999, Michigan Department of Environmental Quality 2000, Brown and Veneman 2001, Balzano et al. 2002, Sudol and Ambrose 2002).

More recent studies (published in 2000 or after) did not report higher levels of compliance than studies conducted in the 1990s. One might therefore assume that compensation projects have not improved over the years. However, it is important to realize that as knowledge of wetland science and compensatory mitigation has improved and evolved, permit requirements have likewise evolved (Kentula 2000). More recent studies may have been evaluating compensation projects that were being held to a higher standard than projects permitted and evaluated in the 1990s (Sudol and Ambrose 2002). However, a study by Cole and Shafer (2002) in Pennsylvania observed that permit requirements had not changed noticeably over the 14-year range of permits they evaluated (1986-1999).

Table 6-2. Level of overall compliance of compensation projects.

Location of Study	No. of Projects Evaluated	% of Projects in Compliance with all Requirements	Evaluation Criteria
Washington (Johnson et al. 2000)	45	29%	• Project installed • Installed according to plan • Meet performance standards
Washington (Johnson et al. 2002)	24	29%	• Establish required wetland acreage • Meet performance standards • Meet goals/objectives
Washington/western (Storm and Stellini 1994) ^a	17	18%	• Installation of both development and compensatory mitigation projects as required

Location of Study	No. of Projects Evaluated	% of Projects in Compliance with all Requirements	Evaluation Criteria
Washington/King County (Mockler et al. 1998) ^b	29 (38)	21% (16%)	• Meet performance standards - vegetation survival, areal cover, invasive species • Design - hydrology, slopes • Installation - soil • Maintenance - mowing, weeding
Oregon/Portland metro area (Shaich and Franklin 1995) ^c	72	36%	• Project installed • Upland buffer area/vegetation requirements • Requirements for timing of project construction • Wetland vegetation requirements • Hydrology requirements • Requirements for water control structures • Fencing requirements
Oregon/Portland metro area (Gwin and Kentula 1990)	11	0%	• Construction plans match permit specs • As-built matches permit specs: wetland area/shape • Actual slopes match planned slopes • Vegetation established as planned
California/ Orange County (Sudol and Ambrose 2002) ^d	57	53%	• Project installed • Meet performance standards/ permit conditions
California/ vernal pools (De Weese 1998)	25	83%	• Attaining performance standards required by Corps
Massachusetts (Brown and Veneman 2001) ^e	109 (7)	43% (100%)	• Project installed • Compensation project of required size • Water inputs sufficient for wetland conditions • At least 75% cover wetland plants (FAC or wetter)
Tennessee (Morgan and Roberts 1999)	50	12%	• Establish required acreage of wetland • Meet performance standards

Location of Study	No. of Projects Evaluated	% of Projects in Compliance with all Requirements	Evaluation Criteria
Michigan (Michigan Department of Environmental Quality 2000) ^f	74	18%	• Mitigation acreage requirement • Implementation of approved mitigation plan • Conservation easement • Submittal of as-built plans • Monitoring • Placement of elevated wildlife structures • Construction schedule with specified completion date • Prohibited actions • Corrective measures identified • Financial assurances
Louisiana (Holland and Bossert 1994)	9	78%	• Meet Corps of Engineers permit conditions
New Jersey (Balzano et al. 2002) ^g	88	48% weighted average	• Grading (56% concurrence) • Hydrology (47% concurrence) • Soil (51% concurrence) • Vegetation cover (39% concurrence) • Vegetation survival (28% concurrence) • Design (56% concurrence)

^a Compliance not determined for 53% of projects due to lack of information.

^b 38 projects examined; 9 not completed. Compliance information for 38 projects is in parentheses.

^c Not all projects had requirements for all criteria (e.g., only 8% had a requirement for fencing).

^d Calculated from data provided.

^e 5 projects did not result in wetland impact and were subtracted from the project total. Results were recalculated from the data provided. Parentheses = data for variance projects (received more oversight).

^f Permit conditions from the criteria list were considered if specified in permit.

^g Evaluated concurrence with applicable criteria. Percent = average concurrence score for 88 projects. Average concurrence score for each criterion provided in parentheses.

6.4.2 Project Installation

A number of studies investigated whether mitigation projects had even been constructed or installed. In these studies, mitigation projects were either randomly selected from a database or a complete inventory of all projects permitted during a specific timeframe was conducted. Four studies were conducted in Washington. Studies in seven other states, including Oregon, also investigated whether mitigation projects had been installed.

Results indicated that most projects were installed (Table 6-3). The four studies from Washington found that 74 to 93% of compensatory mitigation projects had been installed. Studies from most of the other states showed similar results (64 to 99%). However, studies performed in Florida and Tennessee revealed that less than half of the compensatory wetland mitigation projects had been installed (Erwin 1991, Morgan and Roberts 1999).

Due to the relatively high percentage of projects that were installed, one could assume that the low levels of overall compliance result from inadequate design, installation, maintenance, follow-up, or some combination.

Table 6-3. Percent of compensatory mitigation projects that were installed.

Location of Study	No. of Projects Evaluated	Percent of Projects Installed
Washington (Johnson et al. 2000)	45	93%
Washington/ King County (Mockler et al. 1998)	38	76%
Washington/ western (Storm and Stellini 1994)	17	88% ^a
Washington (Kunz et al. 1988)	35	74%
Oregon/ Portland metro area (Shaich and Franklin 1995)	90	99%
California/ southern (Allen and Feddema 1996)	75	93%
California/ Orange County (Sudol and Ambrose 2002)	57	96% ^a
Michigan (Michigan Department of Environmental Quality 2000)	159	85%
Indiana (Robb 2002)	333	64%
Massachusetts (Brown and Veneman 2001) ^b	109	77%
Tennessee (Morgan and Roberts 1999)	100	47%
Florida (Erwin 1991)	NA	~40% ^c
^a Calculated from data provided. ^b Five projects did not result in wetland impact and were subtracted from the project total. Results were recalculated from the data provided. ^c “Out of more than 100 permitted projects requiring wetland mitigation only 40 had undertaken any mitigation activity.”		

6.4.3 Installation According to Plan

Another aspect of determining mitigation compliance is evaluating whether a mitigation project has been installed according to its approved plan. When compensatory wetland mitigation is necessary to offset proposed wetland losses, regulatory staff generally

require a wetland mitigation plan. The mitigation plan should provide specific information about project construction, including detailed design drawings. Approval of a permit for wetland loss is often contingent upon approval or acceptance of the wetland mitigation plan.

It is commonly assumed that a project will be built exactly as it is designed. However, many factors during construction and installation can influence what is actually built on the ground. Therefore, permit requirements often require (or recommend) submittal of an as-built plan or report that documents the final installed conditions of a site after construction is complete. When available, as-built drawings are used to document the baseline conditions for monitoring of a site.

Three studies evaluated whether compensation projects were installed according to approved plans (Table 6-4). Results from both Washington and New Jersey indicate that more than half of the compensatory mitigation projects were installed according to requirements (Johnson et al. 2000, Balzano et al. 2002). Johnson et al. (2000) found that 55% of the projects were installed to plan. For those that submitted an as-built plan or report, 88% of the projects were installed according to plan. A study in Oregon, however, determined that none of the projects were implemented according to plan (Gwin and Kentula 1990). All three studies mentioned grading and vegetation as the elements of the plan that were not implemented according to the approved plan.

It can be hypothesized that the divergent results noted in the studies above might be the result of an increase of knowledge and expertise over time. For instance, the projects reviewed by Gwin and Kentula (1990) were designed, permitted, and constructed in the early 1980s. Since that time much has been learned by those who design, construct, and regulate compensatory mitigation projects. It is possible that improved designs, experience and skill in implementing the designs, and improved regulatory follow-up have resulted in a higher percentage of projects being installed according to plan by the mid- to late 1990s. The current scientific literature does not address this possibility.

Table 6-4. Percent of compensatory mitigation projects installed according to plan.

Location of Study and Reference No.	No. of Projects Evaluated	Percent Installed to Plan	Aspects Not Installed to Plan
Washington (Johnson et al. 2000)	42	55%	Mainly vegetation, also grading, misc. plan elements (e.g., fences, signs)
Oregon/ Portland metro area (Gwin and Kentula 1990)	11	0%	Size, shape, slopes, and vegetation
New Jersey (Balzano et al. 2002)	88	56%	Incorrect elevations, sizes, and/or shapes

6.4.4 Establishment of Wetland Acreage

Compensatory wetland mitigation projects are intended to compensate for the loss of wetland area and functions. Hence, permits and mitigation plans often identify a specific acreage of compensation required to offset those losses. Establishing the required acreage is therefore an important criterion of regulatory compliance. (Functions provided by compensatory mitigation projects are discussed in Section 6.8.)

Thirteen studies examined compensatory wetland mitigation sites to determine if the acreage of wetlands required by the permits had been established (Table 6-5). The studies presented the data from these investigations in two ways.

- **The percentage of projects establishing the required wetland acreage.** Researchers determined if each project met its required wetland acreage, then reported how many projects actually met the wetland acreage requirement as a percentage of the total number of projects considered. A few studies mentioned a specific threshold, such that a project had to be smaller than required by a specific acreage or percentage in order to fail to meet its wetland area (Brown and Veneman 2001, Johnson et al. 2002, Morgan and Roberts 2003).
- **The percentage of compensatory wetland acreage established.** Researchers determined the total acreage of compensatory mitigation that was verified as wetland for all the projects considered. The study then reported the total acreage of wetland compensation that was established as a percentage of the total acreage that was required for all the projects considered.

Over half of projects achieved the required wetland area in Washington and Oregon (Shaich and Franklin 1995, Johnson et al. 2002). In fact, the majority of studies determined that about half of the compensation projects established the required acreage of wetland. However, three studies found that less than 30% of projects met their acreage requirements (McKinstry and Anderson 1994, Balzano et al. 2002, Morgan and Roberts 2003). In New Jersey only 7% of projects achieved the wetland acreage requirements (Balzano et al. 2002).

For the total acreage of wetland achieved versus required, a study from Washington determined that 84% of the required acreage of compensatory wetlands was established (Johnson et al. 2002), while a study in Oregon found about 70% of the required wetland acreage was established (Gwin and Kentula 1990). Results from other states indicated between 44 and 74% of the required wetland acreage had been established.

Why is there a discrepancy between the percent of projects achieving acreage and the percentage of total acreage established? New Jersey, for example, found that only 7% of compensation projects achieved the required wetland acreage, yet 63% of the total required wetland acreage was established. It can be hypothesized that this is due to small, individual projects that establish a portion of the required acreage but fall short of the total amount required. For example, a site that was required to provide 1 acre of mitigation but only provided 0.8 acre would not meet the acreage criteria. However, the 0.2-acre difference may represent a very small fraction of the total acreage of compensation evaluated for a large study, thereby affecting the total acreage percentage very little.

Table 6-5. Establishment of required wetland acreage.

Location of Study	No. of Projects Evaluated	% of Projects Achieving Required Wetland Area	% of Required Wetland Area that Was Established
Washington (Johnson et al. 2002) ^a	24	58%	84%
Oregon/Portland metro area (Shaich and Franklin 1995) ^b	72	53% ^e	NA
Oregon/Portland metro area (Gwin and Kentula 1990)	11	NA	71%
California/southern (Allen and Feddema 1996) ^c	75	NA	69%
California/Orange County (Sudol and Ambrose 2002)	55	52%	NA
Wyoming (McKinstry and Anderson 1994)	64	14% ^e	NA
New Jersey (Balzano et al. 2002)	85	7%	63%
Tennessee (Morgan and Roberts 1999)	50	28%	68%
Ohio (Wilson and Mitsch 1996)	5	40%	66%
Indiana (Robb 2002)	31	NA	44%
Michigan (Michigan Department of Environmental Quality 2000)	159	50%	NA
Massachusetts (Brown and Veneman 2001) ^d	109	46%	NA
Florida (Erwin 1991)	NA	NA	74%
NA= information not available ^a West of the Cascades, projects established 92% of the required acreage; east side projects established 25% of the required acreage. ^b Compensation wetlands were 16 acres (6.5 ha) short of the 69 acres required. ^c Projects > 8.5 acres (3.4 ha) resulted in a net gain of 17 acres (6.9 ha) of wetland area, while projects < 8.5 acres resulted in a net loss of almost 25 acres (10 ha). ^d Five projects did not result in wetland impact and were subtracted from the project total. Results were recalculated from the data provided. ^e Calculated from data provided.			

6.4.5 Attainment of Goals, Objectives, and Performance Standards

Another critical component of compliance for a compensatory wetland mitigation project is determining whether the project has met its goals, objectives, and/or performance standards. Goals, objectives, and performance standards are generally included as part of an approved wetland mitigation plan. Goals and objectives are intended to provide a blueprint for what the project proposes to accomplish in terms of anticipated wetland type, specific habitat, functions, and/or values. The performance standards are intended to provide measurable criteria to determine if the project has accomplished its goals and objectives (Hruby et al. 1994, Ossinger 1999).

Two separate factors were investigated in the studies reviewed:

- Whether a project had goals, objectives, and performance standards
- Whether projects were meeting their goals, objectives, and performance standards

Data in Table 6-6 indicate that at least three-quarters of projects had goals, objectives, or both (Erwin 1991, Storm and Stellini 1994, Johnson et al. 2002). However, fewer projects met the goals/objectives (10 to 38%) according to the two studies that reported this information (Erwin 1991, Johnson et al. 2002).

In general, performance standards were specified less frequently than goals and objectives, though at least half of the projects had them (Erwin 1991, Storm and Stellini 1994, Mockler et al. 1998, Johnson et al. 2000, Cole and Shafer 2002). Two studies conducted in Washington determined that 21% of projects met their performance standards (Mockler et al. 1998, Johnson et al. 2002), while a third study from Washington found that 35% of projects met performance standards (Johnson et al. 2000).

A review of the articles suggests that the percent of projects with performance standards increased with more recent projects. For example, Storm and Stellini (1994) and Cole and Shafer (2002) evaluated compensation projects that were permitted in the mid to late 1980s or early 1990s. Performance standards may not have been as rigorously required (Cole and Shafer 2002) or they may not have been specifically identified as performance standards. For example, of 10 projects that did not contain performance standards, 30% were permitted in the late 1980s and 80% were permitted prior to 1995, while 20% were permitted in the late 1990s (Cole and Shafer 2002).

Data suggest (Table 6-6) that the more recent projects did not appear any more likely to meet performance standards than earlier projects (Mockler et al. 1998, Johnson et al. 2000, Cole and Shafer 2002, Johnson et al. 2002). Some believe that performance standards have become more rigorous overtime, and more recent projects have been held to a higher standard. Cole and Shafer (2002), however, did not find that performance standards noticeably changed in terms of content from projects permitted in the late 1980s to the late 1990s. Therefore, one can conclude that the year of permitting does not appear to be a factor in whether projects met their performance standards.

More information on performance standards is provided in Section 6.10.4.

Table 6-6. Attainment of goals, objectives, and performance standards.

Location of Study	No. of Projects Evaluated	% of Projects w/ Goals or Objectives	% of Projects w/ Performance Standards	% of Projects Meeting Goals or Objectives	% of Projects Meeting Performance Standards
Washington (Johnson et al. 2000)	34	NA	87% ^a	NA	35%
Washington (Johnson et al. 2002)	24	92%	NA	38%	21%
Washington/ King County (Mockler et al. 1998)	29	NA	100%	NA	21%
Washington/ western (Storm and Stellini 1994)	17	76%	53%	NA	NA
Pennsylvania (Cole and Shafer 2002)	23	NA	57%	NA	62%
Florida (Erwin 1991)	40	85%	60%	10%	NA
NA = information not available.					
^a Calculated from data provided.					

6.4.6 Monitoring

To determine if a compensatory wetland mitigation project is in compliance, it is necessary to monitor the project over time. Monitoring requirements are typically identified in the wetland mitigation plan. The duration, frequency, and methods of monitoring should depend on the goals, objectives, and performance standards for the project.

Monitoring is the process through which data about site conditions is gathered. Monitoring data is used to determine whether a project is achieving its performance standards, and therefore its goals and objectives, within a predicted timeframe. Monitoring also provides critical information about whether a site requires maintenance or contingency actions. Monitoring is therefore essential for a project to achieve compliance.

The studies investigating whether compensatory wetland mitigation projects were required to be monitored and whether monitoring actually occurred are summarized in Table 6-7. In general, studies conducted more recently found that monitoring was required for a greater percentage of projects. Data from four studies indicate monitoring

was required for at least three-fourths of projects (Erwin 1991, Morgan and Roberts 1999, Johnson et al. 2000, Michigan Department of Environmental Quality 2000). The remaining two studies, which examined compensation projects permitted in the late 1980s and early 1990s, found that monitoring was required for a third to half of projects (Holland and Kentula 1992, Storm and Stellini 1994).

Less than half of the projects had monitoring data. However, the studies did not determine whether the monitoring was not conducted or whether there was simply no record of the monitoring reports on file with the regulatory agencies. Since over half of the studies mentioned difficulty finding complete project information from the agency files (Storm and Stellini 1994, Morgan and Roberts 1999, Johnson et al. 2000, Cole and Shaffer 2002), it is possible to conclude that monitoring reports may have been submitted to the appropriate agencies but the reports were lost due to a lack of follow-up and poor file maintenance. If monitoring is not conducted there is no means to trigger maintenance or contingency actions. The consequence of inadequate follow-up by regulatory agencies is discussed in Section 6.4.8.

Table 6-7. Percent of projects requiring monitoring and those actually monitored.

Location of Study	% of Projects Requiring Monitoring	% of Projects Monitored
Washington (Johnson et al. 2000)	71%	33%
Washington/ western (Storm and Stellini 1994)	53%	18%
California (Holland and Kentula 1992)	32%	NA
Michigan (Michigan Department of Environmental Quality 2000)	87%	35%
Pennsylvania (Cole and Shafer 2002)	NA	<10%
Tennessee (Morgan and Roberts 1999)	89%	43%
Florida (Erwin 1991)	98%	38% ^a (62%) ^b
^a Represents projects that were adequately monitored.		
^b Calculated from Erwin (1991) indicating all projects that received some level of monitoring.		

6.4.7 Maintenance

Compensatory wetland mitigation sites require maintenance to help ensure that goals and performance standards will be achieved. Maintenance includes implementing corrective actions to rectify problems, such as an insufficient water supply or inappropriate water regime, invasive species infestation (e.g., reed canarygrass, bull frogs), trash, vandalism, or anything else that may result in non-compliance with permit requirements. Johnson et al. (2002) observed that a lack of maintenance was one of the main reasons for poor success of mitigation projects.

Results revealed that permitting agencies did not require all compensation projects to provide maintenance. Studies discovered that permits required site maintenance for 41 to 78% of projects (Erwin 1991, Storm and Stellini 1994, Michigan Department of Environmental Quality 2000). However, even fewer projects (20 to 60%) complied with their maintenance requirements (Erwin 1991, Michigan Department of Environmental Quality 2000).

The research did not investigate the reasons for low compliance with maintenance provisions. One may assume that it is linked to inadequate monitoring, lack of regulatory follow-up, or a lack of cooperation from the owner of the site.

6.4.8 Regulatory Follow-Up

Once compensatory wetland mitigation is required, it is the responsibility of the regulatory agencies to track the project over time and determine if it complies with permit requirements. A regulatory agency follows up on compensatory mitigation projects by:

- Ensuring that the compensation project is constructed as designed and approved, or that the applicant documents, through “as-built” reports why approved plans were modified during installation
- Ensuring that required monitoring reports are submitted on schedule
- Performing site visits to confirm monitoring results and attainment of performance standards
- Ensuring maintenance actions are undertaken on schedule
- Ensuring that appropriate contingency measures are enacted
- Ensuring the compensation site is protected over the long-term (i.e. through a legal protection mechanism such as a conservation easement)

Studies in Washington and Oregon indicated that about half of compensatory wetland mitigation projects received some regulatory follow-up in the form of site visits, phone calls, or letters (Kentula et al. 1992, Johnson et al. 2002). In Michigan only about a quarter of projects received any kind of follow-up after the permit was issued (Michigan Department of Environmental Quality 2000).

A few studies also examined the effect of regulatory follow-up on project compliance, success, or both. Robb (2002) alluded to the fact that the high number of non-compliant compensation projects resulted from a lack of follow-up and enforcement actions. In Washington a study noted that all of the projects lacking regulatory follow-up were either minimally or not successful, while two-thirds of the projects receiving some kind of follow-up were either fully or moderately successful (Johnson et al. 2002).

One team of researchers observed:

The most ecologically successful sites were generally those that had received follow-up work in the form of maintenance, replanting, or improvements to grading or water control structures in accordance with recommendations made by NJDEP [New Jersey Department of Environmental Protection] and other regulatory agencies after initial compliance inspections revealed problems (Balzano et al. 2002).

Studies indicated that regulatory follow-up can help to ensure the success of compensation sites (Johnson et al. 2002, Balzano et al. 2002). It is assumed that applicants will be more likely to abide by permit requirements and submit monitoring reports if regulatory agencies are actively following up on projects. Since monitoring reports are meant to identify what is working and where there are shortfalls, maintenance actions can be initiated or contingency measures can be triggered to correct the shortfalls and problems as soon as possible. Therefore, one can conclude that agency follow-up improves the compliance and success of compensation projects.

6.4.9 Summary of Key Points

- Most compensatory wetland mitigation projects were installed. However, compliance levels overall were generally low.
- Two out of three studies found that more than half of projects were installed according to plan. Projects not installed to plan most often did not comply with grading and vegetation requirements.
- The majority of studies found that about 50% of projects achieved their required wetland acreage.
- Even if individual projects did not fully achieve their required acreage, most studies found that at least 66% of the overall required acreage of compensation had been established.

- The requirement for monitoring as a regulatory condition seems to be increasing in more recent studies (30 to 50% in the early 1980s; 75% in more recent studies).
- Over 50% of the studies noted that it was difficult to find complete project files, thereby making it difficult to document if monitoring was occurring or being tracked by regulatory staff.
- The research found that 41 to 78% of projects required maintenance; however, only 20 to 60% of projects complied with maintenance requirements.
- Studies in Washington and Oregon found that approximately half of projects received some regulatory follow-up.
- Two studies suggested that follow-up had a positive influence on the level of compliance and success for compensatory wetland mitigation projects.

How is compensatory wetland mitigation doing in Washington?*

Five studies of compensatory wetland mitigation have focused on projects in Washington State during the past decade¹. The studies examined success, ecological functioning, permit compliance, and achievement of required wetland area, though not all studies looked at the same factors in the same way. The results suggest that compensatory mitigation in Washington is neither fully successful nor completely unsuccessful.

Most studies found that less than half of wetland compensation projects are fully effective. In the most recent and comprehensive evaluation of compensation projects, Johnson et al. (2002) found that 13% of compensatory wetland mitigation projects were fully successful and 33% were moderately successful. In western Washington, Storm and Stellini (1994) determined that 24% of compensation projects functioned well. In King County, Mockler et al. (1998) indicated that 3% of projects replaced lost wetland functions.

In terms of compliance, Johnson et al. (2000) determined that 29% of projects were in full compliance, while for King County Mockler et al. (1998) found that 21% of projects were meeting their required performance standards.

Kentula et al. (1992) examined Section 404 permit decisions for Washington from 1980 through 1986. Data indicated that permit decisions resulted in a wetland loss of 40 acres (16 ha). Johnson et al. (2002) determined that 24 acres (10 ha) of wetland were lost due to projects that did not successfully establish wetland area and the frequent use of existing wetlands for enhancement.

¹All studies, except Kentula et al. (1992), sampled a sub-set of the applicable mitigation projects.

*Results have been simplified for this summary. Please refer to Sections 6.3 and 6.4 for complete information.

6.5 Types of Compensatory Mitigation

When discussing compensatory mitigation it is important to have a common understanding of the types of compensation that can be used to mitigate for wetland losses. This is difficult because various agencies and organizations often define types of compensation differently (Morgan and Roberts 1999). An added difficulty is that each type of compensation represents a range of activities on a continuum rather than a distinct procedure.

This section describes several types of compensatory mitigation:

- Restoration
- Creation
- Enhancement/exchange
- Preservation
- Mixed compensatory mitigation
- Wetland mitigation banking
- In-lieu fee programs

Definitions given to each of the mitigation types are discussed below, followed by a description of how frequently each type is used and its relative effectiveness.

6.5.1 Restoration

Of the types of compensation, restoration has the widest variety of definitions. The most general is the reestablishment of wetland conditions (i.e., area, functions, and values) at a location where they formerly existed but no longer exist (Johnson et al. 2000, Jones and Boyd 2000). Activities associated with this definition could include removing fill material, plugging ditches, or breaking drain tiles. Other definitions involve returning a site to some historic condition. The following are examples of other definitions.

- Re-establishing historic hydrologic processes (National Research Council 2001) or hydrogeomorphic (HGM) classes (Johnson et al. 2000). Activities associated with this definition typically involve removing a levee or breaching a dike to reconnect an area to the floodplain or to tidal influence.
- “Return of an ecosystem to a close approximation of its condition prior to disturbance (NRC 1992). Restoration requires knowledge of the wetland type prior to disturbance and has the goal of returning the wetland to that type” (Gwin et al. 1999).
- Returning an altered wetland “to a previous, although altered condition (Lewis 1990)” (Gwin et al. 1999).
- “The process, or the result of the process of returning an area or ecosystem to some specific former condition” (Munro 1991).

Perhaps as a result of the numerous definitions, confusion about what constitutes restoration versus other types of compensatory mitigation can occur in regulatory permits and mitigation plans. The last three definitions in the list above could just as easily describe enhancement activities. For example, planting trees in a degraded wet pasture, often considered enhancement, could be an attempt to return an ecosystem (the pasture) to an approximation of its prior condition (forested wetland).

In their study of compensatory wetland mitigation projects in Tennessee, Morgan and Roberts (1999) mentioned that several projects were classified as restoration. Based on the activities specified, however, enhancement would have been a more appropriate term. Similar confusion occurred between restoration and creation. As a result of this confusion, the effectiveness of restoration, as a type of compensation, is difficult to assess.

6.5.1.1 Use of Restoration

For compensatory mitigation, restoration is often cited as the highest priority or most recommended type of compensation “because it offers the highest probability of success (Kruczynski 1990, Kusler and Kentula 1990, USDA-SCS 1992)” (Morgan and Roberts 1999). In addition, the National Academy of Sciences recommended restoration over creation. “Restoration of wetlands has been observed to be more feasible and sustainable than creation of wetlands” (National Research Council 2001).

This emphasis on restoration is not reflected in the number of freshwater, compensatory restoration projects implemented on the ground. Restoration tends to be one of the least utilized types of compensation (Jones and Boyd 2000). In fact, two studies mentioned that none of the projects involved restoration (Shaich and Franklin 1995, Gwin et al. 1999). Most of the studies that specifically mentioned the number or percentage of projects using a particular type of compensation found that 20 to 30% of projects involved some restoration of wetland acreage (Morgan and Roberts 1999, Johnson et al. 2000, Johnson et al. 2002). Projects employing restoration as the sole form of compensation are even fewer (Shaich and Franklin 1995, Johnson et al. 2000, Johnson et al. 2002).

In a departure from the other studies, Holland and Kentula (1992) found that 65% of permits required restoration. However, 42% of the compensatory wetlands they looked at were estuarine or marine. If estuarine and marine projects are subtracted, the percentage of restored, freshwater wetlands is similar to the other studies.

Morgan and Roberts (1999) suggest that the lack of compensatory wetland restoration projects is due to the fact that “most suitable restoration sites are ‘prior converted’ farmland and because sizable acreages are being restored under the Wetland Reserve Program . . . sites available for compensatory mitigation may be limited.” In Washington, however, the authors of Volume 1 believe that restoration is used infrequently because most wetland impacts are relatively small (less than 2 acres [0.8 ha]), and it is very difficult to find restoration opportunities for small sites that are not cost prohibitive. Restoration is typically most feasible and cost effective if done over a

large area. In addition, some regulatory requirements, particularly for local governments, direct applicants to provide compensation on-site, which often precludes an opportunity for restoration.

6.5.1.2 Effectiveness of Restoration

While it is widely stated that restoration is the most effective approach, the data to substantiate this claim are sparse. Studies indicate that there is a limited use of restoration for compensatory mitigation in freshwater wetlands. Thus, there is a substantial lack of data with which to evaluate its effectiveness as a type of compensation.

In Washington Johnson et al. (2000) found that one of three restoration projects was in full compliance. Johnson et al. (2002) found that one of two restoration projects established the required acreage of wetland and was fully successful. In Florida, Erwin (1991) found that restoration successfully established 88 acres (36 ha) more wetland area than was required. The limited existing data appear to suggest that when wetlands are restored, they are relatively effective at compensating for permitted losses.

6.5.2 Creation

It is generally agreed that creation involves establishing wetland conditions (area, functions, and values) in a location where wetland conditions previously did not exist (Johnson et al. 2000) or “that was not a wetland in the recent past (within the last 100-200 years) (Kruczynski 1990, Lewis 1990)” (Gwin et al. 1999). “Typically, a wetland is created by excavation of upland soils to elevations that will support the growth of wetland species through the establishment of an appropriate hydroperiod (Kruczynski 1990, Lewis 1990)” (Gwin et al. 1999).

Gwin et al. (1999) made a distinction between creating a wetland that is isolated from existing wetlands (creation) and creating a wetland that is immediately adjacent to an existing wetland, thereby enlarging the existing wetland (expansion). No other studies made this distinction.

The U.S. Army Corps of Engineers’ Regulatory Guidance Letter -02-2 uses the term *establishment* rather than the previously accepted term *creation*. Federal agencies, as well as the Department of Ecology, have started using the term *establishment*. However, this document synthesizes studies and documents written before this regulatory guidance letter was produced. Therefore, this document uses the term *creation* rather than *establishment*.

6.5.2.1 Use of Creation

Seven studies discussed how frequently creation was required as compensation. All noted that at least 30% and in some cases more than half of compensatory wetland projects were created or involved some creation (Holland and Kentula 1992, Shaich and Franklin 1995, Gwin et al. 1999, Morgan and Roberts 1999, Johnson et al. 2000, Jones and Boyd 2000, Johnson et al. 2002).

6.5.2.2 Effectiveness of Creation

In Washington, Johnson et al. (2000) found that 10% of created wetlands were in compliance. Seventy percent of creation projects established the required acreage of wetland, and 60% of created projects were either fully or moderately successful (Johnson et al. 2002).

In other states, however, created wetlands did not perform as well. Creation projects failed to establish 527 acres (213 ha) of required wetland area in Florida (Erwin 1991). In Tennessee, Morgan and Roberts (1999) found, “Most creation projects...were only partially successful because they failed to develop wetland characteristics throughout... Problems with created wetlands were numerous and involved both site design and vegetation establishment.”

The results on the effectiveness of creation are mixed. Though projects in Washington have poor compliance, other aspects of effectiveness are relatively good. However, other states found poor effectiveness for created wetlands. The data therefore suggest that further study is warranted.

6.5.3 Enhancement/Exchange

Enhancement involves modifying a specific structural feature of an existing degraded wetland to improve one or more functions or values based on management objectives (Gwin et al. 1999, Johnson et al. 2000). Enhancement typically consists of:

- Planting vegetation
- Controlling non-native, invasive species
- Modifying site elevations or the proportion of open water to influence hydroperiods

Gwin et al. (1999) defined exchange as:

Enhancement taken to the extreme (Kruczynski 1990), with most or all of the wetland converted from one type to a different type. For example, resource managers may intend to enhance habitat value for waterfowl by excavating an area of open water within an existing emergent marsh. However, if the open water area replaces the emergent wetland or a large proportion of it, wetland types have been exchanged.

Because enhancement involves altering an existing wetland to compensate for the loss of other wetlands, the scientific literature mentions three main concerns regarding its use.

- Enhancement fails to replace lost wetland area (Shaich and Franklin 1995, Morgan and Roberts 1999). For this reason, the state of Michigan does not allow the use of enhancement for compensatory mitigation (Michigan Department of Environmental Quality 2000).
- Enhancement may fail to replace wetland functions, since “a positive change in one wetland function may negatively affect other wetland functions (Kruczynski 1990, Lewis 1990)” (Gwin et al. 1999). In addition, “there commonly is disagreement about whether or not the practice implemented actually enhances conditions at a site” (Morgan and Roberts 1999).
- Enhancement may result in a conversion of HGM and/or Cowardin classes, typically producing a compensation wetland without natural analogues (Shaich and Franklin 1995, Gwin et al. 1999, Johnson et al. 2002). When enhancement is used for compensation in such cases:

A single Section 404 decision results in the destruction of the wetland for which the permit was issued, along with the conversion of a second wetland to a different, often atypical, HGM type. This ‘double whammy’ means that exchange [enhancement] explicitly does not fulfill the objective of ‘no-net-loss’ of wetlands but, instead, ensures loss of wetland area, additional wetland disturbance, and changes in overall ecological function (Gwin et al. 1999).

6.5.3.1 Use of Enhancement

Studies indicated that more than one-third of compensation projects used enhancement of existing wetlands as compensatory mitigation (Shaich and Franklin 1995, Gwin et al. 1999, Morgan and Roberts 1999, Johnson et al. 2000, Johnson et al. 2002).

6.5.3.2 Effectiveness of Enhancement

The effectiveness of enhanced compensation wetlands was evaluated by only two studies, both conducted in Washington. The researchers found less than 13% of enhanced wetlands were in complete compliance, while 56% of enhanced wetland projects met the requirement for acreage of compensation. (For projects that proposed to enhance existing wetlands, establishing the required acreage of wetland compensation entailed implementing the proposed actions to enhance the mitigation site.) Furthermore, none of the enhanced compensation wetlands were fully successful, while 89% were minimally or not successful (Johnson et al. 2000, 2002). For more information refer to Section 6.3.1 and Table 6-1.

Johnson et al. (2002) suggested two main reasons for the low level of success among enhancement projects.

- The enhancement project did not achieve the proposed vegetative structure, diversity, or both (the planted trees and shrubs did not survive or did not grow). Thus the project did not establish the required acreage of compensation, did not meet performance standards, or both.
- The enhancement project achieved the proposed structure/diversity, but despite this, it did not adequately compensate for the wetlands lost because the contribution of the enhancement to the performance of wetland functions was low.

The enhanced wetlands evaluated by Johnson et al. (2002) were all in the ground for less than eight years. Their study confirmed that for the projects they evaluated, eight years was not sufficient time to achieve the structural and species complexity of shrub and forested habitats. When structurally complex habitats are the goal of a compensatory mitigation design, studies continue to show that longer timeframes are necessary to begin to provide some of the attributes of those functions (National Research Council 2001). If structurally complex habitats are altered, it is possible to conclude that the delay in replicating those functions results in a prolonged temporal loss of functions on the landscape. This is equally true for projects proposing to restore or create wetlands.

Wetland creation vs. enhancement: Which contributes greater functions?

Johnson et al. (2002) determined that created wetlands were significantly more successful than enhanced wetlands. These researchers assessed the potential of compensation wetlands to perform wetland functions. They then determined how much the activities associated with the type of compensation contributed to, or improved, the level of wetland function. For creation/restoration projects it was assumed that if wetland conditions were achieved then the compensation activities were responsible for providing the assessed level of wetland functions. Enhanced wetlands performed some wetland functions prior to implementation of compensation activities. The authors believed it was important to determine how much enhancement activities contributed to, or improved, the level of performance of functions at a compensation wetland. The authors believed this was particularly important since enhancement, as a compensation tool, is based on improvement of wetland functions.

The study compared the contribution of created sites and enhanced sites for three function categories. Results indicated that over half of the created sites provided high or moderate contributions to wildlife habitat, water quality, and water quantity functions. Over half of the enhancement projects provided minimal to no contribution to wetland functions. The vast majority of enhancement actions were targeted at improving wildlife habitat functions. However, the enhanced wetlands were typically surrounded by development and lacked the buffers and connectivity necessary to improve habitat for most wildlife. In addition, most of the wetlands that were enhanced already provided some water quality functions. Thus, creation of wetlands provided a significantly greater contribution to the performance of water quality functions than enhancement of wetlands. Contribution to wetland functions was one element of overall success.

It is important to note that many created wetlands and some enhanced wetlands resulted in Cowardin and hydrogeomorphic (HGM) classes that were not typical for the landscape. This is discussed in more detail in Sections 6.8.2.2 and 6.8.5.1, respectively. Also, because enhancement provides less gain in function per acre than creation or restoration, replacement ratios are generally higher; refer to Section 6.6 for more information.

6.5.4 Preservation

Preservation means “the protection of an existing and well-functioning wetland from prospective future threats” (National Research Council 2001). Preservation, therefore, provides the opportunity to protect wetland areas that might otherwise be in jeopardy. Like enhancement, preservation does not produce any new wetland acreage; for that reason, some concerns have been raised regarding its use as compensation for permitted wetland loss.

- Preservation results in a net loss of wetland acreage.
- Preserved wetlands are generally not large enough to protect ecosystems and biodiversity over the long term (Whigham 1999).
- Preserved areas may not be checked by regulatory agencies to verify that they contain the specified acreage of wetland. For example, Morgan and Roberts (1999) observed that one of the larger preserved wetlands in their study was predominantly upland and “did not meet the criteria for being considered a jurisdictional wetland.”

On the other hand, if an area can be verified as wetland, “Preservation of an existing wetland removes the uncertainty of success inherent in a wetland creation or restoration project and requires no construction to complete” (Washington State Department of Transportation 1999). Preservation, therefore, eliminates the risk of failure and temporal loss of wetland functions since the preserved area is already an existing wetland.

6.5.4.1 Use of Preservation

The studies generally found that preservation was required as compensation for less than one-quarter of projects (Holland and Kentula 1992, Morgan and Roberts 1999, Johnson et al. 2000, Jones and Boyd 2000). Preservation generated about 2% of the compensatory wetland acreage in a study from San Francisco, California (Breaux and Serefiddin 1999). A report from the Washington State Department of Transportation (1999) indicated that 76% of state transportation departments in the United States use preservation as at least one component of compensatory mitigation and 38% use it as a stand-alone form of compensation.

6.5.4.2 Effectiveness of Preservation

There is a general lack of information about the effectiveness of preservation. Only one study examined the effectiveness of preservation as a type of compensatory mitigation. In Washington, Johnson et al. (2000) determined that all four of the projects involving preservation as the sole form of compensation were in compliance. Compliance for preservation projects entailed verifying that the area was preserved and free from development and that a deed restriction or conservation easement was in place to legally protect the parcel from future development.

6.5.5 Mixed Compensatory Mitigation

Mixed projects involve more than one type of compensatory mitigation. For example, a common proposal in the Pacific Northwest entails enhancing an existing wetland and creating additional wetland area immediately adjacent to it. Mockler et al. (1998) observed, “most sites consist of creation—a small pool graded for open water and emergents—and enhancement, typically of wetland buffer.” Mixed compensation, however, can also occur on separate sites, such as a created wetland adjacent to the development site and a preserved wetland some distance away.

Several studies identified mixed compensation projects (Mockler et al. 1998, Gwin et al. 1999, Johnson et al. 2000, Johnson et al. 2002). For their studies of compensation wetlands, Mockler et al. (1998) and Johnson et al. (2002) classified compensation wetlands according to their dominant type of compensation. However, some projects lacked sufficient information to make this determination, while other projects lacked dominance by any one type of compensation.

6.5.5.1 Use of Mixed Compensation Projects

In the six studies that discussed how frequently mixed compensatory mitigation was required, results ranged from 13% (Johnson et al. 2002) to 43% (Johnson et al. 2000). Most studies found that mixtures were used for less than a third of projects (Holland and Kentula 1992, Shaich and Franklin 1995, Gwin et al. 1999, Morgan and Roberts 1999).

6.5.5.2 Effectiveness of Mixed Compensation Projects

Only two studies, both from Washington, examined the effectiveness of projects utilizing a mixture of compensation types. Johnson et al. (2000) found that 32% of mixed projects were in compliance. Johnson et al. (2002) determined that all of the mixed projects were moderately successful.

6.5.6 Wetland Mitigation Banking

Mitigation banking is defined as “the practice of restoring, creating, enhancing, or preserving off-site wetland areas to provide compensatory mitigation for authorized impacts to wetlands” (Environmental Law Institute 2002). Wetland banking provides an alternative to traditional, concurrent, compensatory wetland mitigation, and its acceptance and use continue to grow.

Typically a public agency, organization, or private entrepreneur establishes a bank on a large area to be used to compensate for a number of smaller wetland impacts. Banks are generally established as compensation in advance of authorized impacts to wetlands at another site. One may conclude that this practice could provide advantages over traditional compensatory mitigation by reducing the temporal loss of wetland functions.

6.5.6.1 Use of Wetland Banking

Mitigation banking was used for about 7% of Section 404 permits in California issued from 1971 to 1987 (Holland and Kentula 1992). For permits issued from 1996 to 1998 which required mitigation, the Corps District of Norfolk, Virginia reported about 10% of projects purchased bank credits for use as compensation (Jones and Boyd 2000).

By the beginning of 1996, Brown and Lant (1999) determined that 68 banks had been established across the country, totaling nearly 41,000 acres (16,590 ha). A recent survey by the Environmental Law Institute (2002) determined that 219 banks had been approved across 40 states, totaling more than 139,000 acres (56,250 ha). Though 22 of the 219 banks have already sold all their eligible compensatory wetland acreage/credits, the remaining 197 banks were active, meaning they had credits/acreage that had not yet been purchased for use as compensation (Environmental Law Institute 2002).

Since wetland bank credits result from one or more of the previously mentioned types of compensation, the Environmental Law Institute (2002) investigated how frequently each type was used in mitigation banking. Results indicated that 78% of banks involved multiple types of compensation and that enhancement and restoration are the most commonly used. Of the banks that relied on a single type of compensation, about a third was restoration; another third was creation, while enhancement and preservation were each used on 16% of the banks.

6.5.6.2 Effectiveness of Wetland Mitigation Banks

Only one study has examined the effectiveness of wetland mitigation banks. Brown and Lant (1999) examined banks that had been established by the beginning of 1996. Overall, they found there would be a net loss of over 21,000 acres (8,450 ha) of wetland due to the use of enhancement and preservation at banks. The authors also discovered that eight banks did not provide the functions required or specified, while four banks used or sold more acreage for compensation of wetland loss than was eligible from the bank (in other words, the bank was overdrawn).

Wetland mitigation banking is increasingly being used to compensate for wetland losses. Yet the only study investigating the effectiveness of banks raises concerns about its use. Further study will therefore be critical to determine the level of compliance and success of mitigation banks in providing functions.

Please refer to Section 6.10.6 Mitigation Banking for more information on wetland banking as it relates to improving compensatory mitigation. In addition, the *Draft Programmatic Environmental Impact Statement: Washington State's Draft Rule on Wetland Mitigation Banking* (Driscoll and Granger 2001) contains a more in-depth discussion of the issues involved in mitigation banking (available at: <http://www.ecy.wa.gov/biblio/0106022.html>).

6.5.7 In-Lieu Fee Programs

In-lieu fee programs provide an additional option for compensatory mitigation. They allow permit applicants to compensate for wetland losses by paying a fee to a third party such as a government agency or conservation organization (U.S. General Accounting Office 2001, Environmental Law Institute 2002). The fees are intended to be used to restore, create, enhance, or preserve wetlands (U.S. General Accounting Office 2001).

Generally, in-lieu fee contributions are collected in advance of wetland losses. These funds are accumulated until they are sufficient to design and implement a wetland compensation project (Environmental Law Institute 2002).

6.5.7.1 Use of In-Lieu Fee Programs

A recent survey by the Environmental Law Institute (2002) determined there were 87 active in-lieu fee programs across 27 states. “Through fiscal year 2000, developers used the in-lieu-fee option to fulfill mitigation requirements for over 1,440 acres [583 ha] of adversely affected wetlands, and paid over \$64.2 million to in-lieu-fee organizations” (U.S. General Accounting Office 2001).

6.5.7.2 Effectiveness of In-Lieu Fee Programs

Two studies discussed the effectiveness of in-lieu fee programs. However, neither study provided information on the level of compliance or ecological success of these programs.

A study by the U.S. General Accounting Office (2001) examined the effectiveness of in-lieu fee programs used by the U.S. Army Corps of Engineers (Corps) to compensate for wetland losses permitted through the Section 404 program. Of the 17 Corps districts using in-lieu fees, 65% did not require a specific timeframe for spending or obligating the fees received, and a few districts had not spent or obligated any funds though they had been collecting fees as compensation for wetland losses for at least three years (U.S. General Accounting Office 2001). The study found that three districts used the fees for research and/or education, rather than on-the-ground activities to compensate for wetland loss. In-lieu fee programs in 30% of the districts restored, created, enhanced, or preserved wetland acreage equal to or greater than the wetland acreage lost. The remaining districts either had used the fees to implement wetland activities that did not compensate for the wetland acreage lost, or they did not have any data (U.S. General Accounting Office 2001).

A study by the Environmental Law Institute found that 45% of in-lieu fee programs lacked the data necessary to determine their effectiveness. In-lieu fees replaced more wetland acreage than was lost in 56 programs, while “thirteen in-lieu-fee programs reported replacing fewer acres than had been impacted” (Environmental Law Institute 2002).

These studies paint a rather grim picture of the effectiveness of in-lieu fee programs as compensation for wetland loss. However, both in-lieu fees and mitigation banking can

provide a mechanism to compensate for regulated wetland impacts that are so small they currently do not require compensation, because compensation for such small wetland losses was not considered viable or practical (Shabman et al. 1993). In the year 2000 federal guidance on the use of in-lieu fee arrangements for compensatory mitigation was issued, while prior to this there were no federal requirements for in-lieu fee programs (Environmental Law Institute 2002). Further study will be needed to ensure that abuses of in-lieu fee compensation are not occurring.

6.5.8 Summary of Key Points

- The variety of definitions or criteria associated with types of compensatory mitigation has led to confusion in permitting and evaluating projects. For instance, comparing the effectiveness of one type of compensation with another is impossible when it is not clear if a project involved creation, restoration, enhancement, or some combination thereof.
- Restoration has been recommended as the “highest priority” method for compensation. Research in Washington has found that it is the least used, though one of three projects was in compliance and one of two projects was fully successful.
- Creation was used in one-third to one-half of compensation projects. In Washington, 10% of creation projects were in compliance, 60% were at least moderately successful. Studies from other states indicated that creation projects experienced major problems such as a failure to establish vegetation and produce wetland conditions.
- Enhancement was used for compensation in more than one-third of compensation projects. Research in Washington found that less than 13% of enhancement projects were in compliance. There were no fully successful enhancement projects, while 89% were minimally or not successful.
- The low level of success for enhancement projects was attributed to an inability to achieve the proposed vegetative structure/diversity, a minimal gain in functions, or both. This may partially be a factor of time: There will be continued temporal loss of some functions until young sites mature to more complex structural conditions.
- Two studies from Washington indicated that mixed compensation projects had a higher level of compliance than either creation or enhancement, and all mixed projects were moderately successful.
- Preservation can result in permanent protection of existing wetland resources, but compliance was found to be variable. One study found a large area of preserved wetland was actually predominantly upland habitat. However, a study in Washington found that 100% of preservation sites were in compliance.

- Studies of wetland mitigation banking and in-lieu fee programs focused on whether the goal of preventing the net loss of wetlands had been achieved on paper. The results indicated that a net loss of wetland area was occurring. A few banks were overdrawn, and some of the in-lieu fee programs had not used the money collected to implement compensation activities. No studies determined their effectiveness on the ground.

Does size influence the effectiveness of compensatory wetland mitigation projects?

Studies of the effect of wetland size on compensation projects revealed mixed results.

Two studies indicated that larger projects, which probably involved more planning and regulatory oversight, had a higher level of compliance (Brown and Veneman 2001) or success (Allen and Feddema 1996). Allen and Feddema (1996) noted that large projects (greater than 8.6 acres [3.5 ha]) resulted in a net gain of wetland acreage, while the smaller projects resulted in a net loss of wetland acreage. Though Brown and Veneman (2001) indicated larger projects had a higher level of compliance, larger projects were no more successful at replacing the plant communities or wildlife functions that were lost than the smaller compensation wetlands.

Two other studies determined that no statistically significant correlation existed between wetland size and compliance or success (Balzano et al. 2002, Johnson et al. 2002). Raw data from Johnson et al. (2002) implied that compensatory mitigation projects 5 acres (2 ha) or larger were less successful than smaller projects. Balzano et al. (2002) found that larger compensation wetlands tended to be more successful at establishing the required wetland acreage. However, this trend was attributed to one large site (over 40 acres [16 ha]) that established more wetland acreage than was required.

The Committee on Mitigating Wetland Losses determined that wetland size does affect wetland functions (National Research Council 2001). For example, “for water quality purposes, many small wetlands would be more effective than one large wetland covering the same area.” The committee therefore concluded that “replacement area should be proportional to the area required to replace the functions lost” (National Research Council 2001).

6.6 Replacement Ratios

A replacement ratio, or compensation ratio, is an approach used to determine appropriate reparation for permitted wetland losses. Not all regulatory agencies use this approach. For example, the U.S. Army Corps of Engineers, Seattle District considers the needs for compensation on a project-specific basis rather than assigning replacement ratios.

The replacement ratio reflects the acreage of a particular type of compensatory mitigation (creation, restoration, enhancement, or preservation) required to make up for the loss of an acre of wetland (King et al. 1993, McMillan 1998). For example, a permitted loss of one acre may be compensated with two acres of restoration, thus requiring a 2:1 replacement ratio. The rationale for requiring more than 1:1 replacement for wetland impacts is provided in Section 6.6.1.

This section provides the following information:

- The rationale for using replacement ratios
- A summary of the literature regarding what replacement ratios are being required and if they are being achieved
- Some of the methods used to determine appropriate replacement ratios

6.6.1 Rationale for the Use of Replacement Ratios

When compensatory wetland mitigation was first required, the loss of an acre of wetland would simply require an acre of compensation (McMillan 1998). A simple 1:1 replacement ratio generally is no longer considered appropriate (Castelle et al. 1992a, King et al. 1993, National Research Council 2001) for the following reasons:

- **Risk of failure.** It is possible that compensation projects will not perform as proposed (King and Bohlen 1994) and may fail to compensate for wetland losses (Castelle et al. 1992a).
- **Temporal loss.** It may take anywhere from several years to several decades for a compensation project to achieve ecological equivalency (National Research Council 2001) and to develop the proposed/required wetland structures and/or functions (Castelle et al. 1992a).

Because of the risk of failure and temporal loss, “replacement ratios greater than 1:1 are used as a means of equalizing the tradeoff. While the goal is always to replace the lost functions at a 1:1 ratio, it is almost always necessary to increase the replacement acreage in order to accomplish this” (McMillan 1998).

A literature review performed by Castelle et al. (1992a) concluded that:

The risks of project failure and the time it takes for a created wetland to represent a fully functioning ecosystem should be factored into replacement ratios which exceed 1:1...

Replacement ratios of 2:1 or greater are necessary to compensate for our current rate of failure to achieve permit compliance of basic wetland community structural objectives within attempted mitigation projects, neither of which are accurate measures of functional equivalency.

An additional consideration is that there are many types of wetlands and various degrees of degradation. As a result, not all wetlands provide the same levels of functions or values. Replacement ratios, therefore, should take into account the type and quality of the wetland and the functions and values that would be lost. For example, the loss of a high-quality forested wetland would require a higher replacement ratio than the loss of a highly degraded wet pasture (Breaux and Serefiddin 1999).

Also, the type of compensation can influence the replacement ratio. Johnson et al. 2002 found that the use of enhancement not only results in a net loss of wetland area but provides a limited increase in wetland functions. Therefore, enhancement typically requires higher replacement ratios than restoration or creation (McMillan 1998).

Higher replacement ratios result in more area for compensatory mitigation, but unfortunately size does not guarantee success or quality. A study conducted by the National Academy of Sciences concluded that attempts to compensate for rare wetland types by requiring high replacement ratios yielded wetlands of a common type at a low ratio. Rather than replicating the rare wetland type, a more common wetland type was substituted. “In effect, the regulatory program may reassemble the landscape with a different habitat mix than the wetlands being lost” (National Research Council 2001).

6.6.2 Replacement Ratios Required and Achieved

Table 6-8 summarizes the overall or average replacement ratios that were required for compensatory wetland mitigation projects. A wide range of replacement ratios was required—from 0.66:1 to 5.9:1 (Kunz et al. 1988, Johnson et al. 2000). These are the extremes. The low end represents projects from the early to mid 1980s, when compensatory mitigation was still a relatively new idea. The higher ratios reflect more recent projects using predominantly enhancement and/or preservation, which typically require higher replacement ratios.

Between these extremes, the remaining studies noted ratios ranging from 1.5:1 to 2.7:1 (Wilson and Mitsch 1996, Morgan and Roberts 1999, Michigan Department of Environmental Quality 2000, Balzano et al. 2002, Johnson et al. 2002, Robb 2002).

Actual replacement ratios that were achieved for the projects studied are also shown in Table 6-8. None of the studies found that the required ratios had been realized. In fact, Balzano et al. (2002) determined that forested compensation wetlands achieved only 1/100th of an acre for every acre lost despite the fact that over 2 acres of forested wetland were required. Achieved ratios ranged from 0.7:1 to 1.9:1 (Wilson and Mitsch 1996, Morgan and Roberts 1999, Balzano et al. 2002, Johnson et al. 2002, Robb 2002).

As mentioned in the previous section, replacement ratios typically require greater than 1:1 replacement to factor in the risk of failure. Table 6-8 demonstrates the utility of this approach since all of the studies indicated that the achieved ratios were smaller than those required. All but one of the studies found the achieved ratios were greater than 1:1, though not by a substantial margin. But two of these studies included enhancement of existing wetlands.

Ratios are a tool to address the temporal loss of wetland functions and the historic failure of replicating wetland acreage and functions. The results indicate an inability of compensation projects to achieve their required replacement ratios. It is assumed that this inability reflects the same problems and shortfalls associated with compensation project success and compliance (see Section 6.4).

Table 6-8. Comparison of replacement ratios that were required and achieved.

Location of Study and Reference No.	No. of Projects Evaluated	Replacement Ratio Required	Replacement Ratio Achieved	Comments
Washington (Johnson et al. 2002)	24	2.2:1 ^a	1.87:1 ^a	Enhancement accounted for 65% of the established acreage
Washington (Johnson et al. 2000)	45	5.9:1 ^a	NA	Acreage predominantly preservation and enhancement
Washington (Kunz et al. 1988)	35	0.66:1	NA	Corps and EPA data 1980 to 1986
Michigan (Michigan Department of Environmental Quality 2000)	76	1.82:1 (average)	NA	Required ratios ranged <1:1 to >5:1; study did not include enhancement
Indiana (Robb 2002)	31	2.5:1	1.1:1	Achieved ratios for specific Cowardin classes ranged from 0.48:1 for PFO to 45:1 for POW; study did not include enhancement
Ohio (Wilson and Mitsch 1996)	4 (5)	1.5:1 (1.7:1) ^a	1.4:1 (0.7:1) ^a	Study reviewed 5 projects, results and conclusions focus on 4; parentheses reflect results for all 5
New Jersey (Balzano et al. 2002)	75	1.8:1 (average) 2.04:1 PFO 2.78:1 PSS 1.85:1 PEM 1.07:1 POW	0.78:1 (average) 0.01:1 PFO 0.91:1 PSS 1.29:1 PEM 0.28:1 POW	Sites proposing POW did not achieve the required acreage. However, POW was on sites that did not propose to have open water; thereby resulting in three times more POW acreage than required
Tennessee (Morgan and Roberts 1999)	47	2.7:1	1.9:1	Ratio = 0.88:1 when enhancement and preservation are excluded
NA = not available PFO = palustrine forested; PSS = palustrine scrub-shrub; PEM = palustrine emergent; POW = palustrine open water ^a Calculated from data provided.				

6.6.3 Approaches for Determining Replacement Ratios

King et al. (1993) proposed a framework for calculating replacement ratios, “based on the idea that compensatory mitigation involves trading one form of environmental capital for another and that full compensation requires increases in environmental functions and values from the compensation wetland that are sufficient to make up for the decline in functions and values resulting from the loss of existing wetland.” The authors mentioned five parameters to consider when determining an appropriate replacement ratio.

- The pre-existing level of wetland function per acre at the site proposed for wetland compensation. In the case of enhancement, this ensures that an applicant does not get mitigation credit for functions that were already being provided by a pre-existing wetland.
- The maximum level of function anticipated to be provided by the wetland compensation project.
- The number of years after construction that will be required for the wetland compensation project to reach its anticipated or sustainable level of function.
- The number of years between the loss of the original wetland and the completion of construction of the compensation wetland (temporal loss). Mitigation could be done concurrent with impacts, in advance, or delayed after impacts occur.
- The likelihood that the project will not achieve its anticipated level of function.

King et al. (1993) suggested entering the values for each of the five parameters into an analytic model that then calculates an appropriate compensation ratio for the project-specific information provided. King and Bohlen (1994) provided easy to use tables of replacement ratios that would result from a variety of values for the five parameters identified above. Using parameters comparable to King et al. (1993) for determining appropriate compensation, Rheinhardt et al. (1997) described an approach based on function assessment. The authors proposed the following steps.

1. Develop a function assessment method for the specific regional conditions, including identification of reference wetlands.
2. Assess wetlands proposed to be lost, thereby determining the level of each wetland function that will be lost.
3. Assess potential compensatory mitigation sites to evaluate their current level of function and predict future conditions and levels of function that would result from mitigation activities within the timeframe required for regulatory monitoring.
4. Calculate ratios for compensation for each function “by dividing the degree to which a function is reduced through project alteration by the degree to which a function is increased through restoration” (Rheinhardt et al. 1997).

The ratio “varies among functions and is influenced by (1) the magnitude to which any given function occurs at a project site both before and after the site is altered, (2) the magnitude to which any given function occurs at a compensatory mitigation site both before and after restoration is applied, and (3) the rate at which any given function is restored” (Rheinhardt et al. 1997). The goal of this approach is not just to ensure no net loss of wetland functions but also to restore wetland ecosystems (Rheinhardt et al. 1997).

In contrast, Breaux and Serefiddin (1999) argue that “there has not been any single, universally accepted assessment procedure to determine wetland functions and values (Kusler 1997).” As a result they suggest that “the quantitative measure of area provides a degree of certitude that should be taken advantage of” (Breaux and Serefiddin 1999). In other words, assessing or determining the level of functions provided by a wetland can be time-consuming to near impossible, while acreage provides an easy measurement. The authors mention a few conditions that may require greater than 1:1 replacement ratios (for example 2:1 or 3:1):

1. *If it is determined that the area lost includes functions and values of high quality...*
2. *If... the replacement area is outside the watershed, sub-watershed, or county;*
3. *If the replacement area involves a high risk of failure or uncertain outcome,*
4. *If there are high temporal losses...*
5. *If the habitat loss is likely to be substantially greater than the creation of new habitat; or*
6. *If the connection between two wetland sites is severed or a large site is divided* (Breaux and Serefiddin 1999).

Robb (2002) also proposed using an acreage-based system for determining appropriate replacement ratios. However, where the previous studies did not base ratios on the type of wetland, his system focused on developing replacement ratios for each Cowardin class. This approach resulted from a delineation of 31 compensatory mitigation sites in Indiana. Robb (2002) compared the required acreage of each Cowardin class with the acreage that was established. For example, results indicated that 71% of the required acreage of palustrine forested wetlands was not established (a 71% rate of failure). The ratio recommended to overcome this failure was calculated by dividing the required acreage by the acreage actually established. Using these data, the ratio for palustrine forested wetlands should therefore be 3.5 acres of compensation for every acre of wetland lost. The rationale was that for every 3.5 acres constructed that were intended to be palustrine forested wetland, 1 acre would actually become forested wetland. Proposed ratios for other wetland types included:

- 1.8:1 for scrub-shrub
- 7.6:1 for wet meadow
- 1.2:1 for shallow marsh
- 1:1 for open water

Robb (2002) conceded that his study did not consider the quality of the compensation wetlands or whether they replaced the functions lost. The author mentioned that more regulatory follow-up could result in more successful projects and therefore lower replacement ratios.

6.6.4 Summary of Key Points

- Replacement ratios provide a means of taking into account the potential failure and temporal loss of functions as well as the potential change in acreage or functions to be provided by the compensation project.
- Several methods are available to calculate replacement ratios on a case-by-case basis. Examples of some of the criteria used to determine ratios include the functions proposed to be provided at the compensation site, the functions anticipated to be lost at the impact site, size, landscape position, and relative chance of success.
- Required replacement ratios vary from one state to another, based on the type of compensation proposed, and based on project-specific circumstances.
- Studies found that compensation projects did not achieve their required replacement ratios. In some cases this resulted in less than 1:1 acreage replacement.

6.7 Replacement of Wetland Acreage

This section summarizes the results of studies examining whether compensatory wetland mitigation is replacing the acreage of authorized wetland losses. Replacement of wetland acreage is similar to “no net loss,” which refers to a goal for the nation and Washington State to ensure there will be no overall net loss in acreage and function of the remaining wetland resource base (The Conservation Foundation 1988, McMillan 1998). The no-net-loss goal, however, “does not mean that no further wetlands will be lost; rather, that mitigation and non-regulatory restoration will offset wetland losses” (McMillan 1998). Replacement of wetland acreage, on the other hand, focuses on wetland losses and gains associated with compensatory wetland mitigation.

Replacement of wetland acreage provides a measurable and consistent method for evaluating and comparing the effectiveness of compensatory mitigation programs (Kusler 1988). The scientific literature contained two types of information on this topic.

- Studies that evaluated how well permitting programs (e.g., Section 404) achieved replacement of wetland acreage. Most of these studies used information from permit files and databases.
- Studies that evaluated how well compensation projects achieved the replacement of wetland acreage on the ground. These studies were conducted in the field and typically involved the delineation of wetland boundaries.

6.7.1 Programmatic Evaluations of Acreage Replacement

Programmatic evaluations, in contrast to most of the studies mentioned thus far, are not concerned with the effectiveness of individual compensatory mitigation projects. Instead, programmatic evaluations focus on whether a permitting agency or permit program is requiring sufficient wetland acreage compensation to replace the authorized wetland losses occurring over a specified time.

In a programmatic evaluation, wetland acreage replacement is determined by comparing the acreage of wetlands lost, or adversely altered, with the acreage of wetlands required for compensatory mitigation in a specific geographic area. These evaluations typically rely on information from permit files and databases, rather than verification of on-the-ground, as-built conditions.

Five studies examined the effectiveness of wetland permitting and compensatory mitigation programs (Table 6-9). The earliest study reviewed Section 404 permit data from Washington, 1980 to 1986, and Oregon, 1977 to 1987, “to describe how permit decisions affect the wetland resource” (Kentula et al. 1992). Results indicated that in Washington 39 acres (16 ha) of wetland were not replaced, while in Oregon 79 acres (32 ha) of wetland were not replaced. The authors also observed, “In Washington, approximately 3 percent of the permits issued required compensatory mitigation” (Kentula et al. 1992).

The results of this study should be considered within the context of the Seattle District Corps of Engineers regulatory program in the early 1980s. The authors of Volume 1 observed that in the early 1980s compensatory mitigation, when it was required, was only required for projects that triggered an individual permit. The threshold for wetland fill under a Nationwide Permit 26 (a general permit for headwaters and isolated waters discharges) was 10 acres (4 ha), therefore an individual permit was only required for projects with greater than 10 acres of wetland fill. Fill of 10 acres or less in isolated wetlands was permitted outright. It is therefore possible to conclude that the 40 acres of wetland identified by Kentula et al. (1992) as “not replaced” very likely represents but a fraction of the total acreage of permitted wetland losses that were not compensated for at that time.

A study of Section 404 permitting from southern California noted that 8 acres (3 ha) of wetland were not replaced (Allen and Feddema 1996). The study also determined that “freshwater wetlands are experiencing a disproportionately greater loss of area and that riparian woodland wetlands are most often used in mitigation efforts. The net result of these accumulated actions is an overall substitution of wetland types throughout the region” (Allen and Feddema 1996).

Two of the remaining studies generally found that permitting programs required a net gain from compensatory mitigation (Table 6-9). Gains in acreage ranged from about 47 acres (19 ha) (Torok et al. 1996) to nearly 197 acres (80 ha) (Holland and Kentula 1992). However, the study of the effectiveness of the New Jersey Freshwater Wetlands Protection Act (Torok et al. 1996) mentioned compensatory mitigation acreage only for individual permits. It was not clear from the article if any of the 3,003 general permits, resulting in over 600 acres (243 ha) of wetland loss, required any compensatory mitigation. Furthermore, Holland and Kentula (1992), in their evaluation of Section 404 permitting in California, noted that data on acreage of impacts and compensation were lacking in about 40% of the permit files.

The fifth study focused on the Norfolk Corps District (Jones and Boyd 2000). The authors indicated that new wetland acreage produced by creation or restoration did not fully replace the permitted wetland losses, thereby resulting in a loss of about 260 acres (105 ha) (Jones and Boyd 2000). However, preservation, mitigation bank credits, and substantial in-lieu fee contributions provided additional compensation. If acreages from all types of compensatory mitigation are included, the authors assumed there was a gain of at least 1,500 acres (607 ha). Despite the fact that only 24% of the permits required compensation, the authors concluded that replacement of wetland acreage was achieved, at least on paper (Jones and Boyd 2000).

The results (Table 6-9) indicate that since the early 1980s, permitting programs have required an increasing amount of acreage to compensate for wetland losses. It can be inferred that permits from the mid-1980s did not require the replacement of acreage for wetland losses, whereas permits from the mid- to late 1990s appear to have required replacement of wetland acreage.

Table 6-9. Permitted wetland loss compared to required wetland compensation.

Location of Study	No. of Permits	Wetland Area Lost	Area of Compensation Required	Comments
Washington (Kentula et al. 1992)	35	152 acres (61.4 ha)	112 acres (45.5 ha) created	Section 404 permits 1980-1986
Oregon (Kentula et al. 1992)	58	183 acres (73.9 ha)	103 acres (41.8 ha) created	Section 404 permits 1977-1987
California (Holland and Kentula 1992)	324	2,907 acres (1,176.3) ha	3,103 acres (1,255.9 ha)	Section 404 permits 1971-1987; data on acreages was often lacking

Location of Study	No. of Permits	Wetland Area Lost	Area of Compensation Required	Comments
California/ southern (Allen and Feddema 1996)	75	199 acres (80.5 ha)	191 acres (77.3 ha) completed	Section 404 permits 1987-1989; permits required 276 acres (111.6 ha) of compensatory mitigation
Norfolk Corps District (Jones and Boyd 2000)	1692	863.8 acres (349.6 ha)	538.6 acres created (218.0 ha) 65.5 acres restored (26.5 ha) 1,537.2 acres preserved (622.1 ha) 200.8 bank credits \$2,574,966 in lieu fee	Section 404 permits 1996-1998
New Jersey (Torok et al. 1996)	3003 (107)	602 acres (243.8 ha) <i>164 acres (66.5 ha)</i>	NA <i>171 acres (69.2 ha) created; 41 acres (16.5 ha) restored</i>	New Jersey Freshwater Wetlands Protection Act permits 1988-1993. <i>Numbers in italics are individual permits; all other numbers are state general permits.</i>

6.7.2 Project-Specific Evaluations of Acreage Replacement

Studies that examined the effectiveness of compensation projects often assessed whether the projects achieved replacement of wetland acreage. The assessment generally involved determining how much wetland acreage the compensation projects provided. The wetland compensation acreage produced on the ground was then compared to the acreage of wetland loss associated with those projects. If the compensation acreage was less than the wetland acreage lost, a net loss of wetland occurred. Seven studies analyzed compensatory wetland mitigation project data to determine whether replacement of wetland acreage was achieved.

Four studies either focused on creation or restoration, or they did not mention the type of compensation. The studies noted that the acreage of wetland compensation was less than the acreage of wetland loss by as much as 34%, thereby resulting in a net loss of up to 8 acres (3 ha) (Gwin and Kentula 1990, Allen and Feddema 1996, Wilson and Mitsch 1996). However, a study conducted for the South Florida Water Management District found that creation and restoration activities resulted in 106% of the wetland acreage lost—a net gain of almost 65 acres (26 ha) of wetlands (Erwin 1991).

One issue that emerges when considering replacement of wetland acreage is the use of enhancement and preservation as wetland compensation. Three studies noted that enhanced or preserved wetlands accounted for 45 to 65% of the acreage of compensation (Shaich and Franklin 1995, Morgan and Roberts 1999, Johnson et al. 2002). In Washington nearly two-thirds of the established acreage of compensation involved

enhancing existing wetlands, while creation and restoration of wetland area replaced only 65% of the permitted wetland losses (Johnson et al. 2002).

Some authors discounted the acreage provided by enhancement and preservation. Enhancement and preservation are often not included in determining net loss or gain because neither type of compensatory mitigation produces any new wetland acreage (Breau and Serefidin 1999). When acreage provided by enhancement and preservation are disregarded, three studies found wetland losses of 22, 11, and 24 acres (9, 4, and 10 ha) respectively (Shaich and Franklin 1995, Morgan and Roberts 1999, Johnson et al. 2002). This equaled 58, 12, and 41% of the authorized wetland losses, respectively (Shaich and Franklin 1995, Morgan and Roberts 1999, Johnson et al. 2002).

6.7.3 Summary of Key Points

- Programmatic evaluations have documented an increase in the acreages of wetland compensation required since the early 1980s. However, the acreage of wetland replacement may include preservation, enhancement, or both.
- Project-specific data revealed that compensation wetlands did not replace the acreage of wetlands that were lost. Even larger losses occurred if the acreages of enhancement and preservation were discounted.

6.8 Functions and Characteristics Provided by Created, Restored, or Enhanced Wetlands

This section describes the functions and characteristics provided by wetlands created, restored, or enhanced for compensatory mitigation and non-regulatory projects.

- The capacity of created and restored wetlands to provide wildlife habitat for invertebrates, amphibians, and birds. Wildlife habitat was evaluated through direct observations or evidence of wildlife use, the presence of structural indicators, or comparison to reference wetlands.
- The ability of created, restored, or enhanced wetlands to develop plant communities and vegetative characteristics. Studies involved comparisons with reference wetlands and investigations of factors affecting vegetation.
- The importance of soil conditions, particularly as they relate to establishing vegetation and improving water quality. Soil properties of created and restored wetlands were compared with reference wetlands.
- The ability of created and restored wetlands to provide water quality functions.
- The importance of water regime and how the creation and enhancement of compensation wetlands can result in atypical water regimes.

The scientific literature indicated that the ability of compensatory wetland mitigation projects to perform wetland functions is not noticeably different from that of non-regulatory restoration or creation projects. Newly implemented wetland sites face similar challenges and develop in similar ways regardless of whether they were legally required or voluntarily initiated.

Refer to Chapter 2 of this document for a discussion of the functions that wetlands provide.

In Section 6.8, use of the terms “**significant**” and “**significantly**” implies statistical significance that was determined by the authors of the specific study being discussed.

6.8.1 Wildlife Habitat

Most articles focused on the ability of a created or restored wetland to provide habitat for one specific guild or group of animals, such as invertebrates, amphibians, or birds. Information on other habitat functions provided by created or restored wetlands was lacking.

6.8.1.1 Invertebrates

Several studies have compared the invertebrate communities of created or restored wetlands with those of reference wetlands. Most of these determined that reference wetlands were more diverse, had greater taxon richness, or had higher density of species than created or restored sites (Brown et al. 1997, McIntosh et al. 1999, Fairchild et al. 2000, Dodson and Lillie 2001). One study, however, found “no convincing differences” in fly (dipteran) densities between created and reference wetlands (Streever et al. 1996). None of these studies were conducted in the Pacific Northwest. However, the results should be broadly applicable to wetlands anywhere.

The age of the wetland, or the amount of time elapsed since restoration occurred, was an important factor influencing invertebrate taxon richness, abundance, and/or diversity (Brown et al. 1997, Fairchild et al. 2000, Dodson and Lillie 2001). For example, “insects with aerial dispersal capability rapidly colonized the restored habitats, but some less mobile forms (non-insects and some hemipterans [true bugs]) either colonized more slowly or not at all” (Brown et al. 1997). Dodson and Lillie (2001) determined that a newly restored site would require 6.4 years for the zooplankton taxon richness to resemble that of a minimally disturbed reference wetland.

The growth and development of vegetation also appears to affect invertebrate communities (Chovanec 1994, Brown et al. 1997, Chovanec and Raab 1997, McIntosh et al. 1999, Fairchild et al. 2000). For example, certain predatory groups of beetles were early colonists at young sites with limited development of vegetation, while herbivorous beetle groups occurred at older sites after specific types of vegetation had developed (Fairchild et al. 2000). McIntosh et al. (1999) concluded, “wetlands at different

successional stages may contain very distinct aquatic macroinvertebrate assemblages which may be important to the food web and other functional processes of wetlands.”

6.8.1.2 Amphibians

The amphibian habitat present in created or restored wetlands has been compared with that of reference wetlands in several studies. On the east slope of the Cascade Range in the Teanaway and lower Swauk River drainages of Kittitas County, Quinn et al. (2001) found no difference in species richness of amphibians between created and reference wetlands, “although sample sizes may have been too small for differential species-use patterns to emerge.” Other authors determined that created and restored wetlands differed from reference wetlands in terms of amphibian community structure, species richness, or stomach content (Bursey 1998, Lehtinen and Galatowitsch 2001, Pechmann et al. 2001).

Though created or restored wetlands provide habitat for some amphibian species, conditions within the wetland and conditions outside the wetland may limit productivity, dispersal, colonization, or all three. Conditions within a wetland that appear to affect amphibian communities include hydroperiod, substrate, presence of emergent vegetation, presence of fish, and the availability of an invertebrate prey source (Bursey 1998, Baker and Halliday 1999, Monellow and Wright 1999, Pechmann et al. 2001).

Conditions outside of a restored or created wetland that affect amphibian communities include distance to other wetlands, connectivity between habitats, and the land use of the surrounding terrestrial habitats (Baker and Halliday 1999, Monellow and Wright 1999, Lehtinen and Galatowitsch 2001, Pechmann et al. 2001). For example, Baker and Halliday (1999) observed that two species of amphibians dispersed to new ponds only if they were within 1,312 feet (400 m) of an existing pond, while two other species colonized new ponds up to 3,117 feet (950 m) from an existing pond.

Monellow and Wright (1999) concluded, “The interconnectiveness of amphibian habitat is an essential element in sustaining amphibian populations because it allows amphibians to overcome large population fluctuations and recolonize areas where populations have been extirpated.”

Lehtinen and Galatowitsch (2001) found that the wetlands restored in urban areas had the lowest amphibian species richness. However, authors of a study of wetlands created in a recreational area in an intensively used urban site near Vienna, Austria observed all seven of the amphibian species known to occur in the area. As many as six species were breeding (Chovanec 1994).

6.8.1.3 Birds/Waterfowl

All of the studies that examined the ability of created or restored wetlands to provide habitat for birds focused on non-regulatory projects. Therefore this section does not contain information on the ability of compensatory wetland mitigation projects to provide habitat for birds. However, the information is still relevant based on the similarity of

results among compensatory and non-regulatory projects for the other studies of functions. None of the studies cited below were conducted in the Pacific Northwest.

Studies comparing bird use of created or restored wetlands and reference wetlands demonstrated variable results, perhaps indicating that site-specific conditions influence bird use. For example, two studies found no difference in bird abundance between restored and reference wetlands (Brown and Smith 1998, Ratti et al. 2001), while two other studies determined that reference wetlands had greater bird species richness and abundance (Delphey and Dinsmore 1993, Dobkin et al. 1998). Brown and Smith (1998) found no difference in bird abundance or the number of bird species observed. However, they did determine that the bird communities differed by a statistically significant margin and that density was greater at reference wetlands (Brown and Smith 1998). Regardless of the findings for bird populations in general, two studies noted that ducks had similar or greater abundance, species richness, or density at created and restored wetlands (Delphey and Dinsmore 1993, Ratti et al. 2001).

In the literature, the main factors that appeared to affect wetland use by bird populations were:

- The percent cover of emergent vegetation (Belanger and Couture 1988, Hemesath and Dinsmore 1993, VanRees-Siewert and Dinsmore 1996)
- The density and abundance of invertebrates (Belanger and Couture 1988, Cooper and Anderson 1996)

Though the age of the wetland did not directly affect overall bird populations at created and restored wetlands, VanRees-Siewert and Dinsmore (1996) noted that the richness of breeding bird species was significantly greater at older restoration sites. The composition of the bird community changed with age. Both of these effects were associated with an increase in the emergent vegetation in older wetlands.

6.8.2 Plants

6.8.2.1 Comparisons with Reference Wetlands

This section discusses studies that compared the vegetation of created and restored wetlands to that of reference wetlands. The studies examined a variety of parameters in a number of states and found variable results. Only one study determined that there was no difference in vegetation between created/restored and reference wetlands (Brown 1991). Two studies were conducted in the Pacific Northwest.

In the metropolitan area of Portland, Oregon, reference wetlands differed significantly from mitigation wetlands in terms of floristic composition. Mitigation wetlands had higher overall plant species richness, higher average percentage of native species, and significantly higher average occurrence of introduced and invasive/introduced species than reference wetlands (Magee et al. 1999).

Another study was conducted in the northwestern Great Basin on land that had previously been grazed by cattle. The study found that “sedge cover, forb cover, and foliage height diversity of herbs were greater” on reference plots, in which livestock had been excluded for more than 30 years. “[B]are ground, litter cover, shrub cover, and shrub foliage height diversity were greater” on restored plots, in which livestock grazing pressure had been removed prior to commencement of the study (Dobkin et al. 1998). During the four-year study period, restored plots experienced an increase in grass, forb, rush, and cryptogamic cover, but sedge cover did not change. The authors concluded, “the lack of change in sedge and shrub cover on open [restored] plots suggests that restoration to a sedge-dominated meadow will not happen quickly” (Dobkin et al. 1998).

Restored prairie pothole wetlands were found to lack low prairie and wet meadow zones that reference wetlands possessed. Restored wetlands had significantly higher richness of submersed aquatics and greater coverage by mudflat and open water (Delphey and Dinsmore 1993, Galatowitsch and van der Valk 1995, Galatowitsch and van der Valk 1996). The researchers concluded that restored wetlands are not likely to develop the sedge meadow and wet prairie zones present in reference wetlands (Galatowitsch and van der Valk 1995, VanRees-Siewert and Dinsmore 1996).

Other authors determined that reference wetlands exhibited greater percent cover by wetland species. However, created wetlands had species richness that was equal to or greater than reference wetlands (Moore et al. 1999). Restored wetlands had significantly lower wetland index values (indicating that wetland species were providing more of the total vegetative cover) than reference sites (Brown 1999).

One could hypothesize that created and restored wetlands have greater vegetation species richness due to the level of disturbance associated with creation and restoration and the broad range of niches created on a new site. For example, a newly created or restored site is like a *tabula rasa* (a blank slate) upon which species will be planted (installed or seeded), species from the previous habitat on the site will re-emerge, and species adapted to disturbance will colonize.

6.8.2.2 Cowardin Classes Provided by Compensatory Mitigation Wetlands

Cowardin class refers to a method used to categorize wetlands based on the dominant type of vegetation (Cowardin et al. 1979), as well as other factors. The main Cowardin classes used to categorize freshwater wetlands are:

- Emergent
- Scrub-shrub
- Forested
- Aquatic bed
- Open water (though not technically a Cowardin class, open water is often used to map and describe unvegetated areas of inundation)

Several studies evaluated compensatory wetland mitigation sites to determine which Cowardin classes were being established. Nearly all of these studies found that compensatory mitigation resulted in more acreage of open water/aquatic bed/deep marsh than was originally lost or required (Kentula et al. 1992, Shaich and Franklin 1995, Bishel-Machung et al. 1996, Magee et al. 1999, Cole and Brooks 2000, Michigan Department of Environmental Quality 2000, Balzano et al. 2002, Johnson et al. 2002, Robb 2002).

For example, in Washington State over 16 acres (6 ha) of open water/aquatic bed wetlands were gained (Johnson et al. 2002). In the Portland metropolitan area of Oregon, 29 acres (12 ha) of open water were gained (Shaich and Franklin 1995), and Indiana gained over 3 acres (1 ha) of open water/deep marsh/aquatic bed (Robb 2002). Compensatory wetland mitigation projects in New Jersey generated 50 acres (20 ha) more open water than was required (Balzano et al. 2002).

Results for other Cowardin classes were more variable. For example, four studies noted either a loss of forested wetland area (4 to 8 acres [2 to 3 ha]) or an inability to establish this wetland class (Shaich and Franklin 1995, Bishel-Machung et al. 1996, Brown and Veneman 2001, Balzano et al. 2002, Robb 2002). On the other hand, a study from Washington State observed a net gain of over 12 acres (5 ha) in forested/scrub-shrub wetlands (Johnson et al. 2002).

Additional variability occurred in the balance of emergent wetlands. Two studies from the Pacific Northwest noted a loss of 35 to 51 acres (14 to 21 ha) for emergent wetlands due to their conversion to other Cowardin classes (Shaich and Franklin 1995, Johnson et al. 2002). Studies from other states, meanwhile, found that emergent wetlands were established more successfully than other wetland classes (Bishel-Machung et al. 1996, Brown and Veneman 2001, Balzano et al. 2002). Though the studies did not mention whether the emergent wetlands were dominated by native vegetation, Brown and Veneman (2001) noted “plant communities in replicated wetlands differed significantly from those in wetlands they were designed to replace” in terms of the number and percent cover of species in general and the number and percent cover of wetland species.

Compensatory mitigation may often result in a different wetland type compared to what was lost (Shaich and Franklin 1995, Balzano et al. 2002, Johnson et al. 2002, Robb 2002). For example, if an open-water pond was provided as compensation for an authorized impact to a wetland pasture, a change in wetland type occurred. If the compensatory mitigation was enhancement and involved constructing an open water pond in another wetland pasture, a second change in wetland type occurred.

The studies examining changes in Cowardin classes at compensation wetlands found a net increase in open water/aquatic bed habitats (Shaich and Franklin 1995, Balzano et al. 2002, Johnson et al. 2002, Robb 2002). Though the reasons for this change are not clear for all studies, several studies indicated that open water/aquatic bed resulted from an inability to establish the proposed Cowardin class (Balzano et al. 2002, Robb 2002). One could assume that another reason may be that open water is relatively easy to establish given adequate hydrologic conditions. Furthermore, the authors of Volume 1 have

observed situations in which the wetland mitigation design was intended to maximize a limited space by providing a variety of habitat niches, and open water is often considered a key habitat niche for waterfowl. Therefore, it is possible to conclude that regulatory decisions may have been biased toward the construction of more open water/aquatic bed/emergent wetland complexes in order to achieve an enhancement of functions in a limited space.

Studies from Washington and Oregon reported a net loss of emergent wetlands (Shaich and Franklin 1995, Johnson et al. 2002). However, many wetlands in the Puget Lowlands of Washington and the Willamette Valley of Oregon that are classified as emergent are wet pastures dominated by non-native grasses. Johnson et al. (2002) noted that 90% of the emergent acreage lost or converted was pasture dominated by non-native species. It can be assumed that much of the current area of emergent pasture may historically have been forested wetland. Therefore, one can conclude that converting pastures into other wetland types with a greater diversity of hydroperiod and more structural complexity, such as forested wetlands, may represent an opportunity for a net increase in wetland functions over time, compared with leaving the wet pastures unchanged.

6.8.2.3 Factors Affecting Plants

Several major factors influencing wetland vegetation have emerged from the literature:

- Soil and soil disturbance
- Age of the wetland
- Competition and non-native vegetation
- Seed or plant source
- Human manipulation

The studies summarized in this section looked at different parameters in different types of wetlands across the country; therefore, the results are highly variable.

Soil and Soil Disturbance

Five studies indicated that soil conditions at the created or restored wetlands influenced vegetation composition (Brown 1991, Ashworth 1997, Brown and Bedford 1997, Stauffer and Brooks 1997, Brown 1999). Three of these studies discussed the positive effects of adding salvaged or donor hydric soil to created or restored wetlands. Benefits included increased species richness (Brown 1991, Stauffer and Brooks 1997) and significantly higher number and percent cover of wetland species (Brown and Bedford 1997). Stauffer and Brooks (1997) concluded that more organic matter in the hydric soil improved the retention of moisture and nutrients, thereby helping to increase plant cover, density, and species richness. Another study, involving dike removal to restore a site, observed that disturbance of the soil resulted in vegetation dominated by cattails (Brown 1999).

Age of the Wetland

The effect of age on the vegetation of created and restored wetlands was noted in various studies (Reinartz and Warne 1993, Magee et al. 1999, Moore et al. 1999). Created and restored wetlands less than three years old differed, in terms of floristic composition, from sites three years and older (Reinartz and Warne 1993, Magee et al. 1999). Older sites had higher mean total plant cover and mean cover of native wetland species (Reinartz and Warne 1993). Moore et al. (1999) found that age, in addition to sedimentation, resulted in:

- A decrease in open water and water depth
- An increase in emergent and woody cover
- An increase in the number of plant species
- An increase in wetland vegetation species richness

In western Washington, Celedonia (2002) investigated the age at which canopy convergence occurs. The study found that “aerial [woody] cover increases with age until year 8 and remains constant into years 10-11.” The author noted, “80% cover is generally achieved by year 8, and perhaps as early as year 7.” The study found that the most abundant species in terms of frequency and cover were red alder (*Alnus rubra*), willows (*Salix spp.*), black cottonwood (*Populus balsamifera*) and red osier dogwood (*Cornus sericea*). In addition, Celedonia (2002) found that native woody cover was strongly correlated with the density of stems greater than 6.5 feet (2 m) tall, such that percent cover increased as stem density increased up to about 2,100 stems per acre. Sites with densities higher than 2,100 stems per acre generally had greater than 90% woody cover (Celedonia 2002).

Competition and Non-Native Vegetation

The effect of competition on vegetation has been examined in several studies. The studies focused on specific species or treatments used to manage vegetation, factors that affect competition with non-native species, and the presence and extent of non-native species on compensatory wetland mitigation sites.

A few of the studies were conducted outside of the Pacific Northwest, and may have limited applicability to Washington State. For example, in the southeastern United States McLeod et al. (2001) determined that an existing willow canopy did not detrimentally affect the survival of three under-planted tree species. In the Midwest, Budelsky and Galatowitsch (2000) experimented with hairy sedge (*Carex lacustris*). The authors concluded, “*C. lacustris* can produce dense stands under a primarily annual weed community within two to three growing seasons, but that reed canary grass (*Phalaris arundinacea*) can preclude successful establishment of *C. lacustris*” (Budelsky and Galatowitsch 2000).

In the western Washington, Celedonia (2002) found that reed canary grass (*P. arundinacea*) can exist at relatively high densities (as much as 40% aerial cover) under

abundant canopy cover (>95%). This study was not able to determine: 1) whether reed canary grass was actually spreading through the understory, or whether it was a remnant, and woody species were establishing 'over' it; or 2) the extent to which reed canary grass inhibits establishment of desirable plant species during the re-initiation of the understory (Celedonia 2002).

Research has identified two factors that affect competition with non-native species.

- **Shrub density.** Celedonia (2002) observed, “greater shrub layer densities were associated with less reed canarygrass.” The author suggests that an initial planting of a very dense shrub layer (e.g., more than 3,000 stems per acre) may help to preclude domination of reed canarygrass (*Phalaris arundinacea*).
- **Land use.** Magee et al. (1999) found that “the number of introduced and invasive/introduced species per site increases significantly with more intensive land use.”

A few studies investigated how many compensation projects experienced problems with invasive species or how many non-native species occurred on sites. In Washington State, Johnson et al. (2002) noted that 61% of compensatory mitigation sites had at least 25% of the site dominated by non-native species. Celedonia (2002) found that nearly half of the sites visited in Washington had greater than 10% cover of reed canarygrass. In a study conducted by the Michigan Department of Environmental Quality (2000), “8% of mitigation sites were found to have a problem with invasive species” (defined as constituting 10% or more of the vegetation community).

In the Portland metropolitan area of Oregon, a study of vegetation at compensatory mitigation wetlands observed that non-natives composed more than half of the species present and “nine of the 14 most common taxa were invasive introduced species” (Magee et al. 1999).

Seed or Plant Source

The seed or plant source has been identified as important for restored wetlands (Reinartz and Warne 1993, Galatowitsch and van der Valk 1995). Restoration wetlands seeded with native wetland species had higher diversity and richness and less cover by cattails than the unseeded wetlands (Reinartz and Warne 1993). Emergent perennial species rapidly recolonized restoration wetlands possessing a viable refugium of wetland plant species (e.g., present in existing ditches) that spread through vegetative rooting (Galatowitsch and van der Valk 1995). The importance of proximity to a seed source was mentioned by Reinartz and Warne (1993) but discounted by Galatowitsch and van der Valk (1995).

Kellogg and Bridgham (2002), however, found that low density planting “offered no clear advantages over hydrologic restoration.” Though seeding of a cover crop appeared to limit the establishment of aggressive species such as *Phalaris arundinacea*, it also appeared to limit establishment of wet prairie and sedge meadow species (Kellogg and Bridgham 2002).

Human Manipulation

A study conducted in the Willamette Valley of Oregon examined the response of wetland vegetation to three techniques for the restoration of wet prairie: burning, hand removal, and mowing (Clark and Wilson 2001). Results indicated that:

- **Burning** significantly reduced the survival and percent cover of woody species and non-native forbs (e.g., common St. John's-wort [*Hypericum perforatum*]), increased flowering of slender rush (*Juncus tenuis*), and increased cover of native forbs (e.g., Spanish-clover [*Lotus purshiana*] and marsh speedwell [*Veronica scutellata*]), but decreased flowering of tufted hairgrass (*Deschampsia cespitosa*), the dominant wetland prairie grass.
- **Hand removal** significantly reduced cover by woody species and non-native forbs, increased cover of native forbs, but increased flowering of non-native grasses (e.g., velvet grass [*Holcus lanatus*] and sweet vernal grass [*Anthoxanthum odoratum*]).
- **Mowing** had no effect on cover of woody species, but it increased the flowering of non-native grasses and significantly increased flowering of slender rush.

The authors concluded that though “no treatment was clearly superior in fulfilling the restoration objectives” mowing with removal of cut material was specifically not recommended (Clark and Wilson 2001).

6.8.3 Soil Characteristics

Soils are a critical component of wetlands. Soil characteristics can influence the growth and development of vegetation as well as the ability of wetlands to perform certain water quality functions. Researchers have investigated several factors related to wetland soil characteristics at compensatory wetland mitigation sites, including:

- Organic matter content
- Bulk density (compaction)
- Particle size
- Nitrogen content

Several authors used the approach of comparing soil conditions of created wetlands with reference wetlands. In these studies, the reference wetlands were either of the same wetland types as the mitigation wetlands, or they were adjacent to the mitigation wetlands. Only one study compared treatment plots to control plots at created wetlands. None of the articles on soil characteristics involved non-regulatory projects. Only one was conducted within the Pacific Northwest.

Results consistently indicated that the soil of created wetlands had a lower content of organic matter than reference wetlands (Brown 1991, Bishel-Machung et al. 1996, Streever et al. 1996, Shaffer and Ernst 1999, Whittecar and Daniels 1999, Stolt et al. 2000). Bishel-Machung et al. (1996) found that created wetlands had less organic matter than reference wetlands regardless of the Cowardin class or hydrogeomorphic class.

In the Portland metropolitan area, Shaffer and Ernst (1999) observed that both reference and mitigation wetlands with a high extent and duration of standing water had a lower concentration of soil organic matter. However, the authors also observed a consistent pattern of lower concentrations of organic matter in the soil of mitigation wetlands compared to reference wetlands within the same soil series, texture classes, and associations. Since many of the mitigation wetlands in this study involved construction of a pond in an existing wetland, the authors hypothesized that organic matter in mitigation wetlands is being lost due to the excavation of upper soil layers during project installation (Shaffer and Ernst 1999).

In studies examining created wetlands from one to 11 years old and one to eight years old, the age of the created wetlands did not have an effect on organic matter content of the soil (Shaffer and Ernst 1999, Bishel-Machung et al. 1996). Concentrations of organic matter were relatively uniform between surface and subsurface samples. This indicated that accumulation of organic matter was either not occurring or was occurring so slowly it was not detectable (Bishel-Machung et al. 1996, Shaffer and Ernst 1999).

Stauffer and Brooks (1997) examined the effect of adding organic soil amendments to created wetlands. The authors found that plots treated with “salvaged marsh surface” (hydric topsoil) and leaf litter compost contained more organic matter than untreated, control plots. After two growing seasons, soil organic matter remained higher in plots treated with organic soil amendments.

Studies looking at particle size, bulk density, and nitrogen content found that soils in created wetlands had more sand, higher bulk densities (more compacted), and a lower nitrogen content than reference wetlands (Bishel-Machung et al. 1996, Whittecar and Daniels 1999, Stolt et al. 2000). In combination with low organic content, the soil characteristics of created wetlands may hinder plant establishment and growth (Whittecar and Daniels 1999, Stolt et al. 2000), denitrification and pollutant trapping (Stolt et al. 2000), and redox conditions (Bishel-Machung et al. 1996), thereby influencing microbial activity (Whittecar and Daniels 1999).

In contrast, Gilliam et al. (1999) found that redox levels and nitrogen content (in the form of ammonia) at an eight-month-old created wetland were comparable to a reference wetland after the created wetland was inundated. However, pH, phosphorus, manganese, magnesium, and zinc did not change noticeably at the created site. The authors concluded that eight months was “an insufficient period of time for a complete change toward hydromorphic soils.”

6.8.4 Water Quality

Most of the water quality studies investigated the ability of created or restored wetlands to retain sediment, phosphorus, nitrogen, or some combination. One study compared water quality attributes at created and reference wetlands (Streever et al. 1996). None of the studies were conducted in the Pacific Northwest.

6.8.4.1 Comparison of Water Quality at Created and Reference Wetlands

Streever et al. (1996) determined that created wetlands had higher pH and conductivity than reference wetlands. The authors hypothesized that the amount of organic matter in the soil is related to pH and conductivity: “because decomposition of organic material releases CO₂, lower pH values would be expected in natural systems with well-developed organic soils. A well-developed organic substrate may isolate surface water from underlying sand and rock, leading to decreased dissolution of minerals and lower conductivity.” (See the previous discussion of soil characteristics in Section 6.8.3.)

6.8.4.2 Sediment Removal

Findings related to retention of sediment by created wetlands include the following:

- Wetlands created adjacent to roads were effective at retaining sediment, such that inflow culverts were clogged by accumulated sediment at a couple of sites (Moore et al. 1999).
- Mitsch (1992) found that a created wetland retained 90% of sediments, while a reference wetland retained 3%. The actual amount of sediment retained depends upon the loading rate.
- Fennessey et al. (1994) investigated the location within a created wetland where sediment was retained. Rates of sediment deposition, in general, were highest near the inflow and decreased as distance from the inflow increased, “except when outflow ceased, in which case the maximum sedimentation often occurred near the outfall.” Open water areas also had higher sediment deposition than vegetated areas, which restricted flow. The authors observed that vegetation seems to present a barrier to water and sediment flow and, therefore, the study “did not illustrate the conventional belief that the presence of vegetation enhances sedimentation.” The authors concluded, “deeper open water areas are more conducive to sediment accumulation than are shallower open water areas that are more easily subjected to wind-driven and biological sediment disturbances and subsequent re-suspension.”

6.8.4.3 Nutrient Removal

In several studies, phosphorus retention at created or restored wetlands ranged from 16 to 96% (Mitsch 1992, Mitsch et al. 1995, Niswander and Mitsch 1995, White et al. 2000). In all but one of these studies, created/restored wetlands retained at least 53% of phosphorus (Mitsch 1992, Mitsch et al. 1995, White et al. 2000). The percent of retention varied depending on:

- Whether the wetland experienced high or low flows (Mitsch 1992, Mitsch et al. 1995)
- The configuration of the outflow
- The amount of time water was retained in the wetland (Niswander and Mitsch 1995)

White et al. (2000) mentioned that a restored wetland's capacity for phosphorus retention is limited. Sediments near the wetland inflow had a limited ability for additional uptake of phosphorus. However, approximately 66% of the marsh sediments still had a high capacity for uptake. The authors concluded, "future treatment efficacy may decrease if the remaining sediments become saturated. Continued high P [phosphorus] loading to the marsh may lead to eutrophication problems and downstream P export from the wetland."

Romero et al. (1999) found that total nitrogen retention was 30 to 91% at four restored wetlands. The authors attributed this to the high retention of dissolved inorganic nitrogen, while the retention efficiencies for particulate and dissolved organic nitrogen were much lower. The authors observed no significant difference between nitrogen retention and the age of the restored wetland.

Woltemade (2000) examined the factors that affect the ability of a created or restored wetland to retain nutrients. The most critical design elements for wetlands constructed to treat agricultural runoff were determined to be the retention time (amount of time that water is retained in the wetland) and the wetland-to-watershed ratio (size of the wetland compared to the size of its contributing basin):

If nutrient and sediment concentrations are to be reduced to acceptable levels on a landscape scale, drainage water must be retained for at least one to two weeks within wetlands before being discharged into streams. Monitoring of restored wetlands indicates that the longer the retention time, the greater the water quality benefits. . . Ultimately, the appropriate size of a restored wetland will depend on the contaminant of greatest local concern that requires the longest retention time for its degradation, and on the percent reduction of this contaminant that is required seasonally, annually, or interannually (van der Valk and Jolly 1992). (Woltemade 2000).

6.8.5 Water Quantity

No studies were found that discussed the ability of created or restored wetlands to perform water quantity functions, such as decreasing downstream erosion or reducing peak flows, or that mentioned factors influencing a wetland's ability to perform water quantity functions.

Two studies compared the water regime of compensatory mitigation wetlands with reference wetlands. Both found that the compensatory wetlands had more standing water for a longer period (Shaffer et al. 1999, Cole and Brooks 2000).

6.8.5.1 Using Hydrogeomorphic (HGM) Classification to Study Water Regime at Mitigation Sites

Differences in the water regime between existing wetlands and mitigation wetlands have been examined by several researchers in the Pacific Northwest and elsewhere. The researchers used the hydrogeomorphic (HGM) classification to compare the water regimes of existing wetlands with those of mitigation wetlands. As described in Chapter 2, the HGM classification is based on the position of the wetland in the landscape (geomorphic setting), the wetland's water source, and the flow and fluctuation of the water once in the wetland. These are some of the major environmental factors that control wetland functions (National Research Council 1995).

Gwin et al. (1999) focused on HGM classifications of wetlands to determine how compensatory mitigation was affecting the wetland resource in and around Portland, Oregon. Classification of reference wetlands resulted in three regional HGM classes that were typical in the Portland metropolitan area: slope, riverine, and depressional. However, classification of mitigation wetlands

required development of new, atypical HGM classes to describe the unique combinations of site morphology and landscape setting found in these wetlands:

- *depression-in-riverine setting,*
- *in-stream-depression, and*
- *depression-in-slope setting* (Gwin et al. 1999).

Atypical refers to created or enhanced wetlands that do not match the geomorphic setting, water source, and/or hydroperiod found within the range of existing wetlands in a region. Gwin et al. (1999) characterized atypical classes by:

- Exaggerated depressional morphology with steep banks
- Large areas of open and/or deep water
- A large berm isolating the wetland from an adjacent stream channel
- Excavation within the stream channel producing an open water area wider and deeper than the original stream

In Washington 35% of compensatory mitigation projects resulted in wetlands of an atypical HGM class (Johnson et al. 2002). In Portland, Gwin et al. (1999) found that almost all of the enhanced wetlands and nearly half of the created wetlands resulted in an atypical HGM class.

What are the hydrologic consequences of creating atypical wetlands in the landscape? Shaffer et al. (1999) examined hydrologic conditions in reference and mitigation wetlands in the Portland metropolitan area. The study compared the regional HGM classes identified by Gwin et al. (1999)—slope, riverine, and depressional—with the atypical classes for mitigation wetlands—depression-in-riverine setting, depression-in-slope setting, and in-stream-depression. The results indicated significant differences. For example, slope wetlands had the lowest extent, depth, and duration of inundation, “while depression-in-slope wetlands had the highest water levels and greatest extent/duration of inundation” (Shaffer et al. 1999).

Similarly, Cole and Brooks (2000) noted that created wetlands were dominated by open water, while “most naturally occurring mainstem floodplain wetlands in central Pennsylvania are vegetated with very little open water.” The authors concluded, “in the rush to make sure there is some water in mitigation wetlands we have gone too far in keeping sites inundated. In reality, many wetlands are merely saturated, or much drier” (Cole and Brooks 2000).

Schaffer et al. (1999) state:

Unless wetlands are restored or created in a manner that reproduces the hydrogeomorphic characteristics of naturally occurring wetlands in a region, management activities are unlikely to maintain or replace hydrologic and other valued functions of wetlands.

Similarly, Cole and Brooks (2000) conclude:

The ecological consequences of a different hydrologic regime are clear. Standing water will promote anaerobic conditions in the soil, and the resulting soil chemistry will be defined by anaerobic pathways (Mitsch and Gosselink 1993). When combined with other common construction effects (e.g. soil compaction), this leads to difficult conditions for plant community establishment.

In addition, water regimes exhibiting extensive areas of open water in mitigation wetlands hindered the formation of soil organic matter (Shaffer and Ernst 1999).

6.8.6 Summary of Key Points

- Functions performed and characteristics produced by created, restored and enhanced wetlands differed from those performed and produced by reference wetlands, except water quality functions, which appeared to be performed in a similar capacity.

- Most studies determined that reference wetlands provided habitat for a greater diversity or abundance of wildlife than created or restored wetlands. Birds were an exception since half of the studies found no difference between created/restored sites and reference wetlands, particularly for ducks.
- A variety of factors appeared to influence the abundance and diversity of wildlife at created or restored wetlands: development of vegetation communities, particularly emergent vegetation communities; age of the wetlands, which is often associated with the development of vegetation communities; and availability of a food source, often invertebrates, which is also often associated with the development of vegetation communities.
- Amphibian communities were affected by additional factors, such as the hydroperiod of the wetland, the presence of fish, distance to other wetlands, connectivity between terrestrial and wetland habitats, and surrounding land uses.
- Created and restored wetlands have different vegetation characteristics and plant communities than reference wetlands. A few studies found that certain plant communities, such as sedge meadows, may require many years to develop, if they develop at all.
- Compensatory mitigation is producing more acreage of open water wetlands than was lost. The ability of compensatory mitigation to produce other Cowardin classes varied.
- Several major factors were found to affect vegetation and plant communities, including the age of the wetland (older created/restored sites had a higher percent cover of emergent and woody species than younger sites); soil conditions (positive effects on vegetation resulted from adding hydric topsoil); competition (reed canarygrass can be problematic when attempting to establish emergent vegetation); and a source of native seeds or plants (this may speed up recolonization and increase diversity).
- Created, restored, and enhanced wetlands had less organic matter than reference wetlands. In addition, organic matter at compensation wetlands did not appear to accumulate over time. Plant establishment at compensation sites could be hindered by the low organic content in conjunction with soils that were found to be sandier, more compacted, and lower in nitrogen than soils at reference wetlands.
- Created and restored wetlands were comparable to reference wetlands at retaining sediments, phosphorus, and nitrogen. Factors affecting sediment and nutrient retention included the volume of water flowing into the wetland, the length of time water remains in the wetland, and the size of the wetland compared to the size of the basin.
- Some compensatory mitigation wetlands produced different HGM classes than were present in reference wetlands. This has resulted in wetlands that have more inundation for a longer duration than reference wetlands.

6.9 Reproducibility of Particular Wetland Types

This section discusses findings from the literature regarding the ability to restore, create, or enhance certain wetland types, such as bogs and fens, vernal pools, alkali wetlands, and mature forested wetlands.

6.9.1 Bogs and Fens

Bogs and fens are characterized by their highly organic soils, water regimes, and water chemistries. There were no studies of bog or fen restoration conducted in the Pacific Northwest. However, studies of bog and fen restoration in Northern Europe and Canada concluded that restoration may not be possible due to “irreversible changes of the biotic and abiotic properties” (Schouwenaars 1995, Schrautzer et al. 1996). This includes soil compaction and eutrophication (Grootjans and van Diggelen 1995, Schrautzer et al. 1996, Wind-Mulder and Vitt 2000) and other alterations to bogs resulting from drainage, peat harvesting, pollution, and agricultural practices (National Research Council 2001).

The studies mentioned difficulties in restoring bog vegetation communities (Bolscher 1995, Grosvernier et al. 1995, Schouwenaars 1995, Schrautzer et al. 1996), water regime (Grootjans and van Diggelen 1995, Schouwenaars 1995), and/or water chemistry (Wind-Mulder and Vitt 2000). Major conclusions include the following:

- Restore the water regime and the vegetation community will follow (Grootjans and van Diggelen 1995, Grosvernier et al. 1995).
- Prior to any restoration activity, the chemical state of the bog must be assessed. This influences the vegetation community and will, therefore, dictate the development of a restoration plan (Wind-Mulder and Vitt 2000).
- “Hydrological research may be crucial for a correct assessment of perspectives for rewetting” (Schouwenaars 1995). Prior to restoration it is necessary to determine the reason for a low water table because this affects the activities that will be required to restore a suitable water regime for the desired vegetation communities (Schouwenaars 1995).
- Bogs that were restored by rewetting and tree removal “differed from those of natural raised bogs, particularly in having taller and denser vegetation, a smaller range of moisture gradient and a more uniform vegetation physiognomy. Rewetted bogs did not have an undulating surface relief of hummocks and hollows” (Bolscher 1995).
- The best chance for restoration lies with restoring the least disturbed or damaged bogs or fens (Grootjans and van Diggelen 1995, Schrautzer et al. 1996).
- Restoration of bogs or fens will not yield rapid results (Grootjans and van Diggelen 1995).

- “Research has demonstrated that natural recovery of the moss surface following harvesting takes about 20 years (Elling and Knighton 1984)” (National Research Council 2001).

In terms of creation, research indicates that in reference systems organic soil (peat) accumulates at 0.1 to 3.8 mm per year (National Research Council 2001). At this rate it would take from 7 to 250 years for just 1 inch of peat to accumulate.

No information was available on the success or compliance of bogs or fens that were restored or created as wetland compensation. However, the literature suggests that bogs and fens cannot be reproduced within a regulatory timeframe.

6.9.2 Vernal Pools

Vernal pools are characterized by their short duration of inundation (National Research Council 2001). Thus, in order to reproduce a vernal pool, a site with a suitable substrate must be found and the correct depth and hydroperiod must be created or restored (National Research Council 2001). “In a long-term study of California vernal pools that were created by excavating depressions near natural pools, the hydroperiods did not converge with those of the reference systems until year 10 (Zedler et al. 1993)” (National Research Council 2001). If the hydroperiod is too long, the result will be an emergent marsh or an open water or aquatic bed system. If the site has inadequate substrate or is too shallow, the result may be upland with no inundation.

In terms of compliance, De Weese (1998) examined over 1,500 created vernal pools in California. She found that 83% of projects were in permit compliance, 96% met their hydrologic performance standards for depth of inundation, and 69% met vegetation performance standards. Seventy-two percent of projects were compared with reference vernal pools to determine their biological viability, while 35% of projects required some site remediation.

Guidance on construction has helped to transform the steep-sided “bathtubs” into pools that more closely mimic reference pools with gradual, vegetated slopes (De Weese 1998). De Weese (1998) concluded, “The art and science of constructing vernal pools have greatly improved over the past eight years [1987 to 1994].”

The literature suggests that, in California, vernal pools may be reproduced under the right conditions. However, the right conditions typically occur where vernal pools already exist, so creation of new pools merely increases the density of pools in an area (National Research Council 2001).

No information was found on the reproducibility of vernal pools in Washington.

6.9.3 Alkali Wetlands

No information was found that addressed the reproducibility of alkali wetlands.

6.9.4 Mature Forested Wetlands

Though studies have found that forested wetlands can be reproduced in Washington (Celedonia 2002, Johnson et al. 2002), *mature* forested wetlands have not been successfully reproduced simply because of the time necessary for the trees and the structural characteristics of the forest to mature (National Research Council 2001). Enhanced and created sites that have been planted often have a high density of stems to rapidly provide woody cover and shade out invasive species in the understory (Celedonia 2002, National Research Council 2001). Within a regulatory time-frame, compensatory mitigation wetlands may not begin to reproduce some of the attributes of mature forested reference wetlands unless these sites are thinned (National Research Council 2001).

6.9.5 Summary of Key Points

- The reproducibility of some wetland types is generally dependent upon time. For example, bogs, fens, and mature forested wetlands require several decades at a minimum, and possibly centuries, to develop the structural, chemical, biological, and hydrological attributes that characterize these wetland types.
- Studies suggest that vernal pools, at least in California, may be reproducible under the right conditions.

6.10 Suggestions from the Literature for Improving Compensatory Mitigation

A number of reports and articles suggested or recommended changes that could be made to help improve the effectiveness of compensatory wetland mitigation or alleviate problems that were frequently encountered. The recommendations described below are those of the authors of the literature sources cited, not the agencies or staff who have synthesized the information in this volume.

Data from a variety of sources are summarized throughout this section in a series of tables. To simplify the tables and efficiently use space, each literature source listed in the tables is represented by a reference number listed in Table 6-10. This is not a comprehensive list of all references cited in this section; see the references section at the end of Volume 1 for a complete list of literature sources.

Table 6-10. Literature sources and corresponding reference numbers.

Reference No.	Literature Source	Reference No.	Literature Source
1	Allen and Feddema (1996)	19	Shaich and Franklin (1995)
2	Balzano et al. (2002)	20	Storm and Stellini (1994)
3	Brown (1999)	21	Ossinger (1999)
4	Ashworth (1997)	22	Wilson and Mitsch (1996)
5	Erwin (1991)	23	Barry et al. (1996)
6	Gwin and Kentula (1990)	24	Castelle et al. (1992a)
7	Holland and Kentula (1992)	25	Celedonia (2002)
8	Holland and Bossert (1994)	26	Chovanec (1994)
9	Johnson et al. (2000)	27	Hunt et al. (1999)
10	Johnson et al. (2002)	28	Kentula (2000)
11	Stauffer and Brooks (1997)	29	National Research Council (2001)
12	Kentula et al. (1992)	30	Race and Fonseca (1996)
13	Kunz et al. (1988)	31	Sheldon and Dole (1992)
14	Shaffer and Ernst (1999)	32	Whittecarr and Daniels (1999)
15	Michigan Department of Environmental Quality (2000)	33	Zedler and Callaway (2000)
16	Mockler et al. (1998)	34	Mitsch and Wilson (1996)
17	Morgan and Roberts (1999)	35	Breaux and Serefiddin (1999)
18	Robb (2002)	36	Kellogg and Bridgham (2002)

The scientific literature contained recommendations that fall into three main categories:

- Recommendations for regulators of compensatory mitigation, including guidance on mitigation plans and monitoring reports, compliance tracking and enforcement, and alternative mitigation options
- Recommendations for site selection and design, including comprehensive wetland planning, baseline monitoring, hydrologic analysis, and considerations for site design
- Recommendations for implementing compensatory mitigation, including having a wetland biologist on-site to oversee construction activities, performing monitoring and maintenance of the site

The scientific literature provided more extensive information on additional topics:

- Performance standards
- Compensatory mitigation using a watershed approach
- Mitigation banking and in-lieu fees

Each of these is discussed below.

6.10.1 Regulatory Improvements

Of the suggestions provided by the scientific literature, the majority focused on elements that regulatory agencies should address (Table 6-11), such as:

- Improving guidance for every step of the mitigation process, from avoidance and minimization to submitting a monitoring report for a compensation wetland. This should help regulators with decision-making and provide applicants and consultants with more predictability
- Adjusting replacement ratios to reflect the risk of failure
- Requiring financial assurances or performance bonding
- Protecting all compensatory mitigation sites in perpetuity with a legal mechanism, such as a deed restriction or conservation easement
- Increasing regulatory follow-up and enforcement of compensatory mitigation projects, including developing and maintaining a database and filing system, allocating staff to perform compliance and enforcement activities, and implementing reviews of regulatory program performance
- Developing and implementing alternative mitigation options, such as advance mitigation, mitigation banking, and in-lieu fees

Table 6-11. Suggestions from the literature for regulatory improvement.

Suggestion	Reference No. ^a
Improve mitigation sequencing (i.e., avoidance and minimization)	5, 19, 29, 2, 10
Improve guidance for compensation projects, focusing on replacing functions as well as area	22, 29, 10
Improve site selection criteria. Site selection should be based on a watershed scale to maintain diversity, connectivity, and a balance of upland and wetland	5, 12, 15, 29, 2, 10
Improve goals, objectives, and performance standards, so that they are measurable, meaningful, achievable, and enforceable	13, 5, 31, 20, 19, 17, 9, 29, 10, 21
Standardize report format and elements for mitigation plans and monitoring reports, including an implementation schedule	13, 7, 8, 20, 17, 15, 2, 10

Suggestion	Reference No. ^a
Adjust (increase) replacement ratios to reflect the risk of failure. This should be based on the level of success of previous projects	1, 2, 18
Require performance bonding/financial assurances	13, 5, 8, 20, 15, 29, 2, 18
Require that compensation wetlands be protected in perpetuity with some kind of legal mechanism, such as a deed restriction or conservation easement	20, 29
Improve regulatory follow-up and enforcement of compensatory mitigation projects	5, 20, 19, 1, 30, 17, 15, 9, 29, 10, 18
Develop and maintain a permit/compensatory mitigation project tracking database and filing system	5, 7, 20, 19, 1, 17, 9, 15, 29, 2
Allocate staff for compliance and enforcement	5, 19, 17
Implement regular reviews of regulatory program performance	7, 19, 2
Implement studies of cumulative wetland loss (beyond what is recorded for regulatory permitting programs)	19, 1
Develop and implement alternative compensatory mitigation options: in-lieu fees, mitigation banking	20, 19, 1, 15, 29
Perform the compensatory mitigation in advance of the wetland loss	30, 29, 10, 18
^a See Table 6-10 for a listing of literature sources that correspond to each reference number.	

6.10.2 Improving Site Selection and Design

The scientific literature also suggested site selection and design considerations (Table 6-12), including:

- Using a watershed approach to improve site selection
- Prioritizing wetland restoration
- Performing baseline monitoring of the wetland to be lost, identifying the wetland types and functions so that they can be replaced more effectively
- Performing baseline monitoring of the areas proposed for compensation to document the existing conditions and level of function
- Performing a hydrologic analysis for compensation wetlands to identify where the water will come from, how it will get to the site, and what the extent and duration of inundation or saturation will be
- Designing the compensation site to be self-sustaining and incorporating or simulating natural processes and structures, such as hydroperiods, slopes, shorelines, soils, topography, and vegetation

Table 6-12. Suggestions from the literature for improving site selection and design.

Suggestions	Reference No.^a
Ensure that compensation wetlands will have a suitable source of water and compatible adjacent land uses	5, 28, 17, 29, 2, 10
Use a watershed approach to select compensation sites and support comprehensive wetland planning	19, 1, 28, 17, 29, 10
Prioritize restoration as the first choice for compensatory mitigation	17, 15, 29
Design compensatory mitigation wetlands to be self-sustaining and incorporate natural processes whenever possible	33, 29
Perform baseline monitoring of wetlands to be lost and areas proposed for compensatory wetland mitigation. Monitoring should characterize hydroperiod, soils, water quality, macroinvertebrates, and wetland functions	13, 5, 31, 20, 29, 10
Perform hydrologic analysis: identify hydrologic source, how water will get to the site, the intended depth and duration of inundation, and demonstrate that water source will be reliable and adequate Determine appropriate hydroperiod/hydrologic inputs early in the design stage, so that the water levels of the compensation wetland dictate how to design the building sites and roads, rather than letting the upland development create poor wetland conditions (too wet or too dry)	5, 31, 16, 28, 2
Grade slopes to be as gentle as possible; they should match the slopes of adjacent natural wetlands	6
Provide heterogeneous topography. For example, simulate microtopographic “mound and pool” features (e.g., wind-thrown or toppled trees)	23, 29
Incorporate native upland ecosystems into compensatory mitigation sites	5, 29
Deconsolidate (i.e., break-up) soils to reduce compaction and amend to insure adequate soil organic matter (e.g., 2 inches of coarse sand and 4 inches organic compost, natural hydric muck, or topsoil)	6, 16, 28, 32, 14
Take advantage of native seedbanks, natural recruitment, and salvaged topsoil and plants when available and feasible	29, 3, 4, 11
Minimize human encroachment by planting dense vegetation around the site or installing fences	26, 20, 16
Establish rapid canopy convergence and limit invasive species infestations by planting trees and shrubs at specific densities	25
Indicate the boundaries of the site with signs and markers	20, 16
^a See Table 6-10 for a listing of literature sources that correspond to each reference number.	

6.10.3 Improving Implementation

Compensatory wetland mitigation projects would be greatly improved if they were implemented as designed (Johnson et al. 2000, Balzano et al. 2002). The scientific literature provides numerous suggestions for improving implementation (Table 6-13), such as:

- Having a wetland biologist on-site during construction
- Monitoring the compensation wetland
- Develop an adaptive management plan that allows potential problems to be detected early and identifies how problems will be addressed
- Maintaining the compensation wetland to avoid problems and manage them early in the development of the site

Table 6-13. Suggestions from the literature for improving implementation.

Suggestion	Reference No. ^a
Wetland biologist on-site to oversee construction or train/educate contractors and to authorize and document any necessary changes	5, 31, 9, 2
Monitoring of mitigation sites should characterize baseline, construction, as-built, and post-construction conditions. Monitoring reports should include a section on lessons learned	13, 6, 5, 24, 7, 31, 8, 20, 19, 15, 9, 2, 10
Monitoring parameters and methods should be specific to a project's goals, objectives, and should include: project size, shape, topography, hydroperiod, water quality, flora, and fauna	5, 17, 33
Monitor compensatory mitigation wetlands. Duration of monitoring may range from 3 to more than 20 years, depending on the size of compensation wetland, the proposed wetland type (e.g., Cowardin class), and the likelihood of success	5, 34, 35, 17, 15, 10, 29, 36
Monitor hydrology during the first growing season to characterize the site's hydroperiod. Develop and implement a planting plan after the hydroperiod has been characterized	27
Perform long-term monitoring after a project has been deemed successful to keep track of it over time, study how it matures, use it as model for other sites	5, 28, 36
Develop an adaptive management program, which includes early monitoring of wetland structure, processes, and functions to detect potential problems and allow for corrective actions	29
Maintain compensatory mitigation sites, including a contingency plan for how to address problems. Maintenance should focus on controlling invasive species, providing irrigation, replacing dead plants, correcting slopes and topography	13, 24, 31, 8, 2, 10, 29
^a See Table 6-10 for a listing of literature sources that correspond to each reference number.	

6.10.4 Performance Standards

Performance standards, performance criteria, success criteria, success measures, standards of success, and other terms all refer to regulatory conditions used to determine how effective a mitigation project is at meeting regulatory requirements, which may or may not include compensating for wetland loss. Ideally performance standards should serve as “measurable benchmarks used to evaluate the development of ecological characteristics associated with specific wetland functions” (Azous et al. 1998). Performance standards allow regulators to determine if a compensatory mitigation project has fulfilled its goals, and also provide a mechanism for regulators to implement enforcement actions against unsuccessful projects (Streever 1999).

As explained in Chapter 2, wetlands differ in how they function, by geomorphology and water regime and other characteristics. Compensatory wetland mitigation projects, likewise, exhibit considerable variability with different types of wetland compensation (creation, restoration, etc.). The variability makes it difficult to develop and require universal performance standards, yet in the absence of some kind of uniformity, performance standards that are approved can lack meaning.

6.10.4.1 Shortcomings of Existing Performance Standards

Sheldon and Dole (1992) performed a study of eight compensatory mitigation projects in King and Snohomish Counties in Washington. The authors observed that “none of the goal statements provided a quantifiable method of determining success, thus they provided no means for an agency to assess success/failure or to require remediation.” The Michigan Department of Environmental Quality (2000) similarly found, “The practice of including no specific performance standards, or only very general performance standards (regarding the size and possibly the type of wetland to be constructed), resulted in many unenforceable permits and contributed to the poor quality mitigation wetlands.”

Johnson et al. (2000), in their study of 45 compensatory mitigation wetlands, noted some problems with performance standards, such as:

- Standards that are too general or “easy to attain” and, therefore, are not indicative of ecological development at a site
- Standards that are not measurable and, therefore, cannot be used to evaluate the success or compliance of projects
- Standards that contain confusing or ambiguous language and, therefore, result in inaccurate assessment or preclude assessment

In addition, Johnson et al. (2002) in their evaluation of 24 compensation projects excluded performance standards that were unrealistic, not feasible, or so rigorous that the standard may never be attained. Such standards were “. . . setting sites up for failure” and therefore “. . . did not reflect how the site was functioning or progressing ecologically”

(Johnson et al. 2002). Ossinger (1999), in a guidance document for the Washington State Department of Transportation, suggests that performance standards should strike a balance between accountability and flexibility. The author recommends that crafting performance standards requires a technical knowledge of the quantitative values that are achievable, or to be expected, for the wetland attributes targeted by the standard.

Approved mitigation projects can also lack performance standards for important wetland functions or conditions. Breaux and Serefiddin (1999) discovered in their review of 110 projects in San Francisco, California, that only 22% had quantitative standards focusing on hydrological parameters. Johnson et al. (2000) reviewed 179 performance standards from 36 projects and observed that 8% of the performance standards related to hydrological conditions. The Michigan Department of Environmental Quality (2000) found that “none of the permits examined contained any specific criteria regarding vegetation or hydrology by which the mitigation wetland could be judged for success or failure.” Johnson et al. (2002) noted that most of the projects evaluated in their study of 24 compensation wetlands lacked basic standards for wetland area, water regime, area of Cowardin classes, percent cover of native wetland vegetation, and maximum percent cover of invasive vegetation.

Breaux and Serefiddin (1999) argue, “In seasonal wetlands, hydrology clearly ought to be the reigning criterion given that the successive presence and absence of water is the defining characteristic of a seasonal wetland.” However, the authors go on to admit, “there is no agreement as to what the specific hydrological criterion should be.”

6.10.4.2 Use of Reference Wetlands in Developing Performance Standards

Brinson and Rheinhardt (1996) state that “the proper use of reference wetlands removes potential bias and provides the foundation for more objective functional-assessment procedures...reference wetlands should be central to the development of standards against which impacts to wetlands and restoration efforts are evaluated.”

Azous et al. (1998) also support the use of reference wetlands:

By collecting data on the ecological characteristics associated with reference wetlands, and created or restored wetlands, standards of comparison can be established by which to judge the development of wetland characteristics in compensatory mitigation projects. The use of regional reference wetland characteristics provide greater assurance that project performance standards will be reasonable (i.e., attainable) and useful gauges of the development of wetland functions.

For example, a compensation wetland might have a goal to provide amphibian habitat by the end of the monitoring period. Based on an evaluation of 24 depressional, flow-through, reference wetlands in the Puget Lowlands of western Washington, Azous et al. (1998) proposed performance standards to determine if amphibian habitat had successfully been established. “The standards include specific guidelines for planning

and designing mitigation projects to provide preference for the establishment of amphibian breeding, feeding, and refuge habitats.” The authors suggested the following standard, “Wetlands created for amphibian habitat should have thin-stemmed emergent plants that comprise at least 30% or more of the total wetland area (Azous et al. 1998).”

However, Whittecar and Daniels (1999) mention a problem with using reference wetlands to develop benchmarks or performance standards for compensatory mitigation:

[U]nlike the mitigation site, reference wetlands coexist with landforms that may have required thousands of years to form (Brinson et al. 1995). Each wetland has a history that influences modern functions. Many of these functions will not redevelop in the new wetland within a time span acceptable to regulatory constraints without thoughtful planning and careful attention to construction.

Ehrenfeld (2000) recommends that reference sites be identified in urban areas and used to develop attainable performance standards for compensatory wetland mitigation projects that are also located in urban areas. The author states: “Measures of restoration success and functional performance must start with an appreciation and assessment of the particular conditions imposed by the urban environment.”

6.10.4.3 Longer Period Needed to Evaluate Projects

Part of the problem with developing achievable performance standards is that monitoring periods or regulatory timeframes for the majority of compensatory mitigation projects are relatively short (five to 10 years). The “success” or compliance of compensatory mitigation projects is, therefore, determined or evaluated when the site is still relatively young and immature (Kentula 1995, Mitsch and Wilson 1996). Longer monitoring periods are necessary to allow for secondary succession and natural events (e.g., drought or floods) that may affect or restructure vegetation communities (Kellogg and Bridgham 2002). Long term monitoring would also result in larger data sets upon which realistic performance standards and project goals could be based (Kellogg and Bridgham 2002).

If projects are to be evaluated within five to 20 years, then they should be compared to other compensatory mitigation projects. Kentula (1995) suggests comparing “wetland creation and restoration projects to each other and to similar, naturally occurring wetlands to define standards for project performance over time.” She describes an approach for developing performance standards based on monitoring information from previous projects. “In this way, we can be assured that new projects are doing at least as well as past projects.”

Celedonia (2002) implemented Kentula’s approach by conducting a study of 29 compensatory mitigation projects from six to 11 years old in the lowland wetlands of western Washington. Time series curves were created from the data to determine at what point in time projects could be expected to meet certain vegetative standards, such as percent areal cover of woody vegetation. Based on the data, the author proposed that by year eight a mitigation site could attain 80% cover of native woody vegetation.

6.10.5 Compensatory Mitigation Using a Watershed/Landscape Approach

In the context of compensatory mitigation, a watershed approach means:

to recognize that management of wetland types, functions, and locations requires structured consideration of watershed needs and how wetland types and location serve these needs. A watershed approach means that mitigation decisions are made with a regional perspective, involve multiple agencies, citizens, scientists, and nonprofit organizations, and draw upon multiple funding sources (e.g., permittee-responsible, mitigation banks, and in-lieu fees). A watershed approach means that permitting decisions are integrated with other regulatory programs (e.g., storm water management or habitat conservation) and nonregulatory programs (e.g., conservation easement programs) (National Research Council 2001).

Bedford (1996) explained the need for a watershed/landscape approach as follows:

From a policy perspective, the central issue in wetland mitigation is not the effects on a single site but the cumulative effect of numerous mitigation decisions on landscapes. Mitigation must be recognized as a policy that has the potential to re-configure the kinds and spatial distribution of wetland ecosystems over large geographic areas. ... The net effect is the loss of wetland diversity in terms of both hydrologic functions and biological communities, and a consequent homogenization of wetland landscapes. One way to avoid such cumulative effects is to make decisions about individual projects within a framework focused at larger scales (Lee and Gosselink 1988).

This section describes recommendations from the literature for methods to implement a landscape or watershed-scale approach in order to improve the success of mitigation projects. Further discussion of restoration using a landscape approach is included in Chapter 7 in the context of addressing cumulative impacts to wetlands.

6.10.5.1 Methods for Implementing a Landscape Approach

Three types of watershed planning are described in a report by the National Research Council (2001):

- **Management-oriented** wetland planning, which would replace case-by-case permitting. Decisions about permitting, mitigation sequencing, and the acreage, type, and location of compensation would be made in advance using a watershed approach. This type of watershed plan would require regulatory and non-regulatory programs to be coordinated.

- **Protection-oriented** wetland planning, which is focused on avoiding wetland loss and alteration by identifying wetlands and their ecological value. This type of watershed plan would be used during the mitigation sequencing process.
- **Compensation** wetland planning, which “identifies watershed needs for types, functions, and general locations of wetlands in the landscape in order to establish restoration priorities for both regulatory and nonregulatory programs. . . . This type of planning might link projects undertaken through both regulatory and nonregulatory programs to secure some desired mosaic of wetlands in the landscape.”

Hashisaki (1996) discusses the utility of a landscape-level analysis to examine conditions not just at an impact, compensation, or reference site, but also in the surrounding landscape. A landscape-level analysis “considers the effect of historic, current, and proposed land management practices on the individual functional indicators. . . . In addition to identifying constraints on land management practices, it can be useful in identifying critical preservation and restoration opportunities. Understanding the control that human activities exert on the disturbance regimes of an ecosystem allows projections about expected future conditions.”

Bedford (1996) recommends developing wetland profiles/templates based on the diversity of wetland types that exist in a region as a result of the unique interaction of hydrogeology and climate. By understanding the current and historic wetland types and their relative abundances in a region, decisions regarding compensatory mitigation can be made to help maintain the diversity and hydrologic equivalence.

In some cases, using a watershed approach may result in a watershed plan that identifies all the wetlands in an area and assesses the functions that they perform. Hraby and Scuderi (1995) used this approach for a watershed near Seattle, Washington, that was experiencing development pressure. The goal of the plan was “to ensure that the performance of wetland functions and their societal values continue to be equal to or greater than those currently existing...” (Hraby and Scuderi 1995). Wetland areas targeted for restoration or enhancement were assessed to quantify how much wetland function could be gained. The proposed/potential gain in function through restoration/enhancement could then be used to determine how much wetland function could be lost to development activities in the watershed.

A report by the National Research Council (2001) proposed that “Functional tradeoffs might be considered in the context of the needs of the watershed.” A watershed plan would be developed for an area, such that the functions of wetlands proposed for loss or alteration are understood, as well as the needs of the watershed for wetland functions. Functions that are abundant or a low priority in a watershed could be lost and replaced by other functions that are limited or a higher priority in the watershed.

Race and Fonseca (1996) point out that on a national level, a landscape approach to land use and compensation would require the cooperation/participation of thousands or millions of private landowners:

Taking a large-scale, ecosystem approach to wetlands management is a significant change in natural resource management policies, one representing a major paradigm shift that will require radical revision in values, management practices, and institutional structures in order to succeed (Cortner and Moote 1994). ...Thus, integrating ecologically relevant concepts such as landscape-scale decision criteria need more than good science; it will also require conscious redesign of the entire permitting infrastructure to avoid legal challenges.

6.10.6 Mitigation Banking

Compensatory mitigation banking and other third-party compensation approaches (in-lieu fee, market-based mitigation) are believed by some to provide part of a solution and have offered new hope for successful compensation of wetland impacts (Kukoy and Canter 1995).

Currently, even when wetlands have been avoided or established as compensation they often “have diminished ecological functions from polluted runoff, from changes in hydrologic regimes, and from the fragmentation of the landscape which isolates the wetlands from the surrounding uplands, water, and biological resources of the watershed” (Shabman et al. 1993).

In addition, some federal, state, and local permits for wetland loss do not require compensatory mitigation because the individual impact is so small that compensation is considered impractical, despite the fact that cumulative losses are occurring (Shabman et al. 1993, Kukoy and Canter 1995, Weems and Canter 1995). Finally, even when compensatory mitigation is required there is no guarantee that it will be implemented or successful.

Shabman et al. (1993) outlined a market solution to improve compensatory wetland mitigation. Market-based mitigation approaches start with an entrepreneurial restoration firm seeking to make a profit from selling a product—a wetland ecosystem. If the product is not of a particular quality then it will not sell. For example, if the wetland bank is not in compliance, not meeting its performance standards, or not providing the proposed functions then the regulatory agencies will not accept credits from the bank as compensation for wetland losses. The permit applicant, therefore, will not purchase the “product” of the wetland bank. This is the incentive for the restoration firm to establish a functioning wetland ecosystem.

In addition, a restoration firm can take the time to find a suitable location for the wetland that will minimize problems with fragmentation (Kukoy and Canter 1995). Wetland banks can also secure large sites for restoration that would not be feasible on a small project scale (Weems and Canter 1995).

Once the wetland is established, credits or tradable portions of the wetland can be made available for purchase to compensate for wetland losses (Weems and Canter 1995), even wetland losses that were previously too small to require compensation (Kukoy and Canter 1995). It is assumed that the availability of bank credits for compensation can also provide efficient permitting since the applicant would not have to worry about getting a mitigation plan approved, and regulators could more readily assess the effectiveness of the compensation.

Mitigation banking in Washington State has been more thoroughly discussed in the *Draft Programmatic Environmental Impact Statement: Washington State's Draft Rule on Wetland Mitigation Banking* (Driscoll and Granger 2001, available at: <http://www.ecy.wa.gov/biblio/0106022.html>). For additional information on mitigation banking and in-lieu fee programs refer to *Banks and Fees: The Status of Off-Site Wetland Mitigation in the United States* (Environmental Law Institute 2002).

6.10.7 Summary of Key Points

- The scientific literature provided suggestions for improving virtually every aspect of the mitigation process from regulatory guidance and policies to specifications for controlling invasive vegetation.
- Suggestions included measurable, meaningful, achievable, and enforceable performance standards; better sites that provide increased benefits due to their location within a watershed; better monitoring of compensatory mitigation wetlands; and measures to increase regulatory follow-up of compensation projects.

6.11 Chapter Summary and Conclusions

Wetland compensatory mitigation has been studied in Washington and elsewhere in the United States for the past 15 years. Considerable data are available to evaluate the effectiveness of compensatory mitigation.

The majority of compensatory wetland mitigation projects described in the literature was neither fully successful nor completely unsuccessful. Most projects were found to have an intermediate level of success. While most compensatory mitigation projects were installed, compliance of the projects with permit requirements was generally low. The authors of Volume 1 hypothesized that this was due to shortfalls of wetland acreage, failure to achieve performance standards, and a lack of monitoring and maintenance. The few studies that examined the effect of regulatory follow-up suggested that it had a positive influence on the level of compliance and success for compensatory wetland mitigation projects.

There is a general lack of information about the relative effectiveness of the various types of compensation (e.g., restoration, creation, enhancement, etc.). Creation is generally the most frequently used type of compensation, but studies of its effectiveness produced

mixed results. Enhancement of wetlands was also frequently used, but few studies examined its effectiveness. Limited studies from Washington indicated a low level of success among enhanced wetlands, primarily due to a minimal gain in functions. Restoring wetlands was noted as a high priority, but as a type of compensation it is not frequently used.

Preservation and a mixture of compensation types appear to be used occasionally. Studies provided limited information on the effectiveness of these types. Two studies from Washington indicated that mixed compensation projects had a higher level of compliance than creation or enhancement, and all mixed projects were moderately successful. The lack of data regarding the effectiveness of preservation is problematic since one of the only studies to look at its effectiveness determined that one large site was predominantly upland habitat. On the other hand, if a site can be confirmed as wetland, or if a mosaic of wetland and upland is determined to be acceptable, preservation of existing wetlands offers no risk of failure and no temporal loss of wetland functions, which are inherent in the other types of compensation. Preservation does, however, result in a net loss of wetland area and possibly functions.

Replacement ratios attempt to equalize the trade-off between the wetland being lost and the wetland being provided as compensation by accounting for the risk of failure and temporal loss of functions. Required replacement ratios vary from one state to another, based on the type of compensation proposed, and based on project-specific circumstances. Replacement ratios actually achieved through compensation were less than what was required, which is to be expected since the ratios are meant to encompass a certain level of failure. However, in some cases this resulted in less than 1:1 acreage replacement.

Studies relying solely on permit files and databases indicated that permitting programs have improved over time in terms of wetland acreage required for compensation. However, studies which relied on site visits and field analyses indicated that compensatory wetland mitigation has resulted in a loss of wetland acreage.

Functions performed and characteristics produced by created and restored wetlands differed from those performed and produced by reference wetlands, except water quality functions, which appeared to be performed in a similar capacity. None of the studies compared the functions provided by compensation wetlands with the functions provided by the wetlands that were lost.

For the most part, reference wetlands provided habitat for a greater diversity or abundance of wildlife than created or restored wetlands. Birds were an exception since half of the studies found no difference between created/restored sites and reference wetlands, particularly for ducks. Created and restored wetlands have different vegetative characteristics and plant communities than reference wetlands. Certain plant communities, such as sedge meadows, may require many years to develop if at all.

The authors of Volume 1 conclude that the common finding that wetland compensation sites have greater vegetation species richness is linked to the broad range of niches created on a new site. A newly created or restored site is a “blank slate” upon which

species will be planted, species from the previous habitat on the site will re-emerge, and species adapted to disturbance will colonize. Over time the site will stabilize and mature and only the species adapted to the resulting conditions will remain. However, research on restored, created, or enhanced sites that have stabilized is currently lacking. One could infer, therefore, that sites are not studied for a long enough time, due either to the relatively short regulatory timeframe or the decades or lifetimes necessary to achieve stabilization and maturity.

Researchers observed that created, restored, and enhanced wetlands had less organic matter than reference wetlands. This could be due to the excavation of surface soil layers during project construction. Studies also indicated that organic matter at compensation wetlands did not appear to accumulate over time. Therefore, plant establishment at compensation wetlands could be hindered by low organic content in conjunction with soils that were found to be sandier, more compacted, and lower in nitrogen.

Compensatory mitigation is producing more acreage of open water wetlands than was lost. The ability of compensatory mitigation projects to produce other Cowardin classes varied. Some compensatory mitigation wetlands have produced different HGM classes than were present in the reference wetlands. This has resulted in wetlands that have more inundation for a longer period than reference systems.

Some unique types of wetlands, such as bogs, fens, and mature forested wetlands, may not be reproducible, especially not within current regulatory timeframes. Other wetland types, such as vernal pools, may be reproducible given the right conditions.

The literature provided numerous suggestions on virtually every aspect of the mitigation process. Key suggestions include:

- Improving regulatory guidance on a variety of topics, such as measurable, meaningful, achievable, and enforceable performance standards for compensatory mitigation
- Finding better sites that provide increased benefits due to their location within a watershed
- Monitoring compensatory mitigation wetlands more effectively
- Implementing measures to increase regulatory follow-up of compensation projects

The literature suggests that some improvements have been made in compensatory mitigation over the past two decades, particularly in terms of what is required. However, overall success and permit compliance have not noticeably improved. Most studies indicate that created and restored wetlands do not provide the same characteristics or level of functions as reference wetlands (water quality functions may be the exception).

Since the effectiveness of compensatory mitigation remains highly variable and somewhat questionable, it is increasingly important to understand the cumulative effects of the continuing loss of wetland acreage and functions. This will be addressed in the next chapter.

Chapter 7

Cumulative Impacts to Wetlands and the Need for a New Approach

“Evidence is increasing that the most devastating environmental effects may result, not from the direct effects of a particular action, but from the combination of individually minor effects of multiple actions over time.” (Council of Environmental Quality 1997)

7.1 Reader’s Guide to This Chapter

This chapter introduces the concept of “cumulative impacts” to represent the incremental losses and degradation of wetlands that continue in spite of all the existing regulatory and non-regulatory actions we are taking to protect them. The chapter discusses different types of cumulative impacts and the loss of wetland area as the most easily assessed measure of cumulative impacts. It goes on to present some of the causes of cumulative impacts in Washington.

The synthesis of the scientific literature in Chapters 2, 3, and 4 has clearly established that wetlands do not function in isolation from the landscape that surrounds them. A wetland’s ability to provide certain functions is influenced by the conditions and land uses within their contributing basins, especially by the patterns of water flow and movement that can be changed by different land uses. Existing wetland regulations usually are structured so decisions are made on an application by application basis. There are no provisions for assessing or considering the implications of individual decisions on the resource in general. The information presented in previous chapters demonstrates that project-by-project decisions cannot adequately address the complexities of wetland systems, and new approaches are needed to reduce the continued impacts to wetlands.

7.1.1 Chapter Contents

Major sections of this chapter and the topics they cover include:

Section 7.2, Loss of Wetlands as an Indicator of Cumulative Impacts describes the total wetland losses in Washington and three studies in the Pacific Northwest that illustrate more recent loss.

Section 7.3, Types of Cumulative Impacts describes how cumulative impacts result from disturbances related to geography and time that are not adequately managed. It lists types of cumulative impacts such as fragmentation and time lags.

Sections 7.4, Causes of Cumulative Impacts in Washington describes how the current approach to wetland management and protection results in cumulative impacts. The causes discussed include case-by-case permitting, lack of consistency between jurisdictions, and implementation of local programs for protecting wetlands through regulations. Different types of cumulative impacts are listed along with examples of possible causes from inadequate protection at the local level.

Section 7.5, Chapter Summary and Conclusions ties together the major concepts presented in the chapter.

7.1.2 Where to Find Summary Information and Conclusions

One summary is provided at the end of the chapter, along with the authors' conclusions. The reader is encouraged to remember that a review of the entire section preceding the summary is necessary for an in-depth understanding of the topic.

7.1.3 Sources and Gaps in Information

Much of the literature published on the topic of cumulative impacts is not specific to wetlands. Most of the research has been focused on environmental processes that affect biodiversity (i.e., habitat loss, fragmentation, metapopulations). The available information is weighted toward the impacts of some types of land use (urbanization and forest practices), with less information available on the impacts from other types of land use (agricultural practices, mining).

The 1997 Council of Environmental Quality report (Executive Office of the President) is a key document on cumulative impacts in general, and it provides a good summary of how land uses can cause cumulative impacts. This document is available on the internet at: <http://ceq.eh.doe.gov/nepa/ccenepa/ccenepa.htm> . This information can be applied to the protection and management of wetlands in the state.

The information available that specifically addresses wetlands is very general in nature and addresses cumulative impacts to wetlands only in terms of direct loss of wetland area, not the changes in functions that might result from changes in environmental processes at the landscape scale.

There is a significant gap in information regarding the cumulative impacts to wetlands and their functions resulting from the current approaches to managing wetlands at any level of government. The gap regarding the cumulative impacts and local protection programs is especially significant. The legal framework within Washington State (see Chapter 2 in Volume 2), delegates the decisions about land use, including comprehensive planning, designation of zoning, and regulation of critical areas, to local governments. As the information synthesized in Chapters 2-4 of this document has shown, decisions that change land uses can cause impacts to wetlands. However, little research has been conducted on the effectiveness of local efforts in effectively planning for and protecting wetlands, thereby preventing cumulative impacts. Only two studies were found that

review the effectiveness of local protection programs for wetlands, and they dealt with specific topics relating to regulations: standards for compensatory mitigation in King County and buffer requirements in the critical area ordinances of local jurisdictions in Washington in 1999 (See section 7.4.3).

Some hypotheses about the effectiveness of local programs, however, can be made by correlating the findings of the relevant literature with different aspects of the regulatory framework for wetlands used by local governments. The scientific information provides ample guidance on what is needed to protect wetland functions (e.g., planning to address and protect landscape processes, providing adequate buffers, modifying current practices of compensatory mitigation). A comparison of this information to the usual standards found in current programs can provide insights about the effectiveness of these programs. If they do not provide the range of measures for protection that are suggested by the scientific literature, it can be hypothesized that those programs may not be providing adequate protection to prevent cumulative impacts and assure long-term sustainability of wetlands.

What are Cumulative Impacts?

Cumulative impact, as defined by the Council on Environmental Quality, “is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.” <http://ceq.eh.doe.gov/nepa/regs/ceq/1508.htm#1508.1>

Cumulative impacts also have been described by Hemond and Benoit (1988) as follows: “Wetlands are frequently subject to multiple impacts over time and/or space; the effects of such multiple impacts may be simply additive, or the total effect may be more severe than the sum of the effects of the individual impacts alone. Cumulative impact as used here refers to multiple impacts whose effects on the wetland cannot be predicted by simply adding the effects of all the individual impacts.”

7.2 Loss of Wetlands as an Indicator of Cumulative Impacts

The loss of wetland area that continues to occur as a result of human activities is a general indicator that cumulative impacts are occurring. A net loss of wetland area and the functions it supports is a measure of the incremental impacts of human activities that are not adequately addressed. At the national level, wetlands continue to be lost, according to a report released by the National Research Council (1995). The U.S. Environmental Protection Agency states that although wetland loss rates are slowing, the United States continues to lose approximately 70,000 to 90,000 acres (28,300 to 36,400 ha) of wetlands on non-federal, rural lands each year (U.S. Environmental Protection Agency 2002).

Here in Washington, the state has lost an estimated 31% of its 1.35 million acres (55 million ha) of wetlands up to the 1980s (Dahl 1990). Recent data on total wetland losses in the state are not available, but three studies in the Pacific Northwest illustrate that the loss of wetlands continues:

- Bell (2002) studied sphagnum-dominated peatlands that were originally mapped by Rigg in the early 1950s in King County. Bell found a 69% loss of these wetlands since 1958. Of 26 sites, six remained relatively undisturbed. Eight showed a decline in acreage and quality of plant communities. Five wetlands are now highly disturbed with no sphagnum moss present. The remaining seven wetlands were either drained or filled. Of the 406 acres (162 ha) present in 1958, only 125 acres (50 ha) remain today. The losses were due to agricultural conversion, development, and peat mining.
- A study of recent losses of wetlands within the Willamette Valley, Oregon, found that from 1981/1982 to 1994 there was a loss of approximately 9,500 acres (3,800 ha) of wetlands, representing approximately a 2.1% loss of wetlands within the Willamette Valley study area. They found that 70% of the loss was attributable to agriculture, 6% was associated with the impacts of urbanization, and 24% was attributable to other unidentified causes (Bernert et al. 1999).
- A study conducted by Holland et al. (1995) in the greater Portland, Oregon, area found that 40% of the wetlands identified in the National Wetland Inventory of 1981/1982 were missing in 1992. They attributed most of the loss to the impacts of urbanization, yet they still attributed 31% of the losses to agricultural conversion. One conclusion of their study was that small, often isolated wetlands were lost due to decisions regarding single-project permits that did not take into account the overall pattern of wetland loss.

In addition to the direct loss of wetlands, alterations have occurred from human activities such as diking, draining, and agricultural practices (Washington State Department of Natural Resources 1998). These changes, even if apparently small on an individual basis, can have a cumulative impact on the functions of wetlands.

7.3 Types of Cumulative Impacts

Cumulative impacts result from the spatial (geographic) and temporal (time) crowding of disturbances that are not adequately managed. The impacts of a disturbance can be compounded when a second disturbance occurs at a site before the ecosystem can fully recover from the effect of the first disturbance (Council of Environmental Quality 1997). The scientific community has not yet agreed on a standard definition or method for assessing cumulative impacts because of the diversity of disturbances, the complexity of environmental processes, and the diversity of impacts possible (Council of Environmental Quality 1997). Nonetheless, the Council was able to identify eight scenarios (types of cumulative impacts) by which cumulative impacts occur (Table 7-1). These types are discussed further in Section 7.4.4 (Table 2) in relation to various causes of cumulative impacts in Washington.

Table 7-1. Types of cumulative impacts (modified from Council of Environmental Quality 1997)

Type of Cumulative Impact	Main Characteristics	Examples of Cumulative Impacts
Time crowding	Frequent and repetitive disturbances before the ecosystem has recovered from previous disturbance	Changes in the water regime that increase the depths of water and duration of flooding that, in turn, drowns vegetation not tolerant to prolonged inundation
Time lags	Impacts of disturbance are delayed from the time the disturbance occurs	Changes in water regime that causes a slow shift in the vegetation to species not suitable as sites for laying amphibian eggs
Space crowding	Impacts are occurring in close physical proximity to each other	Construction of new roads and commercial land uses on opposite sides of a wetland, resulting in increased human disturbances, such as noise, lighting, and less upland habitat
Cross-boundary	Impacts occur away from the source	Eutrophication in wetlands and lakes that results from discharges of nutrients in upper watershed
Fragmentation	Changes in the pattern of ecosystems across the landscape	Construction of a subdivision with roads interrupts the natural pathways used by animals for movement between patches of habitat
Compounding effects	Impacts arising from multiple sources or pathways	A small buffer reduces the upland habitat needed for wildlife that is closely associated with wetlands and that allows intrusion by humans and domestic pets
Indirect effects	Additional disturbances that result from changes in human activities that themselves are a result of the initial disturbance	The additional impacts that result from development after roads or other infrastructure are built. The building of a road has direct impacts but also changes human activities that cause additional ones.
Thresholds and triggers	The accumulation of disturbances causes a fundamental change in the behavior of the ecosystem	Changes in land use result in increased surface runoff that causes streams to become incised. As a result, wetlands become disconnected from the floodplain.

7.4 Causes of Cumulative Impacts in Washington

Some of the causes of cumulative impacts on wetlands stem from how wetlands are regulated in Washington State, and how local governments plan for future land use and development. Local city or county governments generally have the authority to plan for, manage, and otherwise regulate land uses within their jurisdictional boundaries, including those within and adjacent to wetlands. They may regulate what occurs directly in a wetland and, in many cases, they regulate land uses adjacent to a wetland and its buffer (see Volume 2). Federal and state agencies may regulate many direct impacts to wetlands. However, state and federal agencies do not regulate all activities that take place in wetlands and do not regulate land uses in the uplands around a wetland. They also don't provide the comprehensive planning and inter-jurisdictional coordination that affects cumulative impacts. Thus, federal and state agencies that regulate wetlands do not manage, and cannot protect, all wetlands nor many of the landscape processes that influence the functions that wetlands provide.

7.4.1 Case-by-case Permitting as a Cause of Cumulative Impacts

Wetlands in Washington are primarily managed by local jurisdictions through regulations that are implemented on a case-by-case or permit-by-permit basis. Proposed actions are often reviewed and approved without a legal authority or mechanism to assess how previous, relevant decisions may have impacted wetlands and caused cumulative impacts. Each action also is not typically reviewed in the context of impacts to associated landscape processes that may result in cumulative impacts.

On a national level, there is information on the relation between case-by-case decision-making and cumulative impacts. One of the reasons often cited for the failure of site-specific management to adequately protect aquatic resources is the inability of such an approach to address cumulative impacts (Johnston et al. 1990, U.S. Environmental Protection Agency 1999, Dale et al. 2000).

The literature has clearly identified that environmental regulations that are implemented on a permit-by-permit basis have a substantial cumulative impact. This occurs because the permit-by-permit approach fails to identify and account for the landscape processes that create and maintain wetlands (Wissmar and Beschta 1998). In the late 1980s, Bedford and Preston (1988) observed, "The incongruity between the regional scales at which wetland losses are occurring and the project-specific scale at which wetlands are regulated, and also studied, has become obvious." Failure to address the landscape processes results in two types of cumulative impacts (see Table 7-1) that are based on larger, geographic scales - cross-boundary impacts and fragmentation.

Bedford and Preston (1988) note that making decisions on a project-by-project basis fails to evaluate the potential impacts within the spatial and temporal scale within which ecosystems function. They state that, although project-by-project decision-making

. . . allows evaluation of the local impacts on resources, it does not allow evaluation of impacts of the project on these resources as a whole, of the total impact on these resources from all anthropogenic disturbances, or of secondary impacts resulting from the interaction of impacts from the project with other anthropogenic disturbances. This is true because the spatial and temporal boundaries of the analysis have not fully enclosed spatial and temporal dynamics of the environmental resources of concern and the anthropogenic activities influencing them.

These authors recognize that impacts can be generated not only from project-specific actions, but they can also result from actions that occur out of time and outside the vicinity of the activity that may be under scrutiny for a particular project. This results in two types of cumulative impacts described on Table 7-1, time-lags and indirect effects.

Others, such as Everard (1999), are concerned that regulating wetlands and other aquatic resources without considering landscape processes creates the illusion that the resources are being protected by case-by-case management decisions. The ramifications of this misconception include:

- Assumptions by the public that current land-use regulations and management decisions are adequate to protect aquatic systems
- The public perception that protection of aquatic resources is an ongoing financial burden
- The assumption that current regulations are adequate eliminates any incentive or perceived need to assess or modify existing policies and/or regulatory programs

Cumulative effects of decisions made project-by-project: An analogy

Understanding the implication of cumulative impacts from a project-by-project perspective rather than one at a landscape scale may seem abstract given the complexity of how the environment functions in the landscape. The following analogy is offered to provide an alternative description of cumulative effects and the need to manage natural resources using a landscape approach. Credit for the following analogy was given to Gosselink and Lee by Preston and Bedford (1988):

Imagine a Renaissance mosaic of a mother and child, composed of beautiful tiles of various shapes and colors. As it has aged the mosaic has begun to lose tiles. As managers responsible for the mosaic, we have to determine which of the tiles to preserve and reinforce, which to attempt to restore, and which we will allow to be further damaged or even destroyed. Our objective is to attempt to preserve the highest value for the mosaic. Using a tile-by-tile decision method (the project-by-project impacts assessment), each tile would be assessed separately and individually for its intrinsic value. Each decision for a tile would not consider the other nearby tiles, nor even how the tiles fit into the whole image. This strategy would very likely not preserve the image of the mother and child. Yet, it is the image that gives the mosaic its inherent value, not the sum of the individual tiles. If one is to preserve the value of the image, then one needs to be able to determine the relative significance of each individual tile relative to each other tile and to the image as a whole.

7.4.2 Lack of Consistent Plans and Regulations between Jurisdictions as a Possible Cause of Cumulative Impacts

The approach of managing wetlands on a permit-by-permit basis described in the previous section is the best documented cause of cumulative impacts. There are other aspects, however, of the regulatory framework in Washington that can be hypothesized to cause cumulative impacts. A possible source of cumulative impacts is the lack of consistent regulations between jurisdictions to protect and manage landscape processes that occur across jurisdictional boundaries. One jurisdiction may manage water flows from impervious surface, but another one that is further upstream may not manage such flows. Or, one jurisdiction may provide a 200-foot buffer on a reach of riparian wetlands while the adjacent jurisdiction may only provide a 50-foot buffer on the same reach.

In Washington State, most local jurisdictions have development codes that establish the regulatory framework for land use in all areas including wetlands. These codes are based on the objectives developed for each jurisdiction. Adjacent jurisdictions may have quite different objectives for managing the resources and therefore adopt distinctly different codes and regulatory protection. A common inconsistency in regulatory protection is the use of different wetland rating systems that result in variable levels of protection. For example, the city of Tukwila in King County has adopted a rating of wetlands into three categories (Critical Areas Ordinance #2074, December 13, 2004) while King County has adopted a four category rating system (Final Critical Areas Ordinance 15051, Adopted

October 29, 2004). The levels of protection assigned each of the wetland categories is also different. Disparities between rating systems may result in different levels of protection to different portions of the same wetland if it crosses jurisdictional boundaries. It is also quite possible that different buffer widths and different ratios for compensatory mitigation could be required for different parts of the same wetland in adjacent jurisdictions. Such discrepancies therefore can result in cumulative impacts across boundaries.

The failure to address the landscape processes consistently can result in two types of cumulative impacts (see Table 7-1) that are based on larger geographic scales - cross-boundary impacts and fragmentation. The differences in rating systems can result in “cross-boundary” impacts while the example of the different buffers for riparian wetlands would cause impacts from fragmentation.

7.4.3 Implementation of Regulatory Programs at the Local Level as a Possible Cause of Cumulative Impacts

Currently, there is little published information on the possible cumulative impacts that may result from the implementation of regulatory programs by local jurisdictions. For example, there is no documentation on the impacts of:

- Exempting wetlands from protection based on size (e.g., wetlands smaller than ¼ acre are not being regulated at all). Such exemptions can be hypothesized to cause cumulative impacts such as fragmentation and exceeding thresholds of ecosystem viability if there are many small wetlands within a jurisdiction.
- Exempting wetlands based on isolation (e.g., isolated wetlands are those that do not have a surface water connection to other water bodies). Such exemptions can be hypothesized to cause cumulative impacts such as fragmentation and exceeding thresholds of ecosystem viability if there are many isolated wetlands within a jurisdiction.
- Inadequate provisions for protection (e.g., inadequate buffer widths). This can be hypothesized to cause cumulative impacts such as “compounding effect” where an inadequate buffer reduces the habitat for species that need the buffer, as well as by introducing additional disturbances from adjacent development.
- Using standards for compensatory mitigation that are inadequate to ensure replacement of wetland area and/or function. This will result in all types of cumulative impacts because there is a continued loss of wetlands and their functions.

Scientific information synthesized in this document provides guidance on what should be used to effectively protect wetland functions (e.g., landscape approaches, buffers, mitigation standards). See Volume 2 in this two-part series for details regarding specific recommendations. To assess the effectiveness of local programs, we can, therefore, compare the requirements developed by local jurisdictions against what natural resource experts say is needed. The information available suggests that local programs do not

provide the level of planning and protection needed to maintain existing functions and address cumulative impacts.

Two studies in Washington provide more direct information regarding this issue. A King County study (Mockler et al. 1998) concluded that standards for compensatory mitigation implemented by the county were significantly less than what was necessary to meet the goal of no net loss of function or area. In addition, data from the Washington State Department of Community, Trade and Economic Development (CTED) addresses the adequacy of buffer requirements by local governments in Washington. The department collects data on the buffer requirements in critical area ordinances of cities and counties in Washington. In the last such survey in 1999 (Chris Parsons, CTED, personal communications 1999, data are available on request from CTED), the buffers for wetlands were considerably narrower than what the scientific information indicates is necessary to protect many functions. Of the 128 jurisdictions in Washington that specify a numeric buffer width, 99 had buffers of 100 ft or less on wetlands that rate high for their habitat functions. The summary of the scientific information provided in Chapter 5 indicates, however, that most habitat functions are not adequately protected by this buffer width.

Additionally, no city or county in Washington has developed and implemented a landscape-based approach to assessing and protecting wetlands. The scientific information summarized by the Ecological Society of America (Dale et al. 2000) and by the Council of Environmental Quality (1997) indicates that a landscape-based approach is necessary to minimize cumulative impacts.

Thus, it is reasonable to hypothesize that existing wetland protection programs, as implemented in Washington, are not adequately protecting wetland functions and values, and cumulative impacts are resulting.

7.4.4 Relating the Types of Cumulative Impacts to Measures Taken by Local Governments

The list of types of cumulative impacts listed in Table 7-1 can be related to inadequacies of the measures taken to protect wetlands at the local level that have been documented or that can be hypothesized. Examples of the different types of cumulative impacts and examples illustrating these inadequacies are provided in Table 7-2. The inadequacies span the realms of planning, coordination, and regulation.

Table 7-2. Types of cumulative impacts and examples of factors at the local level that might cause the impacts.

Type of Cumulative Impact	Main Characteristics	Examples of Cumulative Impacts	Examples at the Local Level That Might Cause This Impact
Time crowding	Frequent and repetitive disturbances before recovery has occurred from previous disturbance	Reoccurring flooding that drowns vegetation that is not adapted to prolonged inundation	Inadequate storm-water regulations that do not address impacts on wetlands of changes in water regime
Time lags	Impacts of disturbance are delayed	Exposure to toxics	No provision for regulating the use of chemicals on residential lawns draining to wetlands
Space crowding	Impacts are occurring in close proximity to each other	Construction of new highways and high-density commercial zones on both sides of a wetland, resulting in increased noise, lighting, and human presence	No provision for planning at the landscape scale that allows the identification and adequate protection of critical landscape linkages between habitats
Cross-boundary	Impacts occur away from the source	Eutrophication in wetlands and lakes that results from nutrient discharges in upper watershed	Lack of coordination among jurisdictions in controlling nutrient inputs to a watershed
Fragmentation	Changes in the pattern of ecosystems across the landscape	Distribution and size of wetlands across the landscape is reduced	No planning at a landscape scale that identifies key landscape processes and incorporates appropriate management options. Permits are issued on a case-by-case basis
Compounding effects	Impacts arising from multiple sources or pathways	Construction of roads, stormwater facilities, and high density commercial development after an approved rezone	The lack of authority to adequately assess potential long-term effects to landscape processes when changing the potential land use of a parcel or area
Thresholds and triggers	The accumulation of disturbances causes a fundamental change in the behavior of the ecosystem	Increased surface runoff causes streams to be incised and wetlands become disconnected from the floodplain	Permit-by-permit decision making precludes the ability to regulate known or anticipated cumulative effects, unless the regulatory framework is in place

7.5 Chapter Summary and Conclusions

Loss of wetland area and alteration of wetland functions due to human activities are indicators that cumulative impacts are occurring. Wetland losses continue to occur on a national level. The few studies done in the Pacific Northwest suggest that losses continue to occur in the region as well.

The Council on Environmental Quality has identified seven types of cumulative impacts: time crowding, time lags, space crowding, cross-boundary, fragmentation, compounding effects, thresholds and triggers.

Some of the causes of cumulative impacts include the following:

- Permit decisions made on a case-by-case basis. The scientific information available has clearly identified that environmental regulations that are implemented on a permit-by-permit basis have substantial cumulative impacts.
- Lack of consistent regulations between jurisdictions. Local governments vary in the protection they provide to wetlands or to different parts of the same wetland if it crosses political boundaries. Therefore, the same wetland may be subject to a variety of policies and regulatory standards. Differing standards can result in cumulative effects and loss of wetland functions across the landscape.
- Insufficient protection at the local level. Most cities and counties in Washington have historically required buffers that are considerably less than what the research indicates are necessary to protect functions.
- The lack of planning at a larger geographic scale. The scientific information shows that a landscape-based approach is needed to effectively manage wetlands. However, no local government in Washington has developed and implemented a landscape-based approach to assessing and protecting wetlands.

Based on the synthesis of the scientific literature, combined with the knowledge of the standards for protection and how land-use decisions are currently made, it can be hypothesized that current protection programs result in cumulative impacts to wetlands.

Improvements in the way wetlands are protected and managed, and therefore how cumulative impacts can be avoided, is the subject of the second volume in this two-part series. It provides guidance in regard to:

- Implementing a four-part framework for protecting and managing wetlands
- Analyzing the landscape and its wetlands
- Using landscape information in developing plans and policies, and incorporating these into comprehensive planning
- Developing and improving tools typically used in local regulations (rating, buffers, compensatory mitigation, etc)

- Developing and improving non-regulatory tools such as preservation, conservation, and restoration
- Identifying the risks from proposed or existing programs
- Implementing programs
- Monitoring wetland protection and management measures that have been implemented, and adapting programs to address the inadequacies identified

The reader is referred to Volume 2 for suggestions regarding solutions to the problem of cumulative impacts.

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The following list of references includes those literature sources obtained, reviewed, and synthesized by the Core Team (See Appendix 1-A) that prepared this document. The list also includes references cited in those portions of “Indicators for Monitoring Biological Integrity of Inland, Freshwater Wetlands” (Adamus et al. 2001) that were adapted for use in this synthesis. The references from the adapted portions of the Adamus et al. (2001) document have not all been obtained and reviewed by the Core Team, but they are included here for the convenience of the reader who wishes to consult the original literature for further information. Not all references listed here are cited in the synthesis. Citations listed as “personal communications” in the text are not listed here since the citation contains the information. The references cited in the appendices are listed here and at the end of each appendix. The authors recognize that the format of the references is not always consistent but that this should not prevent interested persons from locating any of the listed references.

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Glossary

Terms defined in the context of the sentence in which they appear in this document may not be included in the glossary.

Adventitious roots. Additional roots that develop in some plants, such as willows and alders, as an adaptation to saturated or flooded conditions.

Aquatic resources (systems). Refers to ecological systems where the regular or occasional presence of water is the dominant factor determining the characteristics of the site. Aquatic systems are made up of wetlands, rivers, streams, lakes and other deepwater habitats.

Assessment methods. Methods that generate a number representing an estimate of the performance of a wetland function. The number generated is relative to a predetermined standard (e.g., level of function provided by reference wetlands). Numbers do not reflect an actual level of function performance (Hruby 1999). Examples include the Washington State Methods for Assessing Wetland Functions (WFAM) (Hruby et al. 1999 and 2000) and the HGM approach to wetland function assessment (Brinson et al. 1995).

Biological wetland. A biological wetland is a wetland that meets the three parameter criteria of either the 1987 Corps of Engineers Delineation Manual or the 1997 Washington State Wetlands Identification and Delineation Manual (WAC 173-22-035). Compare to jurisdictional wetland.

Bog. A unique type of wetland dominated by mosses that form organic peat. Bogs form in areas where the climate allows the accumulation of peat to exceed its decomposition. Bog hydrology is dominated by precipitation rather than surface inflow. The plant community is specialized to survive in the nutrient-poor and highly acidic conditions typical of bog systems.

Buffers or buffer areas. Vegetated areas adjacent to wetlands, or other aquatic resources, that can reduce impacts from adjacent land uses through various physical, chemical, and/or biological processes.

Canopy cover. The degree to which the foliage of the highest vegetation layer in a plant community blocks sunlight or obscures the sky.

Class. A grouping based on shared characteristics in a classification scheme. In the Cowardin et al. (1979) classification of wetlands a class is the third level in the 'taxonomy' of wetlands whereas in the Hydrogeomorphic Classification (Brinson 1993) it is the highest taxonomic unit.

Compensatory mitigation. The compensation stage of the mitigation sequence where impacts to the functions and values of wetlands are replaced through creation, restoration, or enhancement of other wetlands. Because regulatory requirements and policies tend to focus on the compensation stage, the term “mitigation” is often used to refer to compensation, which is just one part of the overall mitigation sequence. See *mitigation*.

Conductivity. A measure of the amount of dissolved constituents (ions) in water, based on the water’s ability to conduct electricity. See *specific conductance*.

Connectivity. The structures on the landscape that facilitate movement of living organisms between patches or their habitat that are found across the landscape. The movement can occur either within the lifetime of an organism or over a period of generations. The purpose of facilitating movement is to maintain viable populations that allow species and communities of species to persist in time. Connectivity can be achieved via a continuous and linear habitat feature (as in a corridor) or discrete habitat patches comprised of but not limited to individual forests, wetlands, shrub lands, and shorelines.

Conservation easement. A restriction placed on a piece of property to protect the resources (natural or man-made) associated with the parcel. It restricts the type and amount of development that can take place on a parcel of land. For example, the landowner may sell or donate the development rights while retaining the ownership of the property. Easements are recorded on the property deed and are held in trust by a conservation easement “holder” such as a land trust or government agency. The holder polices the terms of the easement for the duration of its existence, which is usually into perpetuity.

Contingency plan. A plan outlining actions that would be triggered if monitoring of a project revealed a problem that would prevent the site from attaining its stated goals, objectives, and performance standards. Contingency plans should identify anticipated problems and the specific maintenance activity that would be implemented to rectify each problem.

Contributing basin. The geographic area from which surface water drains to a particular wetland.

Corixids. A group of aquatic insects commonly called “water boatmen.”

Corridor: Corridors are areas that contain relatively undisturbed habitat and/or vegetation that maintain connections for wildlife throughout the landscape. Corridors usually represent linear habitats with the range of environmental functions necessary to permit the movement of animals between larger and more fully functioning habitats. Corridors can include but are not limited to, annual or seasonal migration corridors that connect wintering and breeding habitat, or intra-seasonal corridors that connect foraging and nesting habitat or breeding and dispersal habitat.

Cowardin classification. The first commonly used classification system for wetlands developed in 1979 by the U.S. Fish and Wildlife Service. The Cowardin system classifies wetlands based on water flow, substrate types, vegetation types, and dominant plant species.

Cumulative impacts. The incremental effect of an impact added to other past, present, and reasonably foreseeable future impacts.

Deed restriction (definition from legal dictionary). Clauses in a deed limiting the future uses of the property. Deed restrictions may impose a vast variety of limitations and conditions, for example, they may limit the density of buildings, dictate the types of structures that can be erected or prevent buildings from being used for specific purposes or even from being used at all.

Depressional wetland. A class of wetlands in the *hydrogeomorphic classification*. These are wetlands that occur in topographic depressions that exhibit closed contour interval(s) on three sides and elevations that are lower than the surrounding landscape.

Dioxin. A group of several hundred chemical compounds that share certain chemical structures and biological characteristics. They include the chlorinated dibenzo-*p*-dioxins (CDDs), chlorinated dibenzofurans (CDFs), and some polychlorinated biphenyls (PCBs). The term dioxin is also used to refer to a well-studied and toxic dioxin, 2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin (TCDD).

Disturbance. An event that disrupts the processes or structure of ecological systems. Disturbances may occur naturally (e.g., wildfires, storms, floods) or be caused by human actions (e.g., clearing land, building roads, altering stream channels). The effects of disturbances on ecological systems are controlled in large part by their intensity, duration, frequency, timing, and size and shape of area affected.

Ditch. Any channel that has been specifically dug to facilitate drainage.

Drainage systems. Often called basins, sub-basins, watersheds, or river basins depending on the size of the area. In this document, drainage systems are generally referred to using one of two terms: 1. *Watershed*. A geographic area of land bounded by topographic high points in which water drains to a common destination; and 2. *Contributing basin*. A geographic area from which surface water drains to a particular wetland.

Drawdown. A lowering of the ground-water surface caused by pumping.

Dytiscids. Predaceous diving beetles.

Ecoregion. Geographic regions where climatic conditions are similar and the ecosystems (including wetlands) are relatively homogeneous. Omernik and Gallant (1986) mapped the following ecoregions in Washington: Coast Range, Puget Lowland, Cascades, Eastern Cascades Slopes and Foothills, North Cascades, Columbia Plateau, Blue Mountains, and Northern Rockies.

Ecosystem. A loosely defined assemblage of co-occurring organisms and the geographic location which they inhabit. The term is an operational convenience defined by the user of the term for the convenience of description (Levin 2001). There is no basic geographic scale associated with the term ecosystem, and that also has to be defined by a user. For example, the term can be used to describe the micro-organisms co-occurring in a spoonful of soil (soil ecosystem) at one end of the scale to the ecosystem of the world that encompasses all organisms on the planet.

Ecotone. An area that is transitional between two different types of ecosystems and has some of the features of both. Wetlands are often characterized as being ecotones between aquatic and terrestrial ecosystems.

Edge. The boundary where habitats meet or where successional stages of plant communities come together.

Emergence trap. A device placed over the water or sediment in a wetland to capture flying aquatic insects as they emerge from their non-flying larval state into their winged adult form.

Environmental processes. The same as *landscape processes*.

Eutrophication. The undesirable overgrowth of vegetation caused by high concentrations of plant nutrients in bodies of water, especially nitrogen and phosphorous, often as a result of human activities.

Evapotranspiration. The combination of water that is evaporated from the surface and that is transpired from the leaves of plants as part of their metabolic process.

Fen. A type of wetland that is similar to a bog, containing accumulated peat. Fens support marsh-like vegetation including sedges and wildflowers. Fens differ from bogs in their plant communities, hydrology, and water chemistry. They are fed by groundwater and are not as acidic as bogs.

Flats. A class of wetlands in the *hydrogeomorphic classification*. These are wetlands that occur in topographically flat areas that are hydrologically isolated from surrounding ground or surface water. They are primarily maintained by precipitation.

Forb. Any herbaceous plant that is not a grass or sedge.

Forested wetland. A wetland *class* in the Cowardin classification where woody plants taller than 20 feet form the dominant cover. Shrubs often form a second layer beneath the forest canopy, with a layer of herbaceous plants growing beneath the shrubs.

Fragmentation. The breaking up of ecosystems into patches of habitat that are separated by areas altered by human land uses. Fragmentation always consists of both the reduction in the area of the original habitat and a change in spatial configuration of what remains.

Functions. The physical, biological, chemical, and geologic interactions among different components of the environment. See *wetland functions*.

Functional feeding group. A group of animals (aquatic insects, birds, etc) that feed in a similar way. For example, insects that scrape algae from rocks in a stream are called scrapers; those that shred leaf material are caked shredders; and those that filter small particles from the water column are filter feeders.

Furans. A chemical substance resulting from the manufacture of organic compounds, such as nylon.

Geomorphic setting. The topographic location of a site within the surrounding landscape and the geology that underlies it.

Geomorphology. The geologic composition and structure of a landscape—its topography, landforms, soils, and geology.

Hemipterans. A group of insects with straw-like, sucking mouth parts.

Herbaceous (stratum). A layer of non-woody vegetation, usually less than 6 feet (2 m) tall.

Hertz (Hz). A unit of frequency equal to one cycle per second.

Humic. Of or pertaining to humus, which consists of partially or wholly decayed plant matter.

Hydrodynamics. Refers to the movement of water and its capacity to do work. There are three qualitative categories of hydrodynamics: (1) vertical fluctuations of the water levels or water table, (2) unidirectional surface or near-surface flows that range from strong currents contained in channels to slow sheet flow down a slope, and (3) bidirectional flows resulting from tides or wind-driven currents in lakes.

Hydrogeomorphic (HGM) classification. A system used to classify wetlands based on the position of the wetland in the landscape (geomorphic setting), the water source for the wetland, and the flow and fluctuation of the water once in the wetland.

Hydroperiod. The pattern of water level fluctuations in a wetland. Includes the depth, frequency, duration, and timing of inundation or flooding. Patterns can be daily, monthly, seasonal, annual, or longer term.

Impact. Changes to the environment that are caused by human disturbances. Impacts can be either beneficial or detrimental to the ecosystem, environmental process, or species.

Interior (species). Animal species that require the conditions found on the interior of a habitat type and which are subject to disturbance in areas toward the edges of that habitat. For example, forest interior birds find optimum conditions within the center of a forested area where they are not subject to domestic pets, noise, severe weather, or other disturbances that penetrate the outer forest edge.

Jurisdictional wetland. A wetland that is regulated by the provisions of the law under the jurisdiction of one or more federal, state, or local agencies. Not all areas of the landscape that have the biological characteristics of wetlands are regulated or jurisdictional wetlands.

Lacustrine. Pertaining to lakes or lake shores.

Lacustrine (lake) fringe wetlands. A wetland *class* under the *hydrogeomorphic classification*. These are wetlands that occur at the margins of topographic depressions in which surface water is greater than 8 hectares (20 acres) and greater than 2 meters deep in western Washington and 3 meters in eastern Washington.

Landscape processes. Environmental factors that occur at larger geographic scales such as basins, sub-basins, and watersheds. Processes are dynamic and usually represent the movement of a basic environmental characteristic such as water, sediment, nutrients and chemicals, energy, or animals and plants. The interaction of landscape processes with the physical environment creates specific geographic locations where groundwater is recharged, flood waters are stored, stream water is oxygenated, pollutants are removed, and wetlands are created.

Landscape scale. The geographic scale that encompasses the broader landscape (i.e., large areas such as basins, sub-basins, watersheds, and habitat corridors). Also see *site scale* and *large scale*.

Large scale. Large in scope. This term is used specifically to indicate geographic areas that extend beyond the boundaries of an individual site, wetland, or resource. Please note that this term has the opposite meaning when it is used in cartography. Large scale maps are ones that cover a smaller geographic area than a small scale map.

Large woody debris (LWD). Large pieces of downed wood, such as logs, rootwads, and limbs, that are in or near a body of water. LWD provides habitat structure for fish and other aquatic organisms.

Lentic. Having slow moving or still water, such as a pond or lake (as compared to lotic – having running water, such as a river or stream).

Metapopulation. A group of local populations between which individuals can migrate.

Microbe. A microscopic organism, such as a bacterium.

Microhm. A unit of measure describing the resistance of a substance to electrical current.

MilliSiemens. A unit of measure for conductivity. See *specific conductance*.

Mitigation (or mitigation sequencing). Mitigation is a series of actions that requires addressing each action, or step, in a particular order. This sequence of steps is used to reduce the severity of negative impacts from activities that potentially affect wetlands. Mitigation involves the following: 1. Avoiding the impact altogether by not taking a certain action or parts of an action; 2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps, such as project redesign, relocation, or timing, to avoid or reduce impacts; 3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment; 4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; 5. Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and 6. Monitoring the required compensation and taking remedial action when necessary (WAC 197.11.768). See *compensatory mitigation*.

Natural Heritage (Wetlands) (as defined by the Natural Heritage Program of the Washington State Department of Natural Resources). Wetlands that are either high quality undisturbed wetlands or wetlands that support threatened, endangered, or sensitive plant species.

Niche. The area within a habitat occupied by an organism; the set of functional relationships of an organism or population to the environment it occupies.

PCBs. Polychlorinated biphenyls, a type of toxic chemical compound once widely used in electrical equipment. See *dioxin*.

Phreatic zone. The area above the groundwater table.

Redox (potential). Reduction-oxidation potential, or a measure of the potential movement of electrons in a system. Reduction refers to the chemical process whereby molecules of a substance gain an electron. Oxidation refers to loss of electrons. Measuring the redox potential of a wetland soil provides information about the types of chemical reactions that are occurring in the soil, and thus whether the soil is more aerobic (contains oxygen) or anaerobic (lacks oxygen).

Richness. The number of different species of organisms present in a community.

Riparian. The strip of land adjacent to a body of water that is transitional between the aquatic system and the upland. Some riparian areas contain wetlands.

Riverine wetlands. A *class* of wetlands in the *hydrogeomorphic classification*. Wetlands that occur in floodplains and riparian corridors in association with stream or river channels where there is frequent overbank flooding.

Rotifers. Minute organisms that live in fresh and salt water. A crown of hair-like structures (cilia) propels them through the water.

Roughness. The amount of friction or resistance a surface provides against water flow. For example, an area containing shrubs and downed branches has greater roughness than a mowed lawn.

Site processes. Environmental factors that occur within the wetland itself or within its buffer. The interactions of site processes with landscape processes define how a wetland functions.

Site scale. The geographic scale that encompasses the area within the boundary of a single wetland and its immediate surroundings. Also see *landscape scale*.

Slope wetlands. A *class* of wetlands in the *hydrogeomorphic classification*. These are wetlands that occur on the slopes of hills or valleys. The principal water source is usually seepage from groundwater.

Specific conductance. A measure of electrical conductivity standardized to 25°C. Use of specific conductance accounts for the fact that the conductivity of water changes as its temperature changes. It is measured in units of milliSiemens per centimeter.

Sub-basin. A smaller drainage basin that is part of a larger drainage basin or watershed. For example, the watershed of a large river may be composed of several sub-basins, one for each of the river's tributaries.

Temporal loss (of functions). The concept that there is a time lag between the loss of existing wetland functions through human or natural disturbance and the reestablishment of functions over time.

Tidal Fringe wetlands. A *class* of wetlands in the *hydrogeomorphic classification*. Wetlands that occur on continental margins where marine waters are greater than 2 meters deep and more than 8 hectares (20 acres) in size.

Trophic level. A concept used to describe feeding levels in a foodweb. Plants fill the first trophic level by utilizing sunlight to create carbohydrates and other compounds. Plants are consumed by plant-eating animals (herbivores) in the second trophic level, which in turn become food for predators in the next trophic level, and so on.

Values. See *wetland values*.

Watershed. A geographic area of land bounded by topographic high points in which water drains to a common destination.

Wetland functions. The physical, biological, chemical, and geologic interactions among different components of the environment that occur within a wetland. Wetlands perform many valuable functions and these can be grouped into three categories: functions that improve water quality, functions that change the water regime in a watershed such as flood storage, and functions that provide habitat for plants and animals.

Wetland rating. Also called a wetland rating system. is a tool for dividing or grouping wetlands into groups that have similar needs for protection. One method used in Washington is the Washington State wetland rating systems (Hruby 2004a,b), which places wetlands in categories based on their rarity, sensitivity, our inability to replace them, and their functions.

Wetland Values. Wetland processes, characteristics, or attributes that are considered to benefit society.

Appendix 1-A

Team Guiding Production of Volume 1

An interagency team (the Core Team) guided all aspects of and participated in the search and reading of the scientific literature, wrote the synthesis, and produced Volume 1. Additional members were added during the production of Volume 2 (see Volume 2).

For Volume 1, the team consisted of staff from the Washington State Department of Ecology, the Washington State Department of Fish and Wildlife, the U.S. Environmental Protection Agency, and Sheldon and Associates, the consulting firm hired to assist with production. Additional Ecology staff served as authors (see the list of authors on the title page of this document). The editor was included on the Core Team in the later stages of production of draft of Volume 1 and was involved through the development of the review draft of Volume 2.

The Core Team included the following individuals (alphabetical by last name):

Teri Granger	Washington State Department of Ecology (coordinator)
Kim Harper	Sheldon and Associates ¹
Tom Hruby	Washington State Department of Ecology
Katherine March	Washington State Department of Fish and Wildlife
Andy McMillan	Washington State Department of Ecology
Sara Noland	2N Publications (editor of the draft)
Ralph Rogers	U.S. Environmental Protection Agency
Dyanne Sheldon	Sheldon and Associates
Erik Stockdale	Washington State Department of Ecology

¹ Currently with the Washington State Department of Ecology.

Appendix 1-B

Characteristics of a Valid Scientific Process

The characteristics of a valid scientific process in the context of “best available science” are defined below, as quoted directly from WAC 365-195-905:

1. **Peer review.** *The information has been critically reviewed by other persons who are qualified scientific experts in that scientific discipline. The criticism of the peer reviewers has been addressed by the proponents of the information. Publication in a refereed scientific journal usually indicates that the information has been appropriately peer-reviewed.*
2. **Methods.** *The methods that were used to obtain the information are clearly stated and able to be replicated. The methods are standardized in the pertinent scientific discipline or, if not, the methods have been appropriately peer-reviewed to assure their reliability and validity.*
3. **Logical conclusions and reasonable inferences.** *The conclusions presented are based on reasonable assumptions supported by other studies and consistent with the general theory underlying the assumptions. The conclusions are logically and reasonably derived from the assumptions and supported by the data presented. Any gaps in information and inconsistencies with other pertinent scientific information are adequately explained.*
4. **Quantitative analysis.** *The data have been analyzed using appropriate statistical or quantitative methods.*
5. **Context.** *The information is placed in proper context. The assumptions, analytical techniques, data, and conclusions are appropriately framed with respect to the prevailing body of pertinent scientific knowledge.*
6. **References.** *The assumptions, analytical techniques, and conclusions are well referenced with citations to relevant, credible literature and other pertinent existing information.*

Information derived from one of these sources can be considered scientific information if it possesses the required characteristics shown in Table 1B-1.

Table 1B-1. Source and characteristics of scientific information.

Sources of Scientific Information	Characteristics					
	Peer Review	Methods	Logical Conclusions & Reasonable Inferences	Quantitative Analysis	Context	References
A. Research. Research data collected and analyzed as part of a controlled experiment (or other appropriate method) to test a specific hypothesis.	X	X	X	X	X	X
B. Monitoring. Monitoring data collected periodically over time to determine a resource trend or evaluate a management program.	NA	X	X	Y	X	X
C. Inventory. Inventory data collected from an entire population or population segment (e.g., individuals in a plant or animal species) or an entire ecosystem or ecosystem segment (e.g., the species in a particular wetland).	NA	X	X	Y	X	X
D. Survey. Survey data collected from a statistical sample from a population or ecosystem.	NA	X	X	Y	X	X
E. Modeling. Mathematical or symbolic simulation or representation of a natural system. Models generally are used to understand and explain occurrences that cannot be directly observed.	X	X	X	X	X	X
F. Assessment. Inspection and evaluation of site-specific information by a qualified scientific expert. An assessment may or may not involve collection of new data.	NA	X	X	NA	X	X
G. Synthesis. A comprehensive review and explanation of pertinent literature and other relevant existing knowledge by a qualified scientific expert.	X	X	X	NA	X	X
H. Expert Opinion. Statement of a qualified scientific expert based on his or her best professional judgment and experience in the pertinent scientific discipline. The opinion may or may not be based on site-specific information.	NA	NA	X	NA	X	X
X = Characteristic must be present for information derived to be considered scientifically valid and reliable. Y = Presence of characteristic strengthens scientific validity and reliability of information derived, but is not essential to ensure scientific validity and reliability. NA = The characteristic does not apply to the source type. For example, monitoring data are not typically peer reviewed.						

Appendix 1-C

Methods Used for Searching and Reviewing the Literature

Searching the Literature

To begin the literature review for Volume 1, personal bibliographies were solicited from a small number of professionals known to have extensive libraries on wetlands in the Pacific Northwest. Other published reference lists were reviewed for relevant documents. In addition to the specified reference lists, computer searches were conducted of databases that are publicly available using a variety of keywords. Table 1C-1 lists the sources of reference lists and the names of the databases searched, as well as the approximate number of documents contained in each source.

Table 1C-2 lists the keywords that were used in the searches of computer databases. This list was developed by the Core Team and expanded based on comments from focus groups (see Chapter 1 for information on focus groups). The searches were done combining the word “wetland” plus one of the keywords. The words in the last column were used to exclude wetland types not covered by this report. Specific wetland types not found in Washington and known to be very dissimilar from Washington wetlands were also excluded, as were estuarine and marine wetlands. Lists resulting from the searches of the computer databases were compiled into a ProCite® database for the project.

Table 1C-1. Summary of reference lists and databases searched for Volume 1.

List Source	Approx. No. of Documents	Notes
Personal Bibliographies		
Dr. Paul Adamus, EPA	1,600	Broad range of documents
Dr. Tom Hruby, WA Ecology	600	Broad range of documents, many focus on wetland functions
Mary Kentula, EPA	170	Focus on wetland mitigation, management, policy effectiveness
Dr. Klaus Richter, King County	3,500	Focus on amphibians w/Pacific NW emphasis
Published Reference Lists		
Management recommendations for WA priority habitats: freshwater wetlands and fresh deepwater (Morgan 1998)	640	Focus on wildlife and aquatic habitats
Management recommendations for WA priority habitats: riparian (Knutson and Naef 1997)	550	Focus on riparian habitats, not necessarily wetlands
Managing for enhancement of riparian and wetland areas of the Western U.S.: an annotated bibliography (Koehler and Thomas 2000)	1,900	Broad application to western U.S.; many documents not relevant to Pac. NW
Classification and management of aquatic, riparian and wetland sites on the national forests of Eastern Washington (Kovalchik 2004)	400	Focus on eastside and forested areas
Effects of urbanization on pond-breeding amphibians: an annotated literature review (Ostergaard 2000)	100	Focus on amphibians and urban effects
Database Searches		
Keyword searches of various databases	9,800	Databases searched included Ovid, ProQuest, Biosis, Dissertation Abstracts, Agricola, Current Contents, Biological Abstracts
Total	~17,860	Total includes an unknown number of duplicates among the various sources

Table 1C-2. Keywords used in searching computer databases of literature.

Base Word	Keywords		Exclusions
Wetland	Aesthetics Agriculture Alkali Alluvial Amphibians Aquifer Recharge Arid Land Artesian Birds Bog Buffers Compensation Conservation Cumulative Impacts Development Disturbed Dynamic Economics Enhancement Erosion Farmed Fen Fish Floodplain Fluvial Functions Geology Geomorphology Grazing Groundwater Habitat Hydraulic Hydric Hydrology Hyporheic Industrial Inventory Invertebrates Irrigation Isolated	Land Use Landscape Maintenance Mammals Mapping Mining Mitigation Mollusks Monitoring Nutrients Perched Policy Public Access Recreation Regulation Reptiles Residential Restoration River Rural Seasonal Septic Slope Soils Spatial Stewardship Stormwater Transportation Corridors Urban Utility Corridors Values Variation Vegetation Types Vernal Pools (not Calif.) Water Quality Water Regime Wells Wildlife	Bottomland Hardwood California Vernal Pools Estuarine Intertidal Lacustrine Marine Mississippi Floodplain Mudflats Salt Marsh Saltwater

Reviewing, Sorting, and Prioritizing the Reference Lists

All reference lists were reviewed by one or more of the Core Team members. From these lists, the Core Team selected those documents that were determined to be relevant to the project, based solely on the title of the article and its date. Those marked documents were then prioritized using a two-tiered system in which those considered most critical to the project were designated as those to be obtained first. Eventually, attempts were made

to obtain all the documents on the lists that were believed to be relevant based on their titles. In addition, references were found while individual authors searched for subjects for which information was lacking. These references are provided in the list of references cited in the report.

Criteria Used to Identify Articles Relevant to the Project

When screening lists of articles, the Core Team used the following criteria to determine, through reading the title and looking at the date, which were relevant to the project and should be obtained. Those that were deemed a “definite yes” were those that were:

- Related to wetland protection and management
- Applied to Washington or the Pacific Northwest
- Were out of region but dealt with land uses
- The only paper on a subject

Those that were rejected out-right were those that were:

- Very old and superceded by newer information
- Related to estuarine and marine systems, which were not going to be covered in the document
- Primarily scientific minutia that weren’t useful to managing and protecting wetlands
- Not related because of region
- Related to wetlands and waste-water treatment, which was not going to be covered in the document

Obtaining & Reading Documents & Writing the Report

Of the more than 17,000 documents on all lists used, copies of over 1,400 documents were obtained after review of the titles and dates, as prioritized using the screening process described above. References were skimmed and those dealing with Washington or the Pacific Northwest and with practical application to the protection and management of wetlands were prioritized for reading.

Each reader summarized the article in the ProCite® database. Searches of the database or the original articles were used by each author to write their portions of the draft document. Additional articles were discovered during the course of writing the draft document. These references were not included in the ProCite® database.

The documents used to write the synthesis included scientific journal articles, government publications, technical books, and other sources, all of which meet the definition and characteristics of BAS in WAC 365-195-905 (see Appendix 1-B and Chapter 1). Conference proceedings and personal communications were occasionally used when no other information was available. In most cases, we were unable to ascertain to what level these additional sources were peer reviewed.

For the most part, available documents from the past ten years were used as the primary sources for this report. It was assumed that this more recent literature would incorporate relevant science from the preceding years. Older documents were used in instances where they had not been superseded by more recent studies.

In a few instances, we used unpublished data collected during the calibration of the Washington State wetland function assessment methods and the Washington State wetland rating systems. These data have not been published in scientific journals. However, these observations reported as “unpublished data” in Volume 1, were collected in the field by interdisciplinary teams of wetland experts and used to support and calibrate the assessment methods and the wetland rating system. The methods and rating system have been extensively reviewed and field tested by peer experts, as well as the public. The data were offered for review upon request during public review and continue to be available on request. See Chapter 1 for discussion of the occasional use of hypotheses and assumptions made by the authors based on the literature or their professional experience.

Obtaining References Suggested by Reviewers

A questionnaire was circulated with the review draft of the document. The draft of Volume 1 was reviewed by peer experts. In addition, we invited anyone who so desired to review it. Reviewers were asked to provide additional references that we may have missed, for topics for which we lacked information, or to support suggested changes to the document. Many references were provided and a screening process was used to prioritize and obtain references. See the document containing our responses to comments for a table listing the references that were suggested, the references which were obtained, and notes of explanation for each reference suggested. (The Comments and Responses for Volume 1 can be found at <http://www.ecy.wa.gov/biblio/0506007.html>.)

Establishing a Repository

The ProCite® database is not available for general use because of technical reasons and the time and money required in making it accessible to a wide variety of users and their varied software programs. However, paper copies of many of the articles reviewed for the synthesis of the science are being held in an archive at the Washington State Department of Ecology. The archive is accessible to the public by appointment.

A number of theses, dissertations, and books are not included in the archive, as well as some articles in private libraries, due to copyright laws and the limited options for purchasing some documents. In these cases, borrowed copies were used and returned, with only the title pages and tables of contents copied for the archive.

Appendix 1-D

Reviewers of Volume 1

Name of Individual or Organization	Affiliation at the Time of Review (if individual)
Paul Adamus, PhD	Private Consultant
Jeff Azerrad, Wildlife Biologist	WA State Department of Fish and Wildlife
Joann Bartlett, PWS	Wiltermood Associates
Doug Beyerlein, PE	Aqua Terra Consultants
Elizabeth Binney, PhD, PWS	ATSI
Catherine Conolly, PWS and Teresa H. Vanderburg, PWS (submitted comments jointly)	Adolfson Associates
Brent Davis, Wetland Biologist	Clark County Community Development Department
Tim Determan, Puget Sound Ambient Monitoring Program Coordinator	WA State Department of Health
Donald F. Flora	Private citizen
Richard R. Horner, PhD	University of Washington
Richard Jack	WA State Department of Ecology
Jim Kelley, PhD	Parametrix, Inc.
Bernard L (Bud) Kovalchik, retired U.S. Forest Service -- Eastern Washington Area Ecologist	Kovalchik Riparian Wetland Consulting
Ivan Lines, Regional Biologist	Ducks Unlimited, Inc.
Scott Luchessa, Certified Ecologist, MS.	Ecological Solutions, Inc.
Chris L. McAuliffe, Ecologist	Private citizen, retired from the Seattle District of the Army Corps of Engineers
Elliot Menashe, Environmental Consultant	Greenbelt Consulting
Jeff Meyer, PWS	Parametrix, Inc.
Jim Mitchell, PE, PWS	Mitchell Consultants L.L.C.
Lyn Morgan-Hill, Natural Resources Specialist	Whatcom County Planning and Development
Francis Naglich	Ecological Land Services, Inc.
Scott Williams, Land Planner	Puget Sound Energy
Klaus Richter, PhD, PWS	King County Department of Natural Resources
Scott J. Rozenbaum, PWS, Certified Professional Soil Scientist	Rozewood Environmental Services, Inc.
Todd Thompson, Fish & Wildlife Program Lead	Spokane District Bureau of Land Mngmt
WETNET (Audubon) Science Committee	
Megan White	WA State Department of Transportation
Bob Zeigler	WA State Department of Fish and Wildlife
Unidentified Individual	

Appendix 2-A

Methods for Organizing and Grouping Information about Wetlands

The following information is adapted from Hruby (1999).

Many groups including federal and state agencies have been developing techniques for analyzing wetland functions ever since wetlands were first subject to regulation in the 1970s. The motivation for developing such methods has primarily been the need to predict the effects of alterations to wetlands and set appropriate requirements for compensatory mitigation.

Methods for organizing knowledge about wetlands have been called classifications, categorizations, characterizations, ratings, assessments, and evaluations. These groupings are meant to indicate the type of information a method provides. Unfortunately, the scientific community has been sloppy in the use of these terms to the extent of misnaming many of the analytical tools developed. Users of methods developed for analyzing wetlands should be aware of some of these problems with definitions. Standard definitions for analytical methods based on Webster's Seventh New Collegiate Dictionary (1963) are described below.

Classification/categorization—a systematic grouping into categories according to established criteria or shared characteristics. The two most common wetland classifications are those of Cowardin et al. (1979), which is based on shared characteristics of vegetation and water regime, and the hydrogeomorphic classification (Brinson 1993b), which is based on shared characteristics of geomorphic setting and water regime. The criteria used for grouping are generally not linked to specific functions, and thus classifications are not true methods for assessing functions. They can, however, provide a basis on which to develop assessment methods (Brinson 1995).

Characterization—a grouping by a distinguishing trait, quality, or property. For example, the Oregon method (Roth et al. 1993) characterizes wetlands by the properties: “provides” a specific function; “has the potential to provide” a function; or “does not provide” a function. These are three distinct attributes that give some information about whether a wetland performs a function, but no information is generated about levels of performance. The Washington State wetland rating systems are characterizations based on five properties (sensitivity to disturbance, rarity, importance, ability to replicate, and relative level of functioning) (Hruby 2004a, b).

Rating—classification based on a grade. Ratings usually group wetlands using the qualitative grades of high, medium, or low on a variety of scales such as the performance of a function or its value. The wetland evaluation technique or WET (Adamus et al. 1987) is probably the most widely used rating method.

Assessment—an estimate or determination of importance or value. This is the first level at which numbers are generated to represent an estimate of performance or value of a function. All commonly used “rapid” numeric methods fall into this category. These methods only provide an assessment that is relative to some predetermined standard. They do not provide an assessment of actual levels of performance or value. The term *assessment* is one of the most commonly misused words in the lexicon of wetland scientists. Almost any method developed is now called an assessment, regardless of whether it might actually be a categorization, a rating, or a true assessment.

Evaluation—a determination or fixing of value. The fixing of value for any item is based on having a generally acceptable currency. Up to now the only currency used has been monetary, and evaluations of wetland functions have most often tried to generate dollar values based on different types of economic models such as the travel cost method, random utility model, hedonic techniques, contingent valuation method (Titre and Henderson 1989, Lipton et al. 1995), or willingness-to-pay method (Farber and Costanza 1987).

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Appendix 2-B

Associations between Species of Wildlife and Wetlands in Washington and Oregon

This appendix shows the level of association between species of wildlife and wetlands in Washington and Oregon in a table. The data are copied directly from the tabulated data on a computer disk provided with Johnson and O'Neil (2001).

Four types of wetland habitat were identified in the document by Johnson and O'Neil. The definitions for these types are summarized below and are from Chappell et al. (2001) and O'Neil and Johnson (2001). Detailed descriptions of the geographic distribution, physical setting, landscape setting, structure, and composition are given in Chappell et al. (2001).

Herbaceous Wetlands (list of species starts on page 4)

Wetlands with the following vegetation types:

- Graminoid Wet Meadow
- Freshwater Aquatic Bed
- Herbaceous and Sedge Wetlands

This habitat is called palustrine emergent wetlands in Cowardin et al. (1979).

Westside Riparian – Wetlands (list of species starts on page 15)

Wetlands with the following vegetation types:

- *Alnus viridis* ssp. *sinuata* – *Acer circinatum* Shrublands
- Westside Riparian and Wetland Deciduous Forests
- *Picea sitchensis* Wetland Forests and Woodlands
- *Tsuga heterophylla*-*Thuja plicata* Coniferous Wetlands
- Westside Riparian/Wetland Shrublands
- Shrub/herbaceous Sphagnum Bogs
- Wooded Bogs

This habitat includes all palustrine forested wetlands and scrub-shrub wetlands at lower elevations west of the Cascades as well as a small subset of persistent emergent wetlands, those with sphagnum bogs. However, drier portions of this habitat in riparian flood plains may not qualify as wetlands according to the Cowardin definition.

Montane Coniferous Wetlands (list of species starts on page 29)

Wetlands with the following vegetation types:

- Westside Montane Coniferous Wetlands
- *Picea engelmannii* Forested Wetlands

This habitat includes nearly all the wettest forests within the *Abies amabilis* and *Tsuga mertensiana* zones of western Washington and most of the wet forests in the *Tsuga heterophylla* and *Abies lasiocarpa* zones of eastern Oregon and Washington.

Eastside (Interior) Riparian – Wetlands (list of species starts on page 38)

Wetlands with the following vegetation types:

- Eastside Midmontane *Alnus incana*-*Salix* spp. Riparian Shrublands
- Eastside Lowland Riparian Shrublands
- Eastside *Populus balsamifera* spp. *trichocarpa*
- *Alnus rhombifolia* Riparian
- *Pinus ponderosa* Riparian Woodlands
- *Populus tremuloides* Riparian/Wetland Forests and Woodlands

This habitat is called palustrine scrub-shrub and palustrine forest in Cowardin and includes some palustrine emergent in the National Wetland Inventory.

Definitions for the Types of Association

(copied from O'Neil and Johnson 2001)

Closely Associated. A species is widely known to depend on a habitat for part or all of its life history requirements. Identifying this association implies that the species has an essential need for this habitat for its maintenance and viability. Some species may be closely associated with more than one habitat; others may be closely associated with only one habitat.

Generally Associated. A species exhibits a high degree of adaptability and may be supported by a number of habitats. In other words, the habitats play a supportive role for its maintenance and viability.

Present. A species demonstrates occasional use of a habitat. The habitat provides marginal support to the species for its maintenance and viability.

The expert panelists developing this list also assigned an overall “confidence rating” to the categorization for each species within each habitat type. The confidence ratings were high (e.g., many peer or published accounts), moderate, and low (e.g., few or no published accounts).

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PLEASE NOTE: The following tables of data do not contain the Latin name of the species. The original tables on Johnson and O'Neil (2001, data on CD) did not have the Latin names although they do have information on each individual species and its Latin name in other databases on the computer disk.

Wildlife Species Found in Herbaceous Wetlands

Amphibians Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Bullfrog	Closely Associated	Feeds and Breeds	High	Requires warm-water ponds, marshes, or river/stream backwaters for breeding.
Columbia Spotted Frog	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish or bullfrogs occur. Requires shallow water in wet meadows or stream/pond edges with abundant aquatic vegetation for breeding.
Great Basin Spadefoot	Closely Associated	Feeds and Breeds	High	Requires ponds or temporary rain-filled depressions for breeding.
Long-toed Salamander	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish are occur. Requires ponds, shallow lake edges, seasonal pools (like elk wallows) or slow streams for breeding.
Northern Leopard Frog	Closely Associated	Feeds and Breeds	High	Requires ponds or lake edges with dense aquatic and emergent vegetation for breeding.
Northwestern Salamander	Closely Associated	Feeds and Breeds	High	Requires ponds or stream backwaters for breeding.
Oregon Spotted Frog	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish or bullfrogs occur. Requires shallow water in wet meadows or stream/pond edges with abundant aquatic vegetation for breeding.
Pacific Chorus (Tree) Frog	Closely Associated	Feeds and Breeds	High	Requires ponds, seasonal pools, temporary rain-filled depressions or slow streams for breeding.
Red-legged Frog	Closely Associated	Feeds and Breeds	High	Requires cool-water ponds, lake edges or slow streams for breeding.
Rough-skinned Newt	Closely Associated	Feeds and Breeds	High	Requires ponds or stream backwaters with abundant aquatic vegetation for breeding.
Tiger Salamander	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish occur. Requires warm ponds or shallow lake edges for breeding.
Western Toad	Closely Associated	Feeds and Breeds	High	Requires ponds or shallow lake edges for breeding.
Woodhouse's Toad	Closely Associated	Feeds and Breeds	High	Requires warm, shallow water in ponds, lakes, or slow streams for breeding.
Cascades Frog	Generally Associated	Feeds and Breeds	Moderate	Range limited to Cascade axis fringe. Requires bogs or ponds with cold springs for breeding.

Birds Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
American Avocet	Closely Associated	Feeds and Breeds	High	None noted.
American Bittern	Closely Associated	Feeds and Breeds	High	None noted.
American Black Duck	Closely Associated	Feeds and Breeds	Low	None noted.
American Coot	Closely Associated	Feeds and Breeds	High	None noted.
American Wigeon	Closely Associated	Feeds and Breeds	High	None noted.
Baird's Sandpiper	Closely Associated	Feeds	Moderate	None noted.
Barn Swallow	Closely Associated	Feeds	High	Can nest anywhere buildings, bridges, or overhanging cliffs occur in close proximity to water.
Black Tern	Closely Associated	Feeds and Breeds	High	None noted.
Black-crowned Night-heron	Closely Associated	Feeds	High	Requires shrubs or trees for nesting.
Black-necked Stilt	Closely Associated	Feeds and Breeds	High	None noted.
Blue-winged Teal	Closely Associated	Feeds and Breeds	High	None noted.
Bufflehead	Closely Associated	Feeds	High	Nests in tree cavities near ponds or lakes.
Canada Goose	Closely Associated	Feeds and Breeds	High	None noted.
Canvasback	Closely Associated	Feeds and Breeds	High	None noted.
Caspian Tern	Closely Associated	Feeds	High	None noted.
Cattle Egret	Closely Associated	Feeds	High	Requires shrubs or trees for nesting.
Cinnamon Teal	Closely Associated	Feeds and Breeds	High	None noted.
Clark's Grebe	Closely Associated	Feeds and Breeds	High	Nests placed on a floating platform of fresh and decaying vegetation in shallow water.
Common Loon	Closely Associated	Feeds and Breeds	Moderate	Nests in emergent vegetation at lake edges. No nesting confirmed in Oregon.
Common Snipe	Closely Associated	Feeds and Breeds	High	None noted.
Common Yellowthroat	Closely Associated	Feeds and Breeds	High	None noted.

Birds Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Dunlin	Closely Associated	Feeds	Moderate	None noted.
Eared Grebe	Closely Associated	Feeds and Breeds	Moderate	Nests placed on a floating platform of fresh and decaying vegetation in shallow water.
Forster's Tern	Closely Associated	Feeds and Breeds	High	None noted.
Franklin's Gull	Closely Associated	Feeds and Breeds	High	Breeds at Mahleur Lake, Oregon.
Gadwall	Closely Associated	Feeds and Breeds	High	None noted.
Great Blue Heron	Closely Associated	Feeds	High	Requires trees for nesting.
Great Egret	Closely Associated	Feeds	High	Requires tall shrubs or trees for nesting.
Greater White-fronted Goose	Closely Associated	Feeds	High	None noted
Greater Yellowlegs	Closely Associated	Feeds	High	Has bred at least four times at Downy Lake, Wallowa County, Oregon.
Green Heron	Closely Associated	Feeds	High	Requires shrubs or trees for nesting.
Green-winged Teal	Closely Associated	Feeds and Breeds	High	None noted.
Horned Grebe	Closely Associated	Feeds and Breeds	Moderate	Nests placed on a floating platform of fresh and decaying vegetation in shallow water.
Least Bittern	Closely Associated	Feeds and Breeds	High	Rare breeder in Oregon; does not occur in Washington.
Least Sandpiper	Closely Associated	Feeds	Moderate	None noted.
Lesser Scaup	Closely Associated	Feeds and Breeds	High	None noted.
Lesser Yellowlegs	Closely Associated	Feeds	High	None noted.
Lincoln's Sparrow	Closely Associated	Feeds and Breeds	Moderate	None noted.
Long-billed Dowitcher	Closely Associated	Feeds	High	None noted.
Mallard	Closely Associated	Feeds and Breeds	High	None noted.
Marsh Wren	Closely Associated	Feeds and Breeds	Moderate	None noted.
Mute Swan	Closely Associated	Feeds and Breeds	Moderate	This is an introduced species which breeds only in urban wetlands.
Northern Pintail	Closely Associated	Feeds and Breeds	High	None noted.

Birds Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Northern Rough-winged Swallow	Closely Associated	Feeds	High	Requires burrows in dirt banks, usually next to water, for nesting.
Northern Shoveler	Closely Associated	Feeds and Breeds	High	None noted.
Pectoral Sandpiper	Closely Associated	Feeds	Moderate	None noted.
Pied-billed Grebe	Closely Associated	Feeds and Breeds	High	Nests placed on a floating platform of fresh and decaying vegetation in shallow water.
Redhead	Closely Associated	Feeds and Breeds	High	None noted.
Red-necked Grebe	Closely Associated	Feeds and Breeds	High	Nests placed on a floating platform of fresh and decaying vegetation in shallow water.
Red-winged Blackbird	Closely Associated	Feeds and Breeds	High	None noted.
Ross's Goose	Closely Associated	Feeds	High	None noted.
Ruddy Duck	Closely Associated	Feeds and Breeds	High	None noted.
Sandhill Crane	Closely Associated	Feeds and Breeds	High	None noted.
Short-eared Owl	Closely Associated	Feeds and Breeds	Moderate	None noted.
Snow Goose	Closely Associated	Feeds	High	None noted.
Snowy Egret	Closely Associated	Feeds	High	Requires tall shrubs or trees for nesting.
Solitary Sandpiper	Closely Associated	Feeds	Moderate	None noted.
Sora	Closely Associated	Feeds and Breeds	High	None noted.
Swamp Sparrow	Closely Associated	Feeds	High	None noted.
Tree Swallow	Closely Associated	Feeds	Moderate	Requires snags not far from open water for nesting.
Tricolored Blackbird	Closely Associated	Feeds and Breeds	High	None noted.
Trumpeter Swan	Closely Associated	Feeds and Breeds	High	None noted.
Tundra Swan	Closely Associated	Feeds	High	None noted.
Virginia Rail	Closely Associated	Feeds and Breeds	High	None noted.

Birds Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Western Grebe	Closely Associated	Feeds and Breeds	High	Nests placed on a floating platform of fresh and decaying vegetation in shallow water.
Western Sandpiper	Closely Associated	Feeds	Moderate	None noted.
White-faced Ibis	Closely Associated	Feeds and Breeds	High	None noted.
Willet	Closely Associated	Feeds and Breeds	High	None noted.
Wilson's Phalarope	Closely Associated	Feeds and Breeds	High	None noted.
Yellow Rail	Closely Associated	Feeds and Breeds	High	None noted.
Yellow-headed Blackbird	Closely Associated	Feeds and Breeds	High	None noted.
American Goldfinch	Generally Associated	Feeds	High	None noted.
American Kestrel	Generally Associated	Feeds	High	None noted.
American Robin	Generally Associated	Feeds	High	None noted.
American White Pelican	Generally Associated	Feeds	High	Feeds in open water areas of wetlands.
Bald Eagle	Generally Associated	Feeds	High	None noted.
Bank Swallow	Generally Associated	Feeds	High	Requires burrows in dirt banks, usually next to water, for nesting.
Barn Owl	Generally Associated	Feeds	High	None noted.
Barrow's Goldeneye	Generally Associated	Feeds	Moderate	Nests in tree cavities near ponds or lakes.
Black-chinned Hummingbird	Generally Associated	Feeds	Low	None noted.
Bobolink	Generally Associated	Feeds and Breeds	Moderate	None noted.
Brewer's Blackbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Brown-headed Cowbird	Generally Associated	Feeds and Breeds	High	None noted.
Burrowing Owl	Generally Associated	Feeds	High	None noted.
California Gull	Generally Associated	Feeds and Breeds	Moderate	None noted.
Cliff Swallow	Generally Associated	Feeds	High	Can nest anywhere rimrock, overhanging cliffs, buildings or bridges occur in close proximity to water.

Birds Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Common Nighthawk	Generally Associated	Feeds	Moderate	None noted.
Common Raven	Generally Associated	Feeds	High	None noted.
Cooper's Hawk	Generally Associated	Feeds	High	None noted.
Double-crested Cormorant	Generally Associated	Reproduces	High	None noted.
Eastern Kingbird	Generally Associated	Feeds	Moderate	None noted.
Eurasian Wigeon	Generally Associated	Feeds	High	None noted.
European Starling	Generally Associated	Feeds	Moderate	Requires snags or trees with cavities or buildings with crevices for nesting. Most likely to use this habitat where adjacent to agriculture or urban habitats.
Glaucous Gull	Generally Associated	Feeds	Low	None noted.
Golden-crowned Sparrow	Generally Associated	Feeds	Moderate	None noted.
Great Gray Owl	Generally Associated	Feeds	High	None noted.
Great Horned Owl	Generally Associated	Feeds	High	None noted.
Gyr Falcon	Generally Associated	Feeds	Moderate	None noted.
Herring Gull	Generally Associated	Feeds	High	None noted.
Hooded Merganser	Generally Associated	Feeds	High	Nests in tree cavities near ponds or lakes.
Killdeer	Generally Associated	Feeds and Breeds	Moderate	None noted.
Long-billed Curlew	Generally Associated	Feeds	Moderate	None noted.
Long-eared Owl	Generally Associated	Feeds	Moderate	None noted.
Northern Goshawk	Generally Associated	Feeds	Moderate	None noted.
Northern Harrier	Generally Associated	Feeds and Breeds	High	None noted.
Palm Warbler	Generally Associated	Feeds	Low	Only along the coast.
Peregrine Falcon	Generally Associated	Feeds	High	None noted.

Birds Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Purple Martin	Generally Associated	Feeds	Low	None noted.
Red-tailed Hawk	Generally Associated	Feeds	High	None noted.
Ring-billed Gull	Generally Associated	Feeds and Breeds	Moderate	None noted.
Ring-necked Duck	Generally Associated	Feeds and Breeds	High	None noted.
Ring-necked Pheasant	Generally Associated	Feeds	High	None noted.
Rough-legged Hawk	Generally Associated	Feeds	Moderate	None noted.
Savannah Sparrow	Generally Associated	Feeds and Breeds	High	None noted.
Sharp-shinned Hawk	Generally Associated	Feeds	High	None noted.
Song Sparrow	Generally Associated	Feeds and Breeds	High	None noted.
Spotted Sandpiper	Generally Associated	Feeds and Breeds	Moderate	None noted.
Swainson's Hawk	Generally Associated	Feeds	Moderate	None noted.
Thayer's Gull	Generally Associated	Feeds	Moderate	None noted.
Turkey Vulture	Generally Associated	Feeds	High	None noted.
Upland Sandpiper	Generally Associated	Feeds and Breeds	High	Has been found at Sycan Marsh, Lake County, Oregon.
Vaux's Swift	Generally Associated	Feeds	Low	None noted.
Violet-green Swallow	Generally Associated	Feeds	Moderate	None noted.
White-crowned Sparrow	Generally Associated	Feeds	Moderate	None noted.
White-throated Swift	Generally Associated	Feeds	Low	Could forage over herbaceous wetlands incidently, such as those found in desert playas.
American Crow	Present	Feeds	High	None noted.
American Dipper	Present	Feeds	Moderate	None noted.
American Pipit	Present	Feeds	Moderate	Winter only.
Bewick's Wren	Present	Feeds	Low	None noted.
Black Swift	Present	Feeds	Low	Black swifts are long-distance foragers that may travel many miles from breeding sites and take advantage of flying insects caught in updrafts over just about any habitat.

Birds Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Black-billed Magpie	Present	Feeds	High	None noted.
Black-capped Chickadee	Present	Feeds	Moderate	None noted.
Calliope Hummingbird	Present	Feeds	Low	None noted.
Cedar Waxwing	Present	Feeds	Moderate	None noted.
Common Goldeneye	Present	Feeds	Moderate	Nests in tree cavities near ponds or lakes.
Golden Eagle	Present	Feeds	High	None noted.
House Finch	Present	Feeds	Moderate	Uses this habitat where it is not too far from urban or agricultural areas.
Lapland Longspur	Present	Feeds	Low	None noted.
Loggerhead Shrike	Present	Feeds	Moderate	None noted.
Merlin	Present	Feeds	Low	None noted.
Northern Pygmy-owl	Present	Feeds	High	None noted.
Northern Shrike	Present	Feeds	High	None noted.
Pine Siskin	Present	Feeds	Low	None noted.
Ruby-crowned Kinglet	Present	Feeds	High	Winter only.
Rufous Hummingbird	Present	Feeds	Moderate	None noted.
Snowy Owl	Present	Feeds	Moderate	None noted.
Western Meadowlark	Present	Feeds	Low	None noted.
Western Screech-owl	Present	Feeds	Moderate	None noted.
Wood Duck	Present	Feeds	Moderate	Nests in tree cavities near ponds or lakes.
Yellow-rumped Warbler	Present	Feeds	Low	None noted.

Mammals Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
American Beaver	Closely Associated	Feeds and Breeds	High	None noted.
Deer Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Long-tailed Vole	Closely Associated	Feeds and Breeds	High	None noted.
Meadow Vole	Closely Associated	Feeds and Breeds	Low	None noted.
Mink	Closely Associated	Feeds	Moderate	None noted.
Montane Vole	Closely Associated	Feeds and Breeds	High	None noted.
Moose	Closely Associated	Feeds	High	None noted.
Muskrat	Closely Associated	Feeds and Breeds	Moderate	None noted.
Northern Bog Lemming	Closely Associated	Feeds and Breeds	Moderate	Cold, wet bogs above 5000 feet.

Mammals Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Northern River Otter	Closely Associated	Feeds and Breeds	High	None noted.
Nutria	Closely Associated	Feeds and Breeds	Moderate	None noted.
Pallid Bat	Closely Associated	Feeds	High	None noted.
Raccoon	Closely Associated	Feeds	Moderate	None noted.
Townsend's Vole	Closely Associated	Feeds and Breeds	High	None noted.
Western Harvest Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Yuma Myotis	Closely Associated	Feeds	High	None noted.
Big Brown Bat	Generally Associated	Feeds	Moderate	None noted.
Black Bear	Generally Associated	Feeds	High	None noted.
Black-tailed Deer	Generally Associated	Feeds	High	None noted.
Bobcat	Generally Associated	Feeds	Moderate	None noted.
Brazilian Free-tailed Bat	Generally Associated	Feeds	High	None noted.
California Myotis	Generally Associated	Feeds	High	None noted.
Columbian White-tailed Deer	Generally Associated	Feeds	High	None noted.
Coyote	Generally Associated	Feeds	High	None noted.
Feral Pig	Generally Associated	Feeds and Breeds	Moderate	Eastern Oregon wet meadows.
Fringed Myotis	Generally Associated	Feeds	Low	None noted.
Hoary Bat	Generally Associated	Feeds	Low	None noted.
Keen's Myotis	Generally Associated	Feeds	Low	None noted.
Little Brown Myotis	Generally Associated	Feeds	High	None noted.
Long-eared Myotis	Generally Associated	Feeds	Moderate	None noted.
Long-legged Myotis	Generally Associated	Feeds	Moderate	None noted.
Long-tailed Weasel	Generally Associated	Feeds	Moderate	None noted.
Mountain Caribou	Generally Associated	Feeds	Moderate	None noted.

Mammals Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Mountain Lion	Generally Associated	Feeds	High	None noted.
Mule Deer	Generally Associated	Feeds	High	None noted.
Pacific Jumping Mouse	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pacific Water Shrew	Generally Associated	Feeds and Breeds	Moderate	Closely tied to water.
Rocky Mountain Elk	Generally Associated	Feeds	High	None noted.
Roosevelt Elk	Generally Associated	Feeds	High	None noted.
Shrew-mole	Generally Associated	Feeds and Breeds	High	None noted.
Silver-haired Bat	Generally Associated	Feeds	Low	None noted.
Spotted Bat	Generally Associated	Feeds	Moderate	None noted.
Striped Skunk	Generally Associated	Feeds	Moderate	None noted.
Townsend's Big-eared Bat	Generally Associated	Feeds	Low	None noted.
Townsend's Mole	Generally Associated	Feeds and Breeds	High	None noted.
Vagrant Shrew	Generally Associated	Feeds and Breeds	Moderate	None noted.
Western Jumping Mouse	Generally Associated	Feeds and Breeds	Low	None noted.
Western Small-footed Myotis	Generally Associated	Feeds	Low	None noted.
White-tailed Deer (Eastside)	Generally Associated	Feeds	High	None noted.
Yellow-bellied Marmot	Generally Associated	Feeds	Low	Requires talus slopes, lava fields, rimrock, or boulder fields in close proximity to grassy openings or meadows.
Common Porcupine	Present	Feeds	Moderate	Needs large shrubs for food.
Feral Horse	Present	Feeds	Low	None noted.
Grizzly Bear	Present	Feeds	Low	None noted.
Preble's Shrew	Present	Feeds and Breeds	Low	None noted.
Wild Burro	Present	Feeds	Low	In southeastern Oregon, this habitat is mostly unavailable due to the fact that they are situated primarily on private lands and are fenced.

Reptiles Associated with Herbaceous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Common Garter Snake	Closely Associated	Feeds and Breeds	High	None noted.
Pacific Coast Aquatic Garter Snake	Present	Feeds and Breeds	Moderate	Uses this habitat where near marshes, streams, rivers, ponds or lakes.
Painted Turtle	Closely Associated	Feeds	Moderate	None noted.
Red-eared Slider Turtle	Closely Associated	Feeds	High	None noted.
Snapping Turtle	Closely Associated	Feeds	Moderate	None noted.
Western Pond Turtle	Closely Associated	Feeds	High	None noted.
Western Terrestrial Garter Snake	Generally Associated	Feeds	High	None noted.

Wildlife Species Found in Westside Riparian - Wetlands

Amphibians Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Bullfrog	Closely Associated	Feeds and Breeds	High	Requires warm-water ponds, marshes, or river/stream backwaters for breeding.
Cascade Torrent Salamander	Closely Associated	Feeds and Breeds	High	Requires very cold, clear seeps, springs, and small streams for breeding.
Columbia Torrent Salamander	Closely Associated	Feeds and Breeds	High	Requires very cold, clear seeps, springs, and small streams for breeding.
Cope's Giant Salamander	Closely Associated	Feeds and Breeds	Moderate	Requires clear, cold steep-gradient streams with a streambed of gravel, boulders and large logs for breeding.
Long-toed Salamander	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish are occur. Requires ponds, shallow lake edges, seasonal pools (like elk wallows) or slow streams for breeding.
Northwestern Salamander	Closely Associated	Feeds and Breeds	High	Requires ponds or stream backwaters for breeding.
Olympic Torrent Salamander	Closely Associated	Feeds and Breeds	High	Requires very cold, clear seeps, springs, and small streams for breeding.
Oregon Spotted Frog	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish or bullfrogs occur. Requires shallow water in wet meadows or stream/pond edges with abundant aquatic vegetation for breeding.
Pacific Chorus (Tree) Frog	Closely Associated	Feeds and Breeds	High	Requires ponds, seasonal pools, temporary rain-filled depressions or slow streams for breeding.
Pacific Giant Salamander	Closely Associated	Feeds and Breeds	Moderate	Requires small to mid-sized streams with a streambed of gravel, boulders and large logs for breeding.
Red-legged Frog	Closely Associated	Feeds and Breeds	High	Requires cool-water ponds, lake edges or slow streams for breeding.
Rough-skinned Newt	Closely Associated	Feeds and Breeds	High	Requires ponds or stream backwaters with abundant aquatic vegetation for breeding.
Southern Torrent Salamander	Closely Associated	Feeds and Breeds	High	Requires very cold, clear seeps, springs, and small streams for breeding.
Tailed Frog	Closely Associated	Feeds and Breeds	Moderate	Requires clear, cold steep-gradient streams for breeding.

Amphibians Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Western Toad	Closely Associated	Feeds and Breeds	High	None noted.
Black Salamander	Generally Associated	Feeds and Breeds	Low	Requires logs, woody debris, or moist talus with woody debris.
California Slender Salamander	Generally Associated	Feeds and Breeds	Moderate	Requires logs.
Cascades Frog	Generally Associated	Feeds and Breeds	Moderate	Requires bogs or ponds with cold springs for breeding.
Dunn's Salamander	Generally Associated	Feeds and Breeds	Moderate	Requires moist or wet rock outcrops, talus, gravel, boulders, or rock crevices
Ensatina	Generally Associated	Feeds and Breeds	High	Requires logs, woody debris, or moist talus with woody debris.
Foothill Yellow-legged Frog	Generally Associated	Feeds and Breeds	High	Requires still-water or gentle gradient portions of streams for breeding.
Oregon Slender Salamander	Generally Associated	Feeds and Breeds	Moderate	Requires large logs, woody debris, or moist talus with woody debris.
Van Dyke's Salamander	Generally Associated	Feeds and Breeds	Moderate	Requires moist talus, rock outcrops, logs, seeps, or woody debris and rocks along streams.
Western Red-backed Salamander	Generally Associated	Feeds and Breeds	High	Requires moist or shaded talus, rocks, or large logs. Occasionally uses springs or stream edges.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
American Black Duck	Closely Associated	Feeds and Breeds	Low	None noted.
American Dipper	Closely Associated	Feeds and Breeds	High	None noted.
Band-tailed Pigeon	Closely Associated	Feeds and Breeds	Moderate	None noted.
Barn Swallow	Closely Associated	Feeds and Breeds	High	Can nest anywhere buildings, bridges, or overhanging cliffs occur in close proximity to water.
Belted Kingfisher	Closely Associated	Feeds and Breeds	High	None noted.
Black Phoebe	Closely Associated	Feeds and Breeds	Moderate	None noted.
Black-throated Gray Warbler	Closely Associated	Feeds and Breeds	High	None noted.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Bullock's Oriole	Closely Associated	Feeds and Breeds	Moderate	None noted.
Cliff Swallow	Closely Associated	Feeds and Breeds	High	Can nest anywhere rimrock, overhanging cliffs, buildings or bridges occur in close proximity to water.
Common Merganser	Closely Associated	Feeds and Breeds	High	Nests in tree cavities near large lakes or rivers.
Common Yellowthroat	Closely Associated	Feeds and Breeds	High	None noted.
Downy Woodpecker	Closely Associated	Feeds and Breeds	Moderate	None noted.
European Starling	Closely Associated	Feeds and Breeds	High	Requires snags or trees with cavities or buildings with crevices for nesting. Most likely to use this habitat where adjacent to agriculture or urban habitats.
Great Blue Heron	Closely Associated	Feeds and Breeds	High	None noted.
Green Heron	Closely Associated	Feeds and Breeds	High	None noted.
Harlequin Duck	Closely Associated	Feeds and Breeds	High	None noted.
Hooded Merganser	Closely Associated	Feeds and Breeds	High	Nests in tree cavities.
Lesser Goldfinch	Closely Associated	Feeds and Breeds	Moderate	None noted.
Lincoln's Sparrow	Closely Associated	Feeds and Breeds	High	None noted.
Mallard	Closely Associated	Feeds and Breeds	High	None noted.
Mourning Dove	Closely Associated	Feeds and Breeds	High	None noted.
Northern Rough-winged Swallow	Closely Associated	Feeds and Breeds	High	Requires burrows in dirt banks, usually next to water, for nesting.
Northern Waterthrush	Closely Associated	Feeds and Breeds	High	None noted.
Purple Finch	Closely Associated	Feeds and Breeds	Moderate	None noted.
Red-eyed Vireo	Closely Associated	Feeds and Breeds	Moderate	Range of red-eyed vireo overlaps that of large black cottonwood groves.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Ring-necked Duck	Closely Associated	Feeds and Breeds	Moderate	None noted.
Ruffed Grouse	Closely Associated	Feeds and Breeds	High	None noted.
Solitary Sandpiper	Closely Associated	Feeds	High	None noted.
Spotted Sandpiper	Closely Associated	Feeds and Breeds	Moderate	None noted.
Swamp Sparrow	Closely Associated	Feeds	High	None noted.
Tree Swallow	Closely Associated	Feeds and Breeds	Moderate	Requires snags not far from open water for nesting.
Warbling Vireo	Closely Associated	Feeds and Breeds	High	None noted.
Western Screech-owl	Closely Associated	Feeds and Breeds	High	None noted.
Willow Flycatcher	Closely Associated	Feeds and Breeds	Moderate	None noted.
Wilson's Warbler	Closely Associated	Feeds and Breeds	High	None noted.
Wood Duck	Closely Associated	Feeds and Breeds	High	Nests in tree cavities.
Yellow Warbler	Closely Associated	Feeds and Breeds	High	None noted.
Yellow-breasted Chat	Closely Associated	Feeds and Breeds	Moderate	None noted.
Allen's Hummingbird	Generally Associated	Feeds and Breeds	Low	None noted.
American Crow	Generally Associated	Feeds and Breeds	High	None noted.
American Goldfinch	Generally Associated	Feeds and Breeds	High	None noted.
American Kestrel	Generally Associated	Feeds and Breeds	High	None noted.
American Robin	Generally Associated	Feeds and Breeds	High	None noted.
American Wigeon	Generally Associated	Feeds	High	None noted.
Bald Eagle	Generally Associated	Feeds and Breeds	High	None noted.
Barn Owl	Generally Associated	Feeds and Breeds	High	Requires cliffs, caves, rimrock, or tree cavities for nesting.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Barred Owl	Generally Associated	Feeds and Breeds	Moderate	None noted.
Bewick's Wren	Generally Associated	Feeds and Breeds	Moderate	None noted.
Black Swift	Generally Associated	Feeds and Breeds	Low	Requires suitable cliffs behind waterfalls for breeding.
Black-capped Chickadee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Black-crowned Night-heron	Generally Associated	Feeds	High	Only one and maybe two known breeding sites exist west of the Cascades, though historically a large breeding colony occurred near Portland.
Black-headed Grosbeak	Generally Associated	Feeds and Breeds	High	None noted.
Brewer's Blackbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Brown Creeper	Generally Associated	Feeds and Breeds	Moderate	None noted.
Brown-headed Cowbird	Generally Associated	Feeds and Breeds	High	None noted.
Bufflehead	Generally Associated	Feeds and Breeds	High	Nests in tree cavities.
Bushtit	Generally Associated	Feeds and Breeds	Moderate	None noted.
California Quail	Generally Associated	Feeds and Breeds	High	Uses this habitat where adjacent to more open habitats.
Cedar Waxwing	Generally Associated	Feeds and Breeds	High	None noted.
Chestnut-backed Chickadee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Common Nighthawk	Generally Associated	Feeds	Moderate	None noted.
Common Raven	Generally Associated	Feeds and Breeds	High	None noted.
Cooper's Hawk	Generally Associated	Feeds and Breeds	High	None noted.
Dark-eyed Junco	Generally Associated	Feeds and Breeds	High	None noted.
Evening Grosbeak	Generally Associated	Feeds and Breeds	Moderate	None noted.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Fox Sparrow	Generally Associated	Feeds	High	Winter only.
Golden-crowned Kinglet	Generally Associated	Feeds and Breeds	High	None noted.
Golden-crowned Sparrow	Generally Associated	Feeds	Moderate	None noted.
Gray Jay	Generally Associated	Feeds and Breeds	Moderate	None noted.
Great Egret	Generally Associated	Feeds and Breeds	Moderate	None noted.
Great Horned Owl	Generally Associated	Feeds and Breeds	High	None noted.
Greater Yellowlegs	Generally Associated	Feeds	Low	None noted.
Green-winged Teal	Generally Associated	Feeds	High	None noted.
Hairy Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Hermit Thrush	Generally Associated	Feeds	High	None noted.
Hermit Warbler	Generally Associated	Feeds and Breeds	Moderate	None noted.
House Wren	Generally Associated	Feeds and Breeds	Moderate	None noted.
Hutton's Vireo	Generally Associated	Feeds and Breeds	High	None noted.
Killdeer	Generally Associated	Feeds and Breeds	Moderate	None noted.
Lazuli Bunting	Generally Associated	Feeds and Breeds	Moderate	None noted.
Least Flycatcher	Generally Associated	Feeds and Breeds	Low	Found nesting near Monroe, Snohomish County, Washington.
Lesser Yellowlegs	Generally Associated	Feeds	Low	None noted.
Macgillivray's Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Merlin	Generally Associated	Feeds and Breeds	Moderate	None noted.
Mountain Quail	Generally Associated	Feeds and Breeds	Moderate	None noted.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Nashville Warbler	Generally Associated	Feeds and Breeds	Moderate	None noted.
Northern Flicker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Northern Goshawk	Generally Associated	Feeds	Moderate	None noted.
Northern Pygmy-owl	Generally Associated	Feeds and Breeds	High	None noted.
Olive-sided Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Orange-crowned Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Osprey	Generally Associated	Feeds and Breeds	High	None noted.
Pacific-slope Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Palm Warbler	Generally Associated	Feeds	Moderate	Only along the coast.
Peregrine Falcon	Generally Associated	Feeds	High	None noted.
Pied-billed Grebe	Generally Associated	Feeds and Breeds	High	Uncertain about the frequency of breeding in this type of habitat.
Pileated Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pine Siskin	Generally Associated	Feeds and Breeds	Moderate	None noted.
Purple Martin	Generally Associated	Feeds and Breeds	Low	None noted.
Red-breasted Nuthatch	Generally Associated	Feeds and Breeds	Moderate	None noted.
Red-breasted Sapsucker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Red-shouldered Hawk	Generally Associated	Feeds and Breeds	Low	None noted.
Red-tailed Hawk	Generally Associated	Feeds and Breeds	High	None noted.
Red-winged Blackbird	Generally Associated	Feeds and Breeds	Low	None noted.
Ring-necked Pheasant	Generally Associated	Feeds and Breeds	High	None noted.
Ruby-crowned Kinglet	Generally Associated	Feeds	High	Winter only.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Rufous Hummingbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Savannah Sparrow	Generally Associated	Feeds and Breeds	Moderate	None noted.
Song Sparrow	Generally Associated	Feeds and Breeds	High	None noted.
Spotted Towhee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Steller's Jay	Generally Associated	Feeds and Breeds	Moderate	None noted.
Swainson's Thrush	Generally Associated	Feeds and Breeds	High	None noted.
Townsend's Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Turkey Vulture	Generally Associated	Feeds and Breeds	High	Requires rocky outcrops, small caves, boulder piles, ledges on high cliffs or large hollow logs for nesting.
Vaux's Swift	Generally Associated	Feeds and Breeds	Moderate	None noted.
Violet-green Swallow	Generally Associated	Feeds and Breeds	Moderate	None noted.
Western Tanager	Generally Associated	Feeds and Breeds	Moderate	None noted.
Western Wood-pewee	Generally Associated	Feeds and Breeds	Moderate	None noted.
White-breasted Nuthatch	Generally Associated	Feeds and Breeds	Moderate	None noted.
White-crowned Sparrow	Generally Associated	Feeds and Breeds	Moderate	None noted.
Wild Turkey	Generally Associated	Feeds	Moderate	Low elevation sites only; likely uses this habitat more for cover than feeding.
Winter Wren	Generally Associated	Feeds and Breeds	Moderate	None noted.
Yellow-rumped Warbler	Generally Associated	Feeds	Moderate	None noted.
American Redstart	Present	Feeds and Breeds	Low	None noted.
American Tree Sparrow	Present	Feeds	Moderate	None noted.
Anna's Hummingbird	Present	Feeds and Breeds	Low	None noted.

Birds Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Ash-throated Flycatcher	Present	Feeds and Breeds	Low	Requires an oak component.
Blue Grouse	Present	Feeds and Breeds	Moderate	None noted.
Bohemian Waxwing	Present	Feeds	Moderate	Occurs in Westside habitats only during irruption years.
Canada Goose	Present	Feeds and Breeds	Moderate	None noted.
Chipping Sparrow	Present	Feeds	Low	None noted.
Common Redpoll	Present	Feeds	Moderate	Only in Skagit and Whatcom counties, Washington.
Double-crested Cormorant	Present	Feeds and Breeds	High	None noted.
House Finch	Present	Feeds and Breeds	Moderate	Uses this habitat where it is not too far from urban or agricultural areas.
Lewis's Woodpecker	Present	Feeds	Moderate	May use as wintering habitat in Oregon; historically occurred in this habitat in western Washington.
Northern Harrier	Present	Feeds and Breeds	High	None noted.
Northern Saw-whet Owl	Present	Feeds and Breeds	Moderate	None noted.
Red Crossbill	Present	Feeds and Breeds	Moderate	None noted.
Rough-legged Hawk	Present	Feeds	High	None noted.
Snowy Egret	Present	Feeds	Moderate	None noted.
Townsend's Solitaire	Present	Feeds	Moderate	None noted.
Veery	Present	Feeds and Breeds	High	None noted.
Western Scrub-Jay	Present	Feeds and Breeds	Moderate	None noted.
White-tailed Kite	Present	Feeds and Breeds	Moderate	None noted.
White-winged Crossbill	Present	Feeds	Low	None noted.

Mammals Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
American Beaver	Closely Associated	Feeds and Breeds	High	None noted.
Deer Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Dusky-footed Woodrat	Closely Associated	Feeds and Breeds	Moderate	None noted.
Fisher	Closely Associated	Feeds and Breeds	Moderate	None noted.
Fog Shrew	Closely Associated	Feeds and Breeds	High	None noted.
Long-tailed Vole	Closely Associated	Feeds and Breeds	High	None noted.
Mink	Closely Associated	Feeds and Breeds	Moderate	None noted.
Mountain Beaver	Closely Associated	Feeds and Breeds	High	None noted.
Muskrat	Closely Associated	Feeds and Breeds	Moderate	None noted.
Northern River Otter	Closely Associated	Feeds and Breeds	High	None noted.
Nutria	Closely Associated	Feeds and Breeds	Moderate	None noted.
Pacific Jumping Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Pacific Shrew	Closely Associated	Feeds and Breeds	High	None noted.
Pacific Water Shrew	Closely Associated	Feeds and Breeds	High	Closely tied to water.
Raccoon	Closely Associated	Feeds and Breeds	Moderate	None noted.
Southern Red-backed Vole	Closely Associated	Feeds and Breeds	High	None noted.
Water Shrew	Closely Associated	Feeds and Breeds	High	Lead a semi-aquatic life and require cold, clear water in small streams or ponds with abundant cover in the form of rocks, overhanging banks, etc.
Water Vole	Closely Associated	Feeds and Breeds	Low	None noted.
White-footed Vole	Closely Associated	Feeds and Breeds	Moderate	None noted.

Mammals Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Yuma Myotis	Closely Associated	Feeds and Breeds	High	More closely associated with water than other bat species. Uses caves, mines, loose bark and bark crevices typically close to water.
Big Brown Bat	Generally Associated	Feeds and Breeds	Moderate	Requires snags, caves, mines, rock crevices, or bridges for breeding and roosting.
Black Bear	Generally Associated	Feeds and Breeds	High	None noted.
Black-tailed Deer	Generally Associated	Feeds and Breeds	High	None noted.
Bobcat	Generally Associated	Feeds and Breeds	Moderate	None noted.
Broad-footed Mole	Generally Associated	Feeds and Breeds	Moderate	None noted.
Brush Rabbit	Generally Associated	Feeds and Breeds	Moderate	None noted.
California Myotis	Generally Associated	Feeds and Breeds	High	Uses rock crevices, hollow trees, mines or caves for breeding.
Coast Mole	Generally Associated	Feeds and Breeds	Moderate	None noted.
Columbian Mouse	Generally Associated	Feeds and Breeds	High	None noted.
Columbian White-tailed Deer	Generally Associated	Feeds and Breeds	High	None noted.
Common Porcupine	Generally Associated	Feeds and Breeds	Moderate	None noted.
Coyote	Generally Associated	Feeds and Breeds	High	None noted.
Creeping Vole	Generally Associated	Feeds and Breeds	High	None noted.
Eastern Cottontail	Generally Associated	Feeds and Breeds	Low	Likely uses this habitat where adjacent to urban or agricultural habitats.
Ermine	Generally Associated	Feeds and Breeds	Low	None noted.
Fringed Myotis	Generally Associated	Feeds and Breeds	Low	Requires caves, mines or rock crevices.
Gray Fox	Generally Associated	Feeds and Breeds	Low	None noted.
Hoary Bat	Generally Associated	Feeds	Low	Requires trees for roosting, but forages in openings and at edges of forests.

Mammals Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Keen's Myotis	Generally Associated	Feeds and Breeds	Low	Little studied; hard to distinguish from long-eared myotis. Likely requires tree cavities for breeding, caves for hibernacula.
Little Brown Myotis	Generally Associated	Feeds and Breeds	High	Uses caves, mines, or hollow trees, often near water.
Long-eared Myotis	Generally Associated	Feeds and Breeds	Moderate	Uses caves, mines, hollow trees, loose bark or rock crevices.
Long-legged Myotis	Generally Associated	Feeds and Breeds	Moderate	Uses caves or mines as hibernacula. Uses hollow trees, loose bark or rock crevices for maternity colonies.
Long-tailed Weasel	Generally Associated	Feeds and Breeds	Moderate	None noted.
Mountain Lion	Generally Associated	Feeds and Breeds	High	None noted.
Northern Flying Squirrel	Generally Associated	Feeds and Breeds	High	None noted.
Pallid Bat	Generally Associated	Feeds	Low	None noted.
Red Fox	Generally Associated	Feeds and Breeds	Low	Non-native Red fox.
Rocky Mountain Elk	Generally Associated	Feeds and Breeds	High	None noted.
Roosevelt Elk	Generally Associated	Feeds and Breeds	High	None noted.
Shrew-mole	Generally Associated	Feeds and Breeds	High	None noted.
Silver-haired Bat	Generally Associated	Feeds	Low	None noted.
Snowshoe Hare	Generally Associated	Feeds and Breeds	High	None noted.
Striped Skunk	Generally Associated	Feeds and Breeds	Moderate	None noted.
Townsend's Big-eared Bat	Generally Associated	Feeds	Moderate	None noted.
Townsend's Chipmunk	Generally Associated	Feeds and Breeds	High	None noted.
Townsend's Mole	Generally Associated	Feeds and Breeds	High	None noted.
Townsend's Vole	Generally Associated	Feeds and Breeds	High	None noted.

Mammals Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Trowbridge's Shrew	Generally Associated	Feeds and Breeds	High	None noted.
Virginia Opossum	Generally Associated	Feeds and Breeds	Low	None noted.
Western Red-backed Vole	Generally Associated	Feeds and Breeds	High	None noted.
Western Spotted Skunk	Generally Associated	Feeds and Breeds	Low	None noted.
American Marten	Present	Feeds and Breeds	Moderate	None noted.
Brazilian Free-tailed Bat	Present	Feeds	Moderate	None noted.
Bushy-tailed Woodrat	Present	Feeds and Breeds	Moderate	None noted.
Heather Vole	Present	Feeds and Breeds	Moderate	None noted.
Masked Shrew	Present	Feeds and Breeds	Moderate	None noted.
Montane Shrew	Present	Feeds and Breeds	Moderate	None noted.
Red Tree Vole	Present	Feeds and Breeds	Moderate	None noted.
Vagrant Shrew	Present	Feeds and Breeds	Moderate	None noted.

Reptiles Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Common Garter Snake	Closely Associated	Feeds and Breeds	High	None noted.
Western Pond Turtle	Closely Associated	Feeds and Breeds	High	None noted.
Northern Alligator Lizard	Generally Associated	Feeds and Breeds	High	None noted.
Northwestern Garter Snake	Generally Associated	Feeds and Breeds	High	None noted.
Pacific Coast Aquatic Garter Snake	Generally Associated	Feeds and Breeds	High	None noted.
Painted Turtle	Generally Associated	Feeds and Breeds	Moderate	None noted.
Red-eared Slider Turtle	Generally Associated	Feeds and Breeds	Moderate	None noted.

Reptiles Associated with Westside Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Rubber Boa	Generally Associated	Feeds and Breeds	High	Usually does not occur far from water.
Sharptail Snake	Generally Associated	Feeds and Breeds	Moderate	None noted.
Snapping Turtle	Generally Associated	Feeds and Breeds	Moderate	Avoids flowing water that lacks vegetation.
Western Rattlesnake	Generally Associated	Feeds and Breeds	High	None noted.
Western Terrestrial Garter Snake	Generally Associated	Feeds and Breeds	High	None noted.
California Mountain Kingsnake	Present	Feeds and Breeds	Moderate	None noted.
Common Kingsnake	Present	Feeds and Breeds	Low	None noted.
Ringneck Snake	Present	Feeds and Breeds	Moderate	None noted.
Southern Alligator Lizard	Present	Feeds and Breeds	Moderate	None noted.

Wildlife Species Found in Montane Coniferous Wetlands

Amphibians Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Long-toed Salamander	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish are occur. Requires ponds, shallow lake edges, seasonal pools (like elk wallows) or slow streams for breeding.
Northwestern Salamander	Closely Associated	Feeds and Breeds	High	Requires ponds or stream backwaters for breeding.
Pacific Chorus (Tree) Frog	Closely Associated	Feeds and Breeds	High	Requires ponds, seasonal pools, temporary rain-filled depressions or slow streams for breeding.
Rough-skinned Newt	Closely Associated	Feeds and Breeds	High	Requires ponds or stream backwaters with abundant aquatic vegetation for breeding.
Western Toad	Closely Associated	Feeds and Breeds	High	None noted.
Cascades Frog	Generally Associated	Feeds and Breeds	High	Requires bogs or ponds with cold springs for breeding.
Columbia Spotted Frog	Generally Associated	Feeds and Breeds	Moderate	Rare or absent where predatory fish or bullfrogs occur. Requires shallow water in wet meadows or stream/pond edges with abundant aquatic vegetation for breeding.
Oregon Spotted Frog	Present	Feeds and Breeds	High	Rare or absent where predatory fish or bullfrogs occur. Requires shallow water in wet meadows or stream/pond edges with abundant aquatic vegetation for breeding.
Pacific Giant Salamander	Present	Feeds and Breeds	High	Requires small to mid-sized streams with a streambed of gravel, boulders and large logs for breeding.
Red-legged Frog	Present	Feeds and Breeds	High	Requires cool-water ponds, lake edges or slow streams for breeding.

Birds Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Bufflehead	Closely Associated	Feeds and Breeds	Moderate	Nests in tree cavities.
Evening Grosbeak	Closely Associated	Feeds and Breeds	Moderate	None noted.
American Robin	Generally Associated	Feeds and Breeds	High	None noted.
Barrow's Goldeneye	Generally Associated	Feeds and Breeds	Moderate	Nests in tree cavities.
Black Swift	Generally Associated	Feeds	Low	Black swifts are long-distance foragers that may travel many miles from breeding sites and take advantage of flying insects caught in updrafts over just about any habitat.
Black-backed Woodpecker	Generally Associated	Feeds and Breeds	Moderate	Reach highest densities in recently burned forests or areas of bark beetle infestations.
Blue Grouse	Generally Associated	Feeds and Breeds	Moderate	None noted.
Bohemian Waxwing	Generally Associated	Feeds	Moderate	There are a few confirmed records of breeding. Nesting habitat usually is beaver ponds and bog areas.
Boreal Chickadee	Generally Associated	Feeds and Breeds	Low	None noted.
Brown Creeper	Generally Associated	Feeds and Breeds	Moderate	None noted.
Calliope Hummingbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Cassin's Finch	Generally Associated	Feeds and Breeds	High	None noted.
Cedar Waxwing	Generally Associated	Feeds and Breeds	Moderate	None noted.
Chestnut-backed Chickadee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Common Nighthawk	Generally Associated	Feeds	Moderate	None noted.
Common Raven	Generally Associated	Feeds and Breeds	High	None noted.
Common Redpoll	Generally Associated	Feeds	Moderate	None noted.
Cooper's Hawk	Generally Associated	Feeds and Breeds	High	None noted.
Dark-eyed Junco	Generally Associated	Feeds and Breeds	High	None noted.

Birds Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Dusky Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Golden-crowned Kinglet	Generally Associated	Feeds and Breeds	High	None noted.
Gray Jay	Generally Associated	Feeds and Breeds	High	None noted.
Great Gray Owl	Generally Associated	Feeds and Breeds	High	None noted.
Hairy Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Hermit Thrush	Generally Associated	Feeds and Breeds	High	None noted.
Hermit Warbler	Generally Associated	Feeds and Breeds	Moderate	None noted.
Macgillivray's Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Mountain Chickadee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Nashville Warbler	Generally Associated	Feeds and Breeds	Moderate	None noted.
Northern Flicker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Northern Goshawk	Generally Associated	Feeds and Breeds	High	None noted.
Northern Pygmy-owl	Generally Associated	Feeds and Breeds	Low	None noted.
Northern Saw-whet Owl	Generally Associated	Feeds and Breeds	Moderate	None noted.
Olive-sided Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pacific-slope Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Peregrine Falcon	Generally Associated	Feeds	High	None noted.
Pileated Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pine Grosbeak	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pine Siskin	Generally Associated	Feeds and Breeds	High	None noted.
Red Crossbill	Generally Associated	Feeds and Breeds	Moderate	None noted.

Birds Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Red-breasted Nuthatch	Generally Associated	Feeds and Breeds	Moderate	None noted.
Red-breasted Sapsucker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Ruby-crowned Kinglet	Generally Associated	Feeds and Breeds	High	None noted.
Ruffed Grouse	Generally Associated	Feeds and Breeds	Moderate	None noted.
Rufous Hummingbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Song Sparrow	Generally Associated	Feeds and Breeds	Moderate	None noted.
Spruce Grouse	Generally Associated	Feeds and Breeds	High	Uses this habitat where adjacent to lodgepole alpine forest.
Steller's Jay	Generally Associated	Feeds and Breeds	Moderate	None noted.
Swainson's Thrush	Generally Associated	Feeds and Breeds	High	None noted.
Three-toed Woodpecker	Generally Associated	Feeds and Breeds	Moderate	Reach highest densities in recently burned forests or areas of bark beetle infestations.
Townsend's Warbler	Generally Associated	Feeds and Breeds	Moderate	None noted.
Tree Swallow	Generally Associated	Feeds and Breeds	Moderate	Requires snags not far from open water for nesting.
Varied Thrush	Generally Associated	Feeds and Breeds	Moderate	None noted.
Vaux's Swift	Generally Associated	Feeds and Breeds	Moderate	None noted.
Violet-green Swallow	Generally Associated	Feeds and Breeds	Moderate	None noted.
Warbling Vireo	Generally Associated	Feeds and Breeds	Low	None noted.
Western Tanager	Generally Associated	Feeds and Breeds	Moderate	None noted.
Williamson's Sapsucker	Generally Associated	Feeds and Breeds	Low	None noted.
Willow Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Wilson's Warbler	Generally Associated	Feeds and Breeds	High	None noted.

Birds Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Winter Wren	Generally Associated	Feeds and Breeds	Moderate	None noted.
Yellow-rumped Warbler	Generally Associated	Feeds and Breeds	Moderate	None noted.
American Crow	Present	Feeds and Breeds	High	None noted.
American Kestrel	Present	Feeds and Breeds	Moderate	None noted.
Barn Swallow	Present	Feeds and Breeds	Moderate	Can nest anywhere buildings, bridges, or overhanging cliffs occur in close proximity to water.
Brown-headed Cowbird	Present	Feeds and Breeds	Moderate	None noted.
Chipping Sparrow	Present	Feeds and Breeds	Low	None noted.
Clark's Nutcracker	Present	Feeds	Low	None noted.
European Starling	Present	Feeds and Breeds	Low	Requires snags or trees with cavities or buildings with crevices for nesting. Most likely to use this habitat where adjacent to agriculture or urban habitats.
Great Horned Owl	Present	Feeds and Breeds	High	None noted.
Merlin	Present	Feeds	Low	None noted.
Mountain Bluebird	Present	Feeds and Breeds	Moderate	None noted.
Northern Rough-winged Swallow	Present	Feeds	Moderate	Requires burrows in dirt banks, usually next to water, for nesting.
Turkey Vulture	Present	Feeds and Breeds	Low	Requires rocky outcrops, small caves, boulder piles, ledges on high cliffs or large hollow logs for nesting.
Western Screech-owl	Present	Feeds and Breeds	Moderate	None noted.
White-winged Crossbill	Present	Feeds and Breeds	Moderate	None noted.
Wood Duck	Present	Feeds and Breeds	Moderate	Nests in tree cavities.

Mammals Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Big Brown Bat	Closely Associated	Feeds and Breeds	High	Requires snags, caves, mines, rock crevices, or bridges for breeding and roosting.
Deer Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Long-tailed Vole	Closely Associated	Feeds and Breeds	High	None noted.
Pacific Jumping Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Snowshoe Hare	Closely Associated	Feeds and Breeds	High	None noted.
Southern Red-backed Vole	Closely Associated	Feeds and Breeds	High	None noted.
Water Shrew	Closely Associated	Feeds and Breeds	High	Lead a semi-aquatic life and require cold, clear water in small streams or ponds with abundant cover in the form of rocks, overhanging banks, etc.
Water Vole	Closely Associated	Feeds and Breeds	Low	None noted.
Yuma Myotis	Closely Associated	Feeds and Breeds	High	More closely associated with water than other bat species. Uses caves, mines, loose bark and bark crevices typically close to water.
American Beaver	Generally Associated	Feeds and Breeds	High	None noted.
American Marten	Generally Associated	Feeds and Breeds	Moderate	None noted.
Black Bear	Generally Associated	Feeds and Breeds	High	None noted.
Black-tailed Deer	Generally Associated	Feeds and Breeds	High	None noted.
Bobcat	Generally Associated	Feeds	Moderate	None noted.
Bushy-tailed Woodrat	Generally Associated	Feeds and Breeds	Moderate	None noted.
California Myotis	Generally Associated	Feeds and Breeds	High	Uses rock crevices, hollow trees, mines or caves for breeding.
Columbian Ground Squirrel	Generally Associated	Feeds and Breeds	Moderate	None noted.
Columbian Mouse	Generally Associated	Feeds and Breeds	High	None noted.

Mammals Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Common Porcupine	Generally Associated	Feeds and Breeds	Moderate	None noted.
Coyote	Generally Associated	Feeds and Breeds	High	None noted.
Creeping Vole	Generally Associated	Feeds and Breeds	High	None noted.
Fisher	Generally Associated	Feeds and Breeds	Low	None noted.
Golden-mantled Ground Squirrel	Generally Associated	Feeds and Breeds	Moderate	None noted.
Hoary Bat	Generally Associated	Feeds	Low	Requires trees for roosting, but forages in openings and at edges of forests.
Little Brown Myotis	Generally Associated	Feeds	High	Uses caves, mines, or hollow trees, often near water.
Long-eared Myotis	Generally Associated	Feeds and Breeds	Moderate	Uses caves, mines, hollow trees, loose bark or rock crevices.
Long-tailed Weasel	Generally Associated	Feeds and Breeds	Moderate	None noted.
Mink	Generally Associated	Feeds and Breeds	Moderate	None noted.
Montane Vole	Generally Associated	Feeds and Breeds	High	None noted.
Moose	Generally Associated	Feeds and Breeds	Moderate	None noted.
Mountain Caribou	Generally Associated	Feeds and Breeds	High	None noted.
Mountain Lion	Generally Associated	Feeds	High	None noted.
Mule Deer	Generally Associated	Feeds and Breeds	High	None noted.
Northern Bog Lemming	Generally Associated	Feeds and Breeds	Moderate	None noted.
Northern Flying Squirrel	Generally Associated	Feeds and Breeds	High	None noted.
Northern Pocket Gopher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pacific Water Shrew	Generally Associated	Feeds and Breeds	High	Closely tied to water.
Rocky Mountain Elk	Generally Associated	Feeds and Breeds	High	None noted.

Mammals Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Roosevelt Elk	Generally Associated	Feeds and Breeds	High	None noted.
Shrew-mole	Generally Associated	Feeds and Breeds	High	None noted.
Silver-haired Bat	Generally Associated	Feeds and Breeds	Moderate	Uses trees, bark crevices, and snags for summer roosts; if present in winter, may use caves, mines, or rock crevices for hibernacula.
Townsend's Big-eared Bat	Generally Associated	Feeds	Moderate	None noted.
Townsend's Chipmunk	Generally Associated	Feeds and Breeds	High	None noted.
Trowbridge's Shrew	Generally Associated	Feeds and Breeds	High	None noted.
Western Jumping Mouse	Generally Associated	Feeds and Breeds	Moderate	None noted.
Western Spotted Skunk	Generally Associated	Feeds and Breeds	Low	None noted.
Wolverine	Generally Associated	Feeds and Breeds	Low	None noted.
Coast Mole	Present	Feeds and Breeds	Moderate	None noted.
Ermine	Present	Feeds and Breeds	Low	None noted.
Fringed Myotis	Present	Feeds	Low	Requires caves, mines or rock crevices.
Grizzly Bear	Present	Feeds	Moderate	None noted.
Heather Vole	Present	Feeds and Breeds	Moderate	None noted.
Long-legged Myotis	Present	Feeds and Breeds	Moderate	Uses caves or mines as hibernacula. Uses hollow trees, loose bark or rock crevices for maternity colonies.
Lynx	Present	Feeds	Low	None noted.
Masked Shrew	Present	Feeds and Breeds	Moderate	None noted.
Montane Shrew	Present	Feeds and Breeds	Low	None noted.
Vagrant Shrew	Present	Feeds and Breeds	Moderate	None noted.

Reptiles Associated with Montane Coniferous Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Common Garter Snake	Closely Associated	Feeds and Breeds	Moderate	None noted.
Rubber Boa	Generally Associated	Feeds and Breeds	High	Usually does not occur far from water.

Wildlife Species Found in Eastside (Interior) Riparian -Wetlands

Amphibians Associated with Eastside (Interior) Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Bullfrog	Closely Associated	Feeds and Breeds	High	Requires warm-water ponds, marshes, or river/stream backwaters for breeding.
Columbia Spotted Frog	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish or bullfrogs occur. Requires shallow water in wet meadows or stream/pond edges with abundant aquatic vegetation for breeding.
Great Basin Spadefoot	Closely Associated	Feeds and Breeds	High	Requires ponds or temporary rain-filled depressions for breeding.
Long-toed Salamander	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish are occur. Requires ponds, shallow lake edges, seasonal pools (like elk wallows) or slow streams for breeding.
Northern Leopard Frog	Closely Associated	Feeds and Breeds	High	Requires ponds or lake edges with dense aquatic and emergent vegetation for breeding.
Pacific Chorus (Tree) Frog	Closely Associated	Feeds and Breeds	High	Requires ponds, seasonal pools, temporary rain-filled depressions or slow streams for breeding.
Tailed Frog	Closely Associated	Feeds and Breeds	Moderate	Requires clear, cold steep-gradient streams for breeding.
Tiger Salamander	Closely Associated	Feeds and Breeds	High	Rare or absent where predatory fish occur. Requires warm ponds or shallow lake edges for breeding.
Western Toad	Closely Associated	Feeds and Breeds	High	None noted.
Woodhouse's Toad	Closely Associated	Feeds and Breeds	High	Requires warm, shallow water in ponds, lakes, or slow streams for breeding.
Cascades Frog	Generally Associated	Feeds and Breeds	Moderate	Requires bogs or ponds with cold springs for breeding.
Northwestern Salamander	Present	Feeds and Breeds	High	Range extends only peripherally into the eastside Cascades in Washington only. Requires ponds or stream backwaters for breeding.
Red-legged Frog	Present	Feeds and Breeds	High	Range extends only peripherally into the eastside Cascades.

Amphibians Associated with Eastside (Interior) Riparian - Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Rough-skinned Newt	Present	Feeds and Breeds	High	Range doesn't extend very far east of Cascades. Needs ponds/backwaters & profuse aquatic vegetation breed.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
American Black Duck	Closely Associated	Feeds and Breeds	Low	None noted.
American Dipper	Closely Associated	Feeds and Breeds	High	None noted.
American Redstart	Closely Associated	Feeds and Breeds	High	None noted.
Bank Swallow	Closely Associated	Feeds and Breeds	High	Requires burrows in dirt banks, usually next to water, for nesting.
Barn Swallow	Closely Associated	Feeds and Breeds	High	Can nest anywhere buildings, bridges, or overhanging cliffs occur in close proximity to water.
Belted Kingfisher	Closely Associated	Feeds and Breeds	High	None noted.
Black-billed Magpie	Closely Associated	Feeds and Breeds	High	None noted.
Black-crowned Night-heron	Closely Associated	Feeds and Breeds	High	Occur in wide bottomlands, not narrow canyons.
Blue Grouse	Closely Associated	Feeds and Breeds	High	None noted.
Bullock's Oriole	Closely Associated	Feeds and Breeds	Moderate	None noted.
Cedar Waxwing	Closely Associated	Feeds and Breeds	High	None noted.
Cliff Swallow	Closely Associated	Feeds and Breeds	Moderate	Can nest anywhere rimrock, overhanging cliffs, buildings or bridges occur in close proximity to water.
Common Merganser	Closely Associated	Feeds and Breeds	High	Nests in tree cavities near large lakes or rivers.
Common Yellowthroat	Closely Associated	Feeds and Breeds	High	None noted.
Cordilleran Flycatcher	Closely Associated	Feeds and Breeds	Moderate	None noted.
Double-crested Cormorant	Closely Associated	Feeds and Breeds	High	None noted.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
European Starling	Closely Associated	Feeds and Breeds	High	Requires snags or trees with cavities or buildings with crevices for nesting. Most likely to use this habitat where adjacent to agriculture or urban habitats.
Fox Sparrow	Closely Associated	Feeds and Breeds	High	None noted.
Gray Catbird	Closely Associated	Feeds and Breeds	High	None noted.
Great Blue Heron	Closely Associated	Feeds and Breeds	High	None noted.
Great Egret	Closely Associated	Feeds and Breeds	High	More common in broad flood plains; does not occur in narrow riparian corridors as a breeder.
Harlequin Duck	Closely Associated	Feeds and Breeds	High	None noted.
Hooded Merganser	Closely Associated	Feeds and Breeds	Moderate	Nests in tree cavities.
Lazuli Bunting	Closely Associated	Feeds and Breeds	High	None noted.
Lincoln's Sparrow	Closely Associated	Feeds and Breeds	Moderate	None noted.
Long-eared Owl	Closely Associated	Feeds and Breeds	High	Typically nests in the abandoned nests of other corvids, raptors or squirrels.
Mallard	Closely Associated	Feeds and Breeds	High	None noted.
Mourning Dove	Closely Associated	Feeds and Breeds	High	None noted.
Northern Rough-winged Swallow	Closely Associated	Feeds and Breeds	High	Requires burrows in dirt banks, usually next to water, for nesting.
Northern Waterthrush	Closely Associated	Feeds and Breeds	High	None noted.
Pygmy Nuthatch	Closely Associated	Feeds and Breeds	Moderate	Uses this habitat where ponderosa pine occurs.
Red-eyed Vireo	Closely Associated	Feeds and Breeds	Moderate	Range of red-eyed vireo overlaps that of large black cottonwood groves.
Red-naped Sapsucker	Closely Associated	Feeds and Breeds	High	None noted.
Ring-necked Pheasant	Closely Associated	Feeds and Breeds	High	None noted.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Ruffed Grouse	Closely Associated	Feeds and Breeds	High	None noted.
Sharp-tailed Grouse	Closely Associated	Feeds	High	In Oregon this was historically very important overwintering habitat.
Snowy Egret	Closely Associated	Feeds and Breeds	High	Requires tall shrubs or trees for nesting.
Solitary Sandpiper	Closely Associated	Feeds	Moderate	None noted.
Spotted Sandpiper	Closely Associated	Feeds and Breeds	Moderate	None noted.
Tree Swallow	Closely Associated	Feeds and Breeds	Moderate	Requires snags not far from open water for nesting.
Veery	Closely Associated	Feeds and Breeds	High	None noted.
Warbling Vireo	Closely Associated	Feeds and Breeds	High	None noted.
Western Screech-owl	Closely Associated	Feeds and Breeds	High	None noted.
Willow Flycatcher	Closely Associated	Feeds and Breeds	Moderate	None noted.
Wood Duck	Closely Associated	Feeds and Breeds	High	Nests in tree cavities.
Yellow Warbler	Closely Associated	Feeds and Breeds	High	None noted.
Yellow-billed Cuckoo	Closely Associated	Feeds and Breeds	Moderate	Not known from eastside Washington (even historically); in Oregon species may still occur in a few scattered locations.
Yellow-breasted Chat	Closely Associated	Feeds and Breeds	Moderate	None noted.
American Crow	Generally Associated	Feeds and Breeds	High	None noted.
American Goldfinch	Generally Associated	Feeds and Breeds	High	None noted.
American Kestrel	Generally Associated	Feeds and Breeds	High	None noted.
American Robin	Generally Associated	Feeds and Breeds	High	None noted.
American Tree Sparrow	Generally Associated	Feeds	Moderate	None noted.
Bald Eagle	Generally Associated	Feeds and Breeds	High	None noted.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Barn Owl	Generally Associated	Feeds and Breeds	High	Requires cliffs, caves, rimrock, or tree cavities for nesting.
Black Swift	Generally Associated	Feeds and Breeds	Low	Requires suitable cliffs behind waterfalls for breeding.
Black-capped Chickadee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Black-chinned Hummingbird	Generally Associated	Feeds and Breeds	Low	None noted.
Black-headed Grosbeak	Generally Associated	Feeds and Breeds	High	None noted.
Black-throated Gray Warbler	Generally Associated	Feeds and Breeds	Low	None noted.
Bobolink	Generally Associated	Feeds and Breeds	Moderate	None noted.
Bohemian Waxwing	Generally Associated	Feeds	Moderate	None noted.
Brewer's Blackbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Broad-tailed Hummingbird	Generally Associated	Feeds and Breeds	Low	High elevation, montane riparian. Breeding suspected but not confirmed. Birds have been found in eastside riparian aspen and willow habitats.
Brown Creeper	Generally Associated	Feeds and Breeds	Moderate	None noted.
Brown-headed Cowbird	Generally Associated	Feeds and Breeds	High	None noted.
Bufflehead	Generally Associated	Feeds and Breeds	Moderate	Nests in tree cavities.
Bushtit	Generally Associated	Feeds and Breeds	Moderate	None noted.
California Quail	Generally Associated	Feeds and Breeds	High	Uses this habitat where adjacent to more open habitats.
Calliope Hummingbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Canyon Wren	Generally Associated	Feeds and Breeds	Moderate	Requires rocky outcrops, cliffs for nesting.
Cassin's Finch	Generally Associated	Feeds and Breeds	High	None noted.
Cassin's Vireo	Generally Associated	Feeds and Breeds	Moderate	None noted.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Cattle Egret	Generally Associated	Feeds and Breeds	High	Requires shrubs or trees for nesting.
Chipping Sparrow	Generally Associated	Feeds and Breeds	Moderate	None noted.
Common Nighthawk	Generally Associated	Feeds	Moderate	None noted.
Common Raven	Generally Associated	Feeds and Breeds	High	None noted.
Common Redpoll	Generally Associated	Feeds	Moderate	None noted.
Cooper's Hawk	Generally Associated	Feeds and Breeds	High	None noted.
Dark-eyed Junco	Generally Associated	Feeds and Breeds	High	None noted.
Downy Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Dusky Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Eastern Kingbird	Generally Associated	Feeds and Breeds	Moderate	Requires groves of hardwoods for breeding.
Evening Grosbeak	Generally Associated	Feeds and Breeds	Moderate	None noted.
Flammulated Owl	Generally Associated	Feeds and Breeds	Moderate	Must have ponderosa pine/aspen.
Golden Eagle	Generally Associated	Feeds and Breeds	High	Needs cliffs for nesting.
Golden-crowned Kinglet	Generally Associated	Feeds and Breeds	Moderate	None noted.
Golden-crowned Sparrow	Generally Associated	Feeds	Moderate	None noted.
Gray Jay	Generally Associated	Feeds and Breeds	Moderate	None noted.
Great Horned Owl	Generally Associated	Feeds and Breeds	High	None noted.
Greater Yellowlegs	Generally Associated	Feeds	Low	None noted.
Green-winged Teal	Generally Associated	Feeds	High	None noted.
Hairy Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Hermit Thrush	Generally Associated	Feeds and Breeds	High	None noted.
House Wren	Generally Associated	Feeds and Breeds	Moderate	None noted.
Killdeer	Generally Associated	Feeds and Breeds	Moderate	None noted.
Least Flycatcher	Generally Associated	Feeds and Breeds	Low	Has bred regularly at Clyde Holiday State Wayside, Grant County, Oregon, and numerous singing males have been found in eastside hardwood riparian habitats in Washington.
Lesser Yellowlegs	Generally Associated	Feeds	Low	None noted.
Lewis's Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Macgillivray's Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Mountain Bluebird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Mountain Chickadee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Mountain Quail	Generally Associated	Feeds and Breeds	High	None noted.
Nashville Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Northern Flicker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Northern Goshawk	Generally Associated	Feeds and Breeds	High	None noted.
Northern Pygmy-owl	Generally Associated	Feeds and Breeds	High	None noted.
Olive-sided Flycatcher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Orange-crowned Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Osprey	Generally Associated	Feeds and Breeds	High	None noted.
Peregrine Falcon	Generally Associated	Feeds and Breeds	High	Needs cliffs for nesting.
Pied-billed Grebe	Generally Associated	Feeds and Breeds	High	None noted.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Pileated Woodpecker	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pine Siskin	Generally Associated	Feeds and Breeds	High	None noted.
Red-breasted Nuthatch	Generally Associated	Feeds and Breeds	Moderate	None noted.
Red-breasted Sapsucker	Generally Associated	Feeds and Breeds	Moderate	Only in south-central Oregon: may hybridize with Red-naped sapsucker in Eastside riparian.
Red-tailed Hawk	Generally Associated	Feeds and Breeds	High	None noted.
Red-winged Blackbird	Generally Associated	Feeds and Breeds	High	None noted.
Ring-necked Duck	Generally Associated	Feeds and Breeds	High	None noted.
Rufous Hummingbird	Generally Associated	Feeds and Breeds	Moderate	None noted.
Sandhill Crane	Generally Associated	Feeds and Breeds	High	Uses open riparian areas with only scattered willows or willow clumps.
Savannah Sparrow	Generally Associated	Feeds and Breeds	Moderate	None noted.
Say's Phoebe	Generally Associated	Feeds and Breeds	Moderate	Needs cliffs or rimrock for nesting.
Song Sparrow	Generally Associated	Feeds and Breeds	High	None noted.
Spotted Towhee	Generally Associated	Feeds and Breeds	Moderate	None noted.
Steller's Jay	Generally Associated	Feeds and Breeds	Moderate	None noted.
Swainson's Hawk	Generally Associated	Feeds and Breeds	High	None noted.
Swainson's Thrush	Generally Associated	Feeds and Breeds	High	None noted.
Townsend's Solitaire	Generally Associated	Feeds	Moderate	None noted.
Turkey Vulture	Generally Associated	Feeds and Breeds	High	Requires rocky outcrops, small caves, boulder piles, ledges on high cliffs or large hollow logs for nesting.
Violet-green Swallow	Generally Associated	Feeds and Breeds	Moderate	None noted.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Western Bluebird	Generally Associated	Feeds and Breeds	High	None noted.
Western Tanager	Generally Associated	Feeds and Breeds	Moderate	None noted.
Western Wood-pewee	Generally Associated	Feeds and Breeds	Moderate	None noted.
White-breasted Nuthatch	Generally Associated	Feeds and Breeds	Moderate	Uses this habitat where ponderosa pine and hardwoods occur in the riparian zone.
White-crowned Sparrow	Generally Associated	Feeds and Breeds	High	None noted.
White-headed Woodpecker	Generally Associated	Feeds and Breeds	Low	Requires a ponderosa pine component.
White-throated Swift	Generally Associated	Feeds	Low	May use riparian areas as travel corridors.
Wild Turkey	Generally Associated	Feeds and Breeds	High	None noted.
Williamson's Sapsucker	Generally Associated	Feeds and Breeds	Low	None noted.
Wilson's Warbler	Generally Associated	Feeds and Breeds	High	None noted.
Winter Wren	Generally Associated	Feeds and Breeds	Moderate	None noted.
Yellow-rumped Warbler	Generally Associated	Feeds and Breeds	Moderate	None noted.
American Wigeon	Present	Feeds	Moderate	None noted.
Ash-throated Flycatcher	Present	Feeds and Breeds	Low	None noted.
Band-tailed Pigeon	Present	Feeds	Moderate	None noted.
Barred Owl	Present	Feeds and Breeds	Moderate	None noted.
Black-backed Woodpecker	Present	Feeds and Breeds	Moderate	None noted.
Canada Goose	Present	Feeds and Breeds	Moderate	None noted.
Chukar	Present	Feeds	Moderate	None noted.
Green-tailed Towhee	Present	Feeds and Breeds	Moderate	None noted.
House Finch	Present	Feeds and Breeds	Moderate	Uses this habitat where it is not too far from urban or agricultural areas.

Birds Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Lesser Goldfinch	Present	Feeds and Breeds	Moderate	None noted.
Merlin	Present	Feeds	Low	None noted.
Northern Harrier	Present	Feeds and Breeds	High	None noted.
Northern Saw-whet Owl	Present	Feeds and Breeds	Low	None noted.
Prairie Falcon	Present	Feeds and Breeds	High	Needs cliffs for nesting.
Red Crossbill	Present	Feeds	Low	None noted.
Rough-legged Hawk	Present	Feeds	High	None noted.
Ruby-crowned Kinglet	Present	Feeds and Breeds	Moderate	None noted.
Three-toed Woodpecker	Present	Feeds and Breeds	Moderate	None noted.
Townsend's Warbler	Present	Feeds and Breeds	Low	Heavy use during migration, and occasional breeding where conifers are present.
Vaux's Swift	Present	Feeds and Breeds	Low	None noted.

Mammals Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
American Beaver	Closely Associated	Feeds and Breeds	High	None noted.
Big Brown Bat	Closely Associated	Feeds and Breeds	High	Requires snags, caves, mines, rock crevices, or bridges for breeding and roosting.
Bushy-tailed Woodrat	Closely Associated	Feeds and Breeds	High	None noted.
Deer Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Long-legged Myotis	Closely Associated	Feeds and Breeds	Moderate	Uses caves or mines as hibernacula. Uses hollow trees, loose bark or rock crevices for maternity colonies.
Long-tailed Vole	Closely Associated	Feeds and Breeds	High	None noted.
Meadow Vole	Closely Associated	Feeds and Breeds	Low	None noted.
Mink	Closely Associated	Feeds and Breeds	Moderate	None noted.

Mammals Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Muskrat	Closely Associated	Feeds and Breeds	Moderate	None noted.
Northern River Otter	Closely Associated	Feeds and Breeds	High	None noted.
Pacific Jumping Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Pallid Bat	Closely Associated	Feeds and Breeds	Moderate	Requires rock cliffs, caves or mines for breeding.
Raccoon	Closely Associated	Feeds and Breeds	Moderate	None noted.
Snowshoe Hare	Closely Associated	Feeds and Breeds	High	None noted.
Southern Red-backed Vole	Closely Associated	Feeds and Breeds	High	None noted.
Water Shrew	Closely Associated	Feeds and Breeds	High	Lead a semi-aquatic life and require cold, clear water in small streams or ponds with abundant cover in the form of rocks, overhanging banks, etc.
Water Vole	Closely Associated	Feeds and Breeds	Low	None noted.
Western Harvest Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Western Jumping Mouse	Closely Associated	Feeds and Breeds	High	None noted.
Western Pipistrelle	Closely Associated	Feeds and Breeds	High	Requires cliffs, rimrock, caves or mines for breeding and roosting.
Western Small-footed Myotis	Closely Associated	Feeds and Breeds	Moderate	Requires cliffs, rimrock, boulders, or talus for breeding.
White-tailed Deer (Eastside)	Closely Associated	Feeds and Breeds	High	None noted.
Yuma Myotis	Closely Associated	Feeds and Breeds	High	More closely associated with water than other bat species. Uses caves, mines, loose bark and bark crevices typically close to water.
Black Bear	Generally Associated	Feeds and Breeds	High	None noted.
Black-tailed Deer	Generally Associated	Feeds and Breeds	High	None noted.
Bobcat	Generally Associated	Feeds and Breeds	Moderate	None noted.
Broad-footed Mole	Generally Associated	Feeds and Breeds	Moderate	None noted.

Mammals Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Brush Rabbit	Generally Associated	Feeds and Breeds	Moderate	None noted.
California Myotis	Generally Associated	Feeds and Breeds	High	Uses rock crevices, hollow trees, mines or caves for breeding.
Columbian Ground Squirrel	Generally Associated	Feeds and Breeds	Moderate	None noted.
Columbian Mouse	Generally Associated	Feeds and Breeds	Moderate	None noted.
Common Porcupine	Generally Associated	Feeds and Breeds	Moderate	None noted.
Coyote	Generally Associated	Feeds and Breeds	High	None noted.
Creeping Vole	Generally Associated	Feeds and Breeds	High	None noted.
Eastern Cottontail	Generally Associated	Feeds and Breeds	Low	Likely uses this habitat where adjacent to urban or agricultural habitats.
Eastern Fox Squirrel	Generally Associated	Feeds and Breeds	Moderate	None noted.
Ermine	Generally Associated	Feeds and Breeds	Low	None noted.
Feral Horse	Generally Associated	Feeds	Low	None noted.
Feral Pig	Generally Associated	Feeds and Breeds	Moderate	None noted.
Fisher	Generally Associated	Feeds and Breeds	Low	None noted.
Fringed Myotis	Generally Associated	Feeds and Breeds	Low	Requires caves, mines or rock crevices.
Hoary Bat	Generally Associated	Feeds	Moderate	Requires trees for roosting, but forages in openings and at edges of forests.
Little Brown Myotis	Generally Associated	Feeds and Breeds	High	Uses caves, mines, or hollow trees, often near water.
Long-eared Myotis	Generally Associated	Feeds and Breeds	Moderate	Uses caves, mines, hollow trees, loose bark or rock crevices.
Long-tailed Weasel	Generally Associated	Feeds and Breeds	Moderate	None noted.
Masked Shrew	Generally Associated	Feeds and Breeds	High	None noted.
Montane Vole	Generally Associated	Feeds and Breeds	High	None noted.

Mammals Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Moose	Generally Associated	Feeds and Breeds	High	None noted.
Mountain Caribou	Generally Associated	Feeds and Breeds	High	None noted.
Mountain Lion	Generally Associated	Feeds and Breeds	High	None noted.
Mule Deer	Generally Associated	Feeds and Breeds	High	None noted.
Northern Flying Squirrel	Generally Associated	Feeds and Breeds	High	None noted.
Northern Pocket Gopher	Generally Associated	Feeds and Breeds	Moderate	None noted.
Pacific Water Shrew	Generally Associated	Feeds and Breeds	Moderate	Closely tied to water.
Red Fox	Generally Associated	Feeds and Breeds	Low	Non-native Red fox.
Rocky Mountain Elk	Generally Associated	Feeds and Breeds	High	None noted.
Shrew-mole	Generally Associated	Feeds and Breeds	High	None noted.
Silver-haired Bat	Generally Associated	Feeds and Breeds	Moderate	Uses trees, bark crevices, and snags for summer roosts; if present in winter, may use caves, mines, or rock crevices for hibernacula.
Spotted Bat	Generally Associated	Feeds and Breeds	Moderate	Requires cliffs for breeding.
Striped Skunk	Generally Associated	Feeds and Breeds	Moderate	None noted.
Townsend's Big-eared Bat	Generally Associated	Feeds	Moderate	None noted.
Trowbridge's Shrew	Generally Associated	Feeds and Breeds	High	None noted.
Virginia Opossum	Generally Associated	Feeds and Breeds	Low	None noted.
Western Spotted Skunk	Generally Associated	Feeds and Breeds	Low	None noted.
Wild Burro	Generally Associated	Feeds	Low	None noted.
Yellow-bellied Marmot	Generally Associated	Feeds and Breeds	Moderate	Requires talus slopes, lava fields, rimrock, or boulder fields in close proximity to grassy openings or meadows.

Mammals Associated with Eastside (Interior) Riparian -Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Yellow-pine Chipmunk	Generally Associated	Feeds and Breeds	Moderate	None noted.
American Badger	Present	Feeds	Moderate	None noted.
American Marten	Present	Feeds and Breeds	Moderate	None noted.
Coast Mole	Present	Feeds and Breeds	Moderate	None noted.
Golden-mantled Ground Squirrel	Present	Feeds and Breeds	Moderate	None noted.
Grizzly Bear	Present	Feeds	Moderate	None noted.
Heather Vole	Present	Feeds and Breeds	Moderate	None noted.
Least Chipmunk	Present	Feeds and Breeds	Low	None noted.
Montane Shrew	Present	Feeds and Breeds	Moderate	None noted.
Preble's Shrew	Present	Feeds and Breeds	Low	None noted.
Pronghorn Antelope	Present	Feeds	Moderate	None noted.
Vagrant Shrew	Present	Feeds and Breeds	Moderate	None noted.
White-tailed Jackrabbit	Present	Feeds and Breeds	Moderate	None noted.

Reptiles Associated with Eastside (Interior) Riparian-Wetlands				
Species (alphabetically by common name within each association)	Association	Activity	Confidence	Comments
Common Garter Snake	Closely Associated	Feeds and Breeds	High	None noted.
Gopher Snake	Generally Associated	Feeds and Breeds	High	None noted.
Northern Alligator Lizard	Generally Associated	Feeds and Breeds	High	None noted.
Painted Turtle	Generally Associated	Feeds and Breeds	Moderate	None noted.
Racer	Generally Associated	Feeds and Breeds	High	None noted.
Rubber Boa	Generally Associated	Feeds and Breeds	High	Usually does not occur far from water.
Sharptail Snake	Generally Associated	Feeds and Breeds	Moderate	None noted.
Western Rattlesnake	Generally Associated	Feeds and Breeds	High	None noted.
Western Terrestrial Garter Snake	Generally Associated	Feeds and Breeds	High	None noted.
Southern Alligator Lizard	Present	Feeds and Breeds	Low	None noted.

From: [CityClerk](#)
To: [City Council](#)
Cc: [Measamer, Don](#); [Grage, Libby](#); [Cooper, Tess](#)
Subject: FW: draft CAO
Date: Monday, April 19, 2021 7:50:29 AM

From: KATHRYN ALEXANDRA <kalexandra@comcast.net>
Sent: Sunday, April 18, 2021 6:22 PM
To: CityClerk <cityclerk@cityofanacortes.org>
Subject: draft CAO

I am concerned about protecting Anacortes' natural environment. I support Evergreen Islands recommended improvements to the Anacortes CAO, draft three.

sincerely,
Kathryn Alexandra
4311 Ginnett rd
Anacortes, WA 98221

From: [CityClerk](#)
To: [City Council](#)
Cc: [Measamer, Don](#); [Grage, Libby](#); [Cooper, Tess](#)
Subject: FW: Ordinance 3087 6b. Critical Area Regulations draft 3
Date: Monday, April 19, 2021 8:59:33 AM
Attachments: [Ordinance 3087.docx](#)

From: Jane Brandt <vjbrandt@hotmail.com>
Sent: Monday, April 19, 2021 8:53 AM
To: CityClerk <cityclerk@cityofanacortes.org>
Subject: Ordinance 3087 6b. Critical Area Regulations draft 3

Comment for Mayor and City Council
Regarding tonight's agenda
Thank you
Jane Brandt

Sent from [Mail](#) for Windows 10

Ordinance 3087

6b. Critical Area Regulations Draft 3

Anacortes City Mayor and City Council Members

I am contacting you to express concern that the proposed 6b. Critical Areas Draft 3 does not offer important protection for areas such as SHIP. I am grateful that the March Point Heronry and the AFCL have increased protection but areas such as SHIP have diminished protection. SHIP is designated a Habitat of Local Importance and the language in Draft 3 is weakened from Draft 2. The Washington Department of Ecology gave SHIP a score of 8 for habitat which is the second highest rating. This area is important to the nesting bird population and to other forms of wildlife. As natural areas disappear in the city, areas such as SHIP will become even more important to sustaining the bird and other wildlife populations. This year a new nesting colony of great blue herons has been established at SHIP and the Ospreys have nested there for years, telling us that this is an important area to be protected. I am not a great birder but those who are, have noted 30 to 40 species in this area.

I am very concerned about the loss of critical habitat for flora and fauna in this city. I hope that you will think of the future and protect areas that have contributed to Anacortes being special. I urge you to take seriously and support Evergreen Islands recommendations to the Anacortes CAO, Draft 3. Please think of the future of Anacortes and do not decrease protection for critical areas of importance to the natural environment which supports the bird and other wildlife populations in the city.

Respectfully submitted

Jane Brandt

3936 W. 12th Street

Anacortes, WA 98221

From: [Konrad Kurp](#)
To: [Young, Anthony](#); [McDougall, Bruce](#); [Moulton, Carolyn](#); [Cleland-McGrath, Christine](#); [Carter, Jeremy](#); [Miller, Matt](#); [coa.mayor](#); [Walters, Ryan \(Anacortes City Council\)](#); [Measamer, Don](#); [Grage, Libby](#); [Cooper, Tess](#)
Subject: ANACORTES CAO UPDATE: Please Adopt Evergreen Islands Suggested Changes
Date: Monday, April 19, 2021 8:09:36 AM

Like to say: horses on often wet-land trails is not such a good idea. Maybe remove horseback riding from the list of exempted activities in critical areas!?!
K.Kurp

From: [Neil O'Hara](#)
To: [Young, Anthony](#); [McDougall, Bruce](#); [Moulton, Carolyn](#); [Cleland-McGrath, Christine](#); [Carter, Jeremy](#); [Miller, Matt](#); [coa.mayor](#); [Walters, Ryan \(Anacortes City Council\)](#); [Measamer, Don](#); [Grage, Libby](#); [Cooper, Tess](#)
Subject: ANACORTES CAO UPDATE
Date: Monday, April 19, 2021 11:18:16 AM

Dear Council Members,

Why is this item on the agenda when the period for public comment to the Planning Department does not close until 4/23?

Sincerely,
Neil A. O'Hara
4407 Anaco Beach Place
Anacortes, WA 98221-8767

Tel: 781-290-9083

From: [CityClerk](#)
To: [City Council](#)
Cc: [Measamer, Don](#); [Grage, Libby](#); [Cooper, Tess](#)
Subject: FW: Protect anacortes natural enviroment
Date: Monday, April 19, 2021 7:49:05 AM

From: Rosann Wuebbels <rwuebbels@yahoo.com>
Sent: Monday, April 19, 2021 7:01 AM
To: CityClerk <cityclerk@cityofanacortes.org>
Subject: Protect anacortes natural enviroment

Dear mayor and city council members,
I support evergreen islands recommended modifications proposal for anacortes critical areas.CAO
DRAFT 3
Our natural treasures are our gems and they deserve protection..
Sincerely,
rosann wuebbels and George Reeves
Anacortes wa
[Sent from Yahoo Mail on Android](#)

From: [CityClerk](#)
To: [City Council](#)
Cc: [Measamer, Don](#); [Grage, Libby](#); [Cooper, Tess](#)
Subject: FW: Critical area comments
Date: Monday, April 19, 2021 2:18:52 PM

From: Andrea Doll <andrea.doll@gmail.com>
Sent: Monday, April 19, 2021 2:13 PM
To: CityClerk <cityclerk@cityofanacortes.org>
Subject: Critical area comments

My name is Andrea Doll
I reside at 1319 8th St.
Anacortes

The intention of the Critical Area Ordinance is to “Protect, maintain and restore healthy, functioning ecosystems through the protection of unique, fragile, and valuable elements of the environment, including, but not limited to wetlands, and fish and wildlife and their habitats, and to conserve the biodiversity of plant and animal species;

But is it?

the draft ordinance offers developers this assurance: “it is not the intent of Chapter to make a parcel of property unusable by denying its owner reasonable economic use of the property..”

The question is: does the ordinance offer EQUAL protection for habitat as it does for property rights?

Through out the CAO draft there are assurances and reassurances: One can skirt environmental restrictions by the use of variances, mitigation and loopholes

Examples:

1. If wetlands are on part of a property the homeowner can encroach on the wetland if it is necessary to add to their residence, i.e. patio, garage
2. If a property has extensive wetlands and streams the developer may build a road through it or relocate a stream in to access a proposed development.
3. A wetland may be filled in for development if a “new wetland” is created elsewhere, the criterion: “no net loss”

People are coming to Anacortes, you can see development every where. It is critical that what we love be protected, not degraded and compromised.

What is YOUR -Anacortes’s position. Is it **slogging defense** of the environment or—are you. taking bold steps forward

For example, Are we increasing, not decreasing wet land buffers
Are we inventorying wetlands with an eye to the future
As it stands now:
The CAO as currently written is an invitation to loss, not gain.

I would urge you ,our city council to decide your position, your intent: is it -compromise or bold leadership.

Andrea Doll
1319 8th St.
Anacortes, WA 98221
360 317 4557

Anacortes Critical Area Regulations

Additional 2nd Draft Changes

January 30, 2021

The following table lists the changes recommended for the 2nd draft the Anacortes Critical Area Regulations resulting from City Council discussion. In addition to Planning Commission recommendations these recommendations were considered in compiling draft 3.

AMC Reference	City Council Discussion	Staff Response
Appendixes	Hate to lose this historical background, can we save it somewhere easily accessed?	Noted
19.70.010 (B)(5)	I like the purpose being identified to "Alert the Public"	Noted
19.70.015 (A)	PC recommended change to applicability – Supported by CC.	Revised
19.70.025	Protections discussed to be no net loss – should wordsmith .025 and .125 to remove redundant language.	Noted
19.70.030	As part of the review the city will... specify what review.	Revised
19.70.035	PC recommended change to Ferry terminal language change is supported by CC, with the edit to add "withing the existing footprint".	Revised
19.70.040	Exemption section and change from "uses by right" – Supported by CC	Noted
19.70.040 Table	PC recommendation for Passive Outdoor Activities add back in the word "bicycles" and use previous language from 17.70.380 – Supported by CC	Revised
19.70.040 Table	PC recommendation to remove the word "non-motorized" from trail maintenance provision – Supported by CC	Revised
19.70.045	Permitted Alteration section – Supported by CC with maybe some wordsmithing to clarify permit types and terms.	Noted
19.70.045 Table	PC recommended changes to Public Roads and Utilities – Supported by CC	Revised
19.70.045 Table	PC recommend removing ACFL from the Recreational Area & Facilities – Supported by CC.	Revised
19.70.045 Table	Recreational Areas / Facilities – wordsmith or specify the concept of depending on sensitivity and how this is determined?	Noted
19.70.045 Table	Recreational Areas / Facilities – remove typo 's' trees.	Revised
19.70.045 Table	Recreational Areas / Facilities – fishing access points defined? As Parks?	Noted
19.70.045 Table	Reasonable Use discussion of ADU's etc. SFR normal vs. necessary appurtenances – define.	Revised
19.70.045 Table	PC recommendation to add to the table ACFL and CARA's.	Revised
19.70.050	Reasonable Use Variance – Ask Ms. Swetnam about regulatory takings.	Completed
19.70.115	Director vs. Decision maker – revise for most appropriate.	Revised
19.70.135	Notice on Title. Why not improve maps and not rely on Notice? Would be nice to have interactive maps with parcel layer and buffers for property owners to use.	Completed

19.70.165	Penalties for violations: money vs. misdemeanor? We want to be sure the consequence is enough to be a deterrent. AMC 1.24 makes any violation of municipal code a misdemeanor.	Noted
19.70.215	PC recommendation to uphold the removal of Regionally Significant Wetlands, but add them to FWHCA Habitats of Local Importance for the sake of maintaining special protections – Supported by CC	Revised
19.70.235	Variable Buffer approach – not sure about Ecologies recommendation for increasing buffer sizes backed by science? Recommend streamlining LUI language. – Supported by CC	Revised
19.70.235	Would like more examples of rating and buffer determination.	To be provided
19.70.335	PC Recommended addition of wetlands to FWHCA Habitats of Local Importance – Supported by CC	Revised
19.70.335	PC Recommended addition of purpose to the ACFL as a Habitat of Local Importance – Supported by CC	Revised
19.70.335	PC Recommended addition of purpose to March Point Heronry – Supported by CC	Revised
19.70.335	Heron Management – Should we define “unusually loud”? – link to WDFW document included in the text.	Noted
Definitions	PC Recommended addition of the omitted language to the Passive Recreation definition. Does Ecology have a definition?	Revised
Definitions	PC Recommended based on Ecologies addition to the definition for Qualified Professional.	Revised
19.20.030-1	PC Recommendation to amend the review classification table to include new permit types.	Revised
AMC Reference	Additional Recommendations Incorporated	
Multiple	SMP Integration language added to facilitate coordination.	Revised
19.70.040 Table	Trail maintenance may include relocation when further away from the CA	Revised
19.70.010	Limit the degree of flexibility in administration of this chapter	Revised
19.70.020 B	Add the line “prior to acting on any development permit the city”... to may require technical information.	Revised
19.70.020	Add a disclaimer that rating categories will not change due to illegal modifications.	Revised
19.70.035 A.	Add more specificity to vegetation alteration.	Revised
19.0.035 C.	Specify the burden of proof is on the property owner for non-conforming section	Revised
19.70.040 Table	Specify mowing and hand removal for yard and garden activities	Revised
19.70.045 E	Add protect adjacent property owners to conditions may be required	Revised
19.70.045	Add it is not feasible for reconfiguration of the lots in same ownership to SFR’s	Revised
19.70.050 D.6	Add ‘adjacent property owners’ to threats to public health and safety	Revised
19.70.225	Specify that subdivisions must meet all zoning standards without encroaching into the wetland or buffer.	Revised
	See attached recommendations from Carolyn Moulton	Most Revised
	See attached recommendations from Ryan Walters	Most Revised

AMC Reference	Additional Revisions Still Needed	
19.70.430	Seismic Hazard area somehow omitted between 2 & 3 needs put back in	To be Revised
19.70.025	Recommend putting enforcement authority in the protection section (front and center in the document)	To be Revised
19.70.165	Should strengthen enforcement language for potential/unknown critical areas and actions can require a report and restoration even if permits are not required.	To be Revised
19.70.045	's' trees as edited... the word "significant" needs to be added back in	To be Revised

From: [Moulton, Carolyn](#)
To: [Cooper, Tess](#)
Subject: Draft CAO proofreading
Date: Monday, September 7, 2020 9:12:34 PM

Hi Tess!

You've done a great job drafting and presenting Draft 2 of the CAO. Thank you!

Below are some nitpicky proofreading questions and suggestions on the text.

On page 18 in Table 19.70.045 under Recreational Areas/Facilities (B)(b) there's an extra "s" before the word trees.

On page 42, section 19.70.235(A)(3), it should say "existing" instead of "exiting."

On page 46, section 19.70.245(A), there should be an "of" between "requirements" and "AMC" on the third line, and the fourth line should read "AMC 19.70.135" instead of "ACM".

Random question: Is the approval authority the same as the decision maker on page 51 on the third-to-the-last line of section 19.70.240(H)?

On page 52, section 19.70.240(I)(1)(e) I think "standard" should be plural.

Page 63, 19.70.330(G)(2) should say "encouraged" rather than "encourage."
19.70.330(G)(2)c) should be "feet" instead of "foot."

Page 67, 19.70.335(D)(2)c)(ii.) should say "loud" rather than "load."

On page 67, 19.70.340(3) there's a semi-colon where it looks like a word should be.

On page 70, 19.70.350(E)(1), should we take out the word "Indian?" It's also on page 46 in section 19.70.240(B)(1).

On page 73, 19.70.415(A)(3)(a), is "mustow" a type of groundwater table?

Page 78, 19.40.430(A)(8) there should be a "u" in "Manual for Western Washington."

Page 82, 19.70.435(C)(7)(a)(i) there should be an "of" between "effect" and "construction."

Page 83, 19.70.435(C)(7)(c)(iii) change "sing" to "single" and "exits" to "exit."

Page 83, 19.70.435(C)(7)(d) should it say "of or to the crest" instead of "of the to or crest?"

On page 84, 19.70(D)(1)(a) the language is confusing.

Page 94, 19.70.625C) should it say "Project mitigation is permitted in accordance with..." instead of "Project mitigation is not permitted in accordance with...?"

I hope you had a great and relaxing holiday weekend!

Thanks!

Carolyn

Carolyn Moulton
Anacortes City Council, Position 6
360-472-0335

From: [Walters, Ryan \(Anacortes City Council\)](#)
To: [Cooper, Tess](#); [Grage, Libby](#); [Measamer, Don](#)
Subject: CAO Edits
Date: Monday, August 17, 2020 6:04:28 PM

Tess,

Here are my notes from last week's CAO presentation, some of which I addressed in the meeting and others that I didn't.

1. 19.70.025.D is duplicated in 19.70.125 (also .025 incorrectly references .135). Remove the nominalizations in .125
2. Aquafer is spelled wrong in a lot of places, including on the PowerPoint
3. We have top-level headings without numbers in the document, eg "General Provisions," "Critical Areas Review Procedures," "Wetlands", etc. It's bad form to have unnumbered headings. Section 19.70.125 calls those "subchapters," but a more standard term would be "parts." (We're already using "divisions" to segregate portions of Titles 13 and 19, so that's out.)
4. We should also start Part 1 with section .100 so that the section numbers correspond to the part numbers. Part 2 would start with section .200, etc. I recommend we make this numbering change at the very end of the adoption process, after all public comment.
5. Elsewhere in Title 19 we put definitions into the unified definitions chapter in chapter 19.12. Why not do that with this chapter as well?
6. "Prior notification" is undefined and not used, as is "piped stream", "replacement", some others.
7. 19.70.030 "general requirements" should be retitled to make clear what it is.
8. Pg 9 in the footer; page 11 of the PDF chrome)--revised wording should be reversed to allow redevelopment but NOT increase footprint; "must" instead of "shall"
9. 19.70.035.D shouldn't have a sentence starting with "subject to"--use plain language
10. Table 19.70.040(A) -- emergencies, make (c) into the last list item and make it clear the "Director" can take action to enforce the chapter, including for if the landowner doesn't do the mitigation
11. Pg 15 -- 19.70.045, c4 public comment. Should be more prescriptive, e.g., "city must ask relevant fed, state, tribal natural resource agencies for comment."
12. Pg 16, D Decision criteria "alterations may only be issued" should be "a critical areas permit" may only be issued. Harmonize and simplify terms.
13. I wouldn't mind striking all instances of "permitted alteration" in favor of a better term. I think that's a bad term that really muddies the concepts; is it an alteration of a structure? Or an alteration of a critical area? If we can use simpler terms like "Critical areas permit" I'd be much happier.
14. 19.70.050.C, we should not spell out the type of review here--we should let it be articulated by the table 19.20.030
15. "No permit must be issued unless" should be "A permit may not be issued unless" or "The City may not issue a permit unless" to avoid passive tense.
16. Pg 16 -- public services allowing development by a public agency to "public roads and utilities" is a good change. "will" is not desirable in code language—use "must"

17. Pg 18 -- what constitutes "fishing access" -- piers? Or just clearings?
18. Pg18--"s" trees. Significant trees? Fix in text and revision in comment.
19. Pg18 -- (A) is followed by (a) (incorrect hierarchy) and (B) is missing a subparagraph (d)
20. Pg 19 -- we're not calling it the ACFL comprehensive plan any more; citing AMC 19.70 doesn't mean much; where else in the doc do we have citations regulating this type of CA?
21. The term "decision maker" should be hyphenated to be consistent with Title 19, although it should have originally just been one word.
22. Pg 43 -- "averaging buffer widths" heading looks to be at the wrong level of hierarchy; needs to be promoted.
23. Pg 49; wetland bank; the failed Shell railroad project was going to be allowed to use the wetland bank over in MV; Clear Valley or the other one even though their banking instrument restricted them to WRIA 1 and 2 east of the Swinomish Channel. Maybe this is not so much of a future use item.

Ryan Walters, JD, AICP

City Councilmember, Ward 1
City of Anacortes

April 22, 2021

To: City of Anacortes Planning, Community & Economic Dev. Department

From: Carol Bordin

RE: Draft #3 CAO for City of Anacortes, Public Comments

In celebration of Earth Day, I have provided my comments on the Draft #3 Critical Areas Ordinance (CAO), moving forward. As always, my comments bring out the fact that our Critical Areas have now become even more “Critical” to protect and share our natural environment with the birds, insects, wildlife, freshwater and saltwater aquatic life forms, and all the associated herbaceous and aquatic species of plants, and trees, found in these various ecosystems.

From my perspective and my review of the various versions, or drafts of the CAO, it appears that the CAO has been severely reduced in its protection of our critical areas in Anacortes. This is not the document I was hoping to see developed over all these months. Draft #3 is too sparse for protecting Critical Areas and it leaves too much room for developing “so-called buffers” of the forests, streams, wetlands, shorelines, and aquifers. These natural areas need our protection and should not be reduced: in number/quantity or quality, size, function, value, name, buffer, habitat, water quality, or biodiversity because these are ecosystems that are homes to various species that depend on them for continued survival, fractured though many of them are, due to “progressive” and “unregulated” development in Anacortes.

From the original Chapter 17.70 CAO, it was so much more inclusive of the natural environment including the “at risk” or “indicator” species of insects, birds, and wildlife that are known to exist in the forests, wetlands, lakes, and along streams in the City of Anacortes. This entire section was purposely and completely chopped out of the draft CAO’s thus far, as if to say, these are No Longer Important to the CAO and how we develop the City of Anacortes.

In this Draft #3 Version of the CAO, the following has been a problem to adequately protect Critical Areas in the City of Anacortes:

From my previous comments regarding Draft #2, and as it now relates to Draft #3, to Reiterate:

“From comparing the AMC Chapter 17.70 CAO to the Draft #2 CAO, (and the Draft #3) there seems to be more protections for the critical areas in the pre-existing Chapter 17.70.

Wetlands: For example, for Category III and IV wetlands the buffers were wider in Chapter 17.70. Category I and II wetlands also need the largest buffers possible, not reduced, encroached upon, or developed! All Categories of wetlands should be recorded and archived at the highest possible ranking, and data never aborted, but kept as a baseline to not allow further development in them as they are critical areas, even fractured, they are still critical for life and maintaining species richness and biodiversity. Fractured ecosystems that are impaired should be restored to optimal health and productivity, not reduced or eliminated due to any and all land-use development. They are critical areas!!! What has been, and is, taking place in the City of Anacortes is to reclassify, recategorize wetlands that have in the past had a higher ranking to less of a ranking, or category for the sole purpose of being developed into roads, houses, condos, cottages, or other infrastructures. This is NOT protecting Critical Areas, so why have any CAO? Why?

Furthermore, when wetlands are recategorized to meet the expectations of the land developers, their buffers are also reduced to allow the maximum number of parcels and development within wetlands, critical areas. This doesn't say much for protecting wetlands in the City of Anacortes. It's blatant disrespect and greed to simply “bring more people” into Anacortes for profiteering. And it's not environmentally or ecologically good business. To blatantly disregard wetlands by reducing them into lesser Categories with narrower Buffers is an egregious and intentional misfortune, misguidance, mismanagement, and error by the City of Anacortes officials who are paid to protect Our Critical Areas.

One of our locally significant wetlands known as Copper Pond Wetland is owned by the Port of Anacortes on the western portion while Anacortes LLC owns the eastern portion of this archived and documented Category II Wetland, one

wetland, with records on file. (Another example of culverts is how they are sized and placed in streams and in wetlands. As a matter of fact, 2 improperly sized and improperly installed culverts are located underneath Anacopper Mine Road that allow connectivity between the eastern and western portions of Copper Pond Wetland.) However, new delineations by a company separated this one wetland into two separate wetlands, thus creating less of a buffer, thus more density with housing development within 95ft of the wetted perimeter on the eastern portion, very egregious undertaking here.

Recently water quality sampling and testing has proven that Copper Pond Wetland has been severely impaired due to encroachments and mis-categorizing this wetland. In addition, water quality data was recently generated on behalf of Evergreen Islands to provide comments sent to DOE regarding stormwater construction permitting for this project. This critical area needs further protection and restoration moving forward, not being developed to further impair and degrade this wetland.

SHIP wetland also needs further protection. New water quality monitoring may indicate the need to improve the management of the existing housing in this area. A Category I wetland has been designated for the SHIP wetland. It needs the appropriate 225' to 300' buffer, and no new building into the buffer accordingly.

We need to consider "pocket wetlands" into the CAO due to the fact that even though they may be small in size or area they still provide habitat for wildlife, birds, amphibians, insect, hydrophytes, and help provide a home/habitat and food for creatures that utilize them. They may be isolated, but because many of Anacortes's wetlands have been eliminated, filled in, or encroached upon and even these small areas are vital to those species that utilize them. They need protection and should be kept in place in any land development in the future.

Streams: The streams also have had more protections in the pre-existing AMC Chapter 17.70 CAO as well, "and they are named, not "unnamed" as in Draft #2, and Draft #3). I believe the newly created Draft #3 CAO needs more work and more protections for wetlands and streams to name just two examples here, or reject it and start over, or keep the 17.70 existing CAO in its entirety. Keep the streams named, and this needs to be clear, and those streams that have been piped, need day lighting.

Streams of any size or shape, or location need much bigger buffers than say 50ft here, 40ft there, or no buffer whatsoever. These streams are Critical Areas and should protected in their entirety, and those degraded need to be rebirthed, restored, rehabilitated and given a new lease on life. Those streams that are being proposed for development should be protected from any and all development within their large buffers, not a stone throw away, from the OHM.

Culverts need to be only in areas where they are necessary, and or bridges placed across streams when necessary. Streams that have been buried need to be daylighted. Streams that are intact do not need to be rechanneled, realigned elsewhere to suit land use development for housing projects, (ie Hidden Shores).

If you're going to have a Critical Areas Ordinance than it needs to be a solid one that protects all the Critical Areas and their "Large" buffers from any and all development, or why even have one?

My recommendation from what I've reviewed is to rebirth the Chapter 17.70 CAO and it stronger, and reject the Draft #3 the way it is written. There are not enough protections for the critical areas: wetlands and their buffers; streams and their buffers; forest and trees and their buffers; etc.

In addition, I appreciate the way 17.70.010 reads beginning with "Article I. with Introduction Section (Appendices A-D) and continuing all the way through to, and including, Article VII Marine Shoreline Vegetation, basically all of Chapter 17.70 CAO because the draft #2 and #3 just doesn't read as well and doesn't offer as much protection for the critical areas that certainly need it.

Again, the 17.70 version provides more protection for critical areas than the Draft #2 or #3 ever could and we should not let development happen in these critical areas for birds, mammals, reptiles, and all the life in these biologically diverse ecosystems that cannot ever be replaced once land development begins.

There needs to be a cut-off point for development in the critical areas. The City of Anacortes should respect and protect Critical Areas in Anacortes. What do you wish to see Anacortes look like, Seattle? I don't!!

Future development at Copper Pond wetland needs to be further evaluated based upon the fact those wetlands are Category II in nature, function, and value. Even though the Anacopper Mine Road separated this once intact wetland, the City

allowed the road to be built years ago, thus separating them, but not hydrologically. These wetlands therefore, on both sides of the road need to be designated as Category II wetlands that are “locally significant” and receive 225ft of buffer from the edge of the water. There has never been an environmental impact study, nor a biological assessment, nor water quality monitoring/reporting (over a period of time) conducted and completed and it should be done.

Perhaps some of the “vulnerable species of concern” are yet to be known or found here in this complex locally significant priority habitat wetland, Copper Pond Wetland. That’s also why we need to keep 17.70 version because in Appendix D –Vulnerable Species of Anacortes” is provided.

Wildlife Corridors and Wildlife Crossings: None are found in Draft #2 or Draft #3 CAO document. There needs to be a special section in the document, either in 17.70 existing document, or a new document that includes these parameters. Wildlife travel along corridors, mainly roads nowadays because their corridors disappeared due to land development. Deer and other mammals simply cannot move back and forth from forests to seashore with fences barricading their travel. There should be openings put into these 6-8' fences on these developments along Portalis subdivision and those to the east and west of this development and also the in Leeward development fencing on top of the Guemes Channel Trail.

There also needs to be designated crossings either above or below the Oakes/12th Street to and from the ferry terminal. A tunnel or overpass would serve the wildlife that wish to travel in this north/south pattern without being hit, wounded, crippled which I see often enough due to cars and trucks crashing into them during the morning and evening. (Canada uses these types of crossings and they work!)

As a further note, please strongly consider establishing a more protective Tree Ordinance into the City of Anacortes regulations. The forested area below the Leeward subdivision development on the Guemes Channel Trail is showing mass wasting more and more every time I walk there. The impervious surfaces placed for housing/homes, and the removal of the forested area that existed in this location is a geologically hazardous area. The problem as I see it is that when you remove the trees that were holding the soil and the bank, erosion and mudslides advance with gravity downslope. The impervious surfaces and the weight of the

homes above the Trail have caused problems with slope stability. Monitoring of the slopes before development needed to occur, and, more healthy trees should have been left to hold the upper bank/cliff from furthering erosion, mass wasting, and slumps, and potential mudslides.

The SEPA DNS for the Critical Areas Ordinance did not help protect the Critical Areas of Anacortes. There is no justified reason for designating our critical areas as not significant! I would hope that, yet today, that the DNS could be and should be appealed to a higher order or court due to the fact that the Critical Area Ordinance that is eventually adopted and codified is the groundwork for anything and everything that can or cannot occur near, on, around, or in, critical areas.

Thank you for your time, due diligence, and consideration in this very important matter for the City of Anacortes, its citizens, its wildlife, its habitats, and amazing ecosystems. Keep Anacortes Green and Blue!

Respectfully,

Carol Bordin

POB 3034

3934 W.12th St. Anacortes, WA 98221

From: [Catherine Houck](#)
To: [Cooper, Tess](#)
Subject: CAO draft 3 comments
Date: Friday, April 23, 2021 4:55:47 PM

Dear City Council Members, Mayor, and Staff,

Thank you for the opportunity to comment on Anacortes' draft 3 of the Critical Areas Ordinance update.

My comments:

1. Correction from transfer of Draft 2 from Planning Commission to Draft 3 City Council. As I remember, the final draft that was presented to the Planning Commission included an error pertaining to small hydrologically isolated wetlands. The draft that was approved by the Planning Commission was approved with a **verbal** correction by the chairperson to **only include category IV wetlands in reduced development standards**. It appears that Draft 3 partially corrected this error, but not fully.

19.70.230 Wetlands-Specific Wetland Category Develop Standards (pg 192 Draft 3):

B.3. Small hydrologically isolated Category IV wetlands

d. *Should read "low quality Category IV wetlands" **ONLY***

B.4. Only Category IV wetlands (<1,000 sq ft) are exempt from buffer provisions.

2. **ACFL Buffers.** Most Anacortes people cherish our forestlands. Why don't we **require** a small, 50 ft native growth protection easement in our Critical Areas Ordinance? Saying that City staff will work closely with developers to gain a 30 ft buffer just doesn't work; the public loses something in the deal. 50 foot buffers around a regionally significant wildlife area seem like a minimum attempt to safeguard these lands from windthrow, invasive plants, encroachment, noise, light, and disturbances to roots, soil, and hydrology.

Please give this addition and teeth to protecting our ACFL some thought and debate.

3. Streams. Pg. 217, 19.70.330 Fish and Wildlife Habitat

F. Additional Allowed Activities: Stream relocation

Are you kidding? Stream relocation should not be allowed within the city. Our streams have had enough destruction.

G. Setbacks for roadside ditches. I monitor Ace of Hearts Creek as part of the Skagit Stream Team. A part of this creek flows as a "roadside ditch" along H Avenue; it needs more protection, not less! Roadside ditches are still streams, but in a compromised state. They should still have the scant CAO buffer that is afforded to streams that aren't considered "roadside ditches".

Next update I'll champion larger stream buffers too.

Thank you for the opportunity to comment.

Sincerely,
Catherine Houck
Anacortes resident

From: [Wayne Huseby](#)
To: [Cooper, Tess](#)
Subject: COMMENT ON 3RD DRAFT OF ANACORTES CAO
Date: Friday, April 23, 2021 4:03:49 PM
Attachments: [Letter to City re CAO_Draft3_Apr23_2021-signed.pdf](#)

Dear Ms. Cooper,

Please find attached my comment on the 3rd draft of the City of Anacortes' Critical Areas Ordinance.

Regards,

Wayne

Wayne Huseby
Friends of Skagit Beaches - Treasurer/Past President
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April 23, 2021

Tess Cooper, Senior Planner
Planning, Community & Economic Development Department
PO Box 547
Anacortes, WA 98221
tessc@cityofanacortes.org

Re: 3rd Draft of the City of Anacortes Critical Areas Ordinance Update

Dear Ms. Cooper,

I am writing to you to express my concern about protections for the unique Category I wetland located at Ship Harbor. This wetland is rated a Category I wetland for a reason. According to the most recent Washington State Wetland Rating System – 2014 Update:

“Category I wetlands are those that 1) represent a unique or rare wetland type; or 2) are more sensitive to disturbance than most wetlands; or 3) are relatively undisturbed and contain ecological attributes that are impossible to replace within a human lifetime; or 4) provide a high level of functions. We cannot afford the risk of any degradation to these wetlands because their functions and values are too difficult to replace. Generally, these wetlands are not common and make up a small percentage of the wetlands in the region. Of the 111 wetlands used to field-test the current rating system, only 11 (10%) were rated as a Category I”.

According to the City’s website, Phase II of the Guemes Channel Trail (GCT) is proposed to pass through the buffer surrounding this sensitive wetland. Further, the proposed trail would be built to WSDOT standards (wide and paved) to support both foot and bicycle traffic. Unlike the current relatively low impact trail along the beach, this would be a high impact trail that would significantly affect the natural drainage of the area and its delicate ecosystems.



I am in 100% agreement with the recommendations proposed by Kyle Loring on behalf of Evergreen Islands in his memo to you dated 4/16/2021. Implementing the changes proposed by Mr. Loring would provide the appropriate protection for the Ship Harbor wetland and other critical areas within the City.

Thank you for allowing me to comment on this most important document.

Respectfully,

Wayne M. Huseby

Mt. Baker Group
Washington State Chapter Sierra Club
MtBaker@washington.sierraclub.org

Chair: Rick Eggerth
Vice-Chair: Susan Kane-Ronning
Secretary: Lynn Colson
Treasurer: Ron Colson
At Large: Judith Akins Mike Sennett

April 26, 2021

By Email

Tess Cooper, Senior Planner
Planning, Community & Economic Development Department
PO Box 547
Anacortes, WA 98221
tessc@cityofanacortes.org



Re: PLN-2019-0010: Mt. Baker Group, Sierra Club Comments on the 3rd Draft of the City
of Anacortes's Critical Areas Ordinance Update

Dear Ms. Cooper:

I write for the Mt. Mount Baker Group, Washington State Chapter, Sierra Club (MBG). MBG represents thousands of Sierra Club members and supporters in Whatcom, Skagit, and San Juan counties, including over 1000 in Skagit County and over 500 in or near Anacortes. On April 16, 2021, Loring Advising emailed you a letter on behalf of Evergreen Islands commenting on the 3rd Draft of Anacortes's Critical Areas Ordinance Update. MBG supports and endorses the comments, points, and arguments in that letter and its attachments as if made on behalf of the Mt. Baker Group.

Thank you for your assistance in this matter. Please direct any questions to me, and also please keep me apprised of developments in this matter as they occur.

Sincerely,

A handwritten signature in blue ink, which appears to read "Rick Eggerth", is positioned above the printed name and title.

Rick Eggerth
Chair, Mt. Baker Group, Washington State Chapter, Sierra Club

cc: Kyle Loring, Marlene Finley, Anacortes City Council, Anacortes Mayor, MBG Exec. Committee



Skagit Audubon Society

*PO Box 1101
Mount Vernon, WA 98273*

April 22, 2021

Ms. Tess Cooper
Senior Planner
City of Anacortes Planning Department

Dear Ms. Cooper,

I am submitting comments on Draft 3 of the Anacortes Critical Areas Ordinance both as a private citizen and as a board member of Skagit Audubon Society (SAS), the local chapter of the National Audubon Society. SAS has 375 members throughout Skagit County, 140 of whom reside in Anacortes. The following comments are endorsed in full by the Board of Skagit Audubon.

The mission of SAS is to conserve and restore natural ecosystems, focusing on birds, other wildlife, and their habitats for the benefit of humanity and the earth's biological diversity. SAS is therefore concerned about how the proposed CAO would affect areas of particular importance to birds and other wildlife, including but not limited to Ship Harbor Interpretive Preserve (SHIP), March Point heronry (MPH) and the Anacortes Community Forest Lands (ACFL).

Draft 3 does offer improved protections for MPH and the ACFL, which we strongly support. MPH and the ACFL would be designated Habitats of Local Importance under the proposed rules governing fish and wildlife habitat, which means "all new development activities and uses are prohibited from habitat conservation areas and their buffers except in accordance with this Chapter ..." In addition, specific provisions relating to MPH and the ACFL are spelled out in 19.70.335 C. We appreciate the recognition given to the great importance of protecting the March Point heronry by assigning it a year-round buffer of 984 feet.

SHIP is designated a Habitat of Local Importance but does not enjoy enhanced protection under Draft 3. In fact, the protections for SHIP have been weakened from the language staff recommended in Draft 2, which treated SHIP as a Class I wetland regardless of its score under the new rating system. In January 2020, the Washington Department of Ecology gave SHIP a score of 22, which lowers its rating from the Category I under the existing CAO to Category II. The score for habitat was 8, the second highest rating, which demonstrates how important SHIP is to birds and other wildlife. The many Skagit Audubon members and other birders who frequently visit SHIP for wildlife observation attest to the accuracy of this high rating as well as the importance the public attaches to protecting SHIP.

The numerous bird species known to breed at SHIP include great blue herons, which were observed this year establishing a small nesting colony near the tree in which an osprey pair has nested for many years. WDFW recommendations for this species require, once the breeding season is over in September, delineation of the heronry and development of a heron management plan, including a year-round buffer of 197 feet in accordance with the proposed CAO.

Given the stated intention that the revised CAO is meant to enhance protections for critical areas and the great importance of SHIP to the public, we urge that SHIP continue to be classified as a Category I wetland regardless of its score.

The revised CAO exempts certain “Passive Outdoor Activities, including fishing, birdwatching, hiking, boating, biking, horseback riding, swimming, canoeing, and similar activities with limited environmental impact.” In Draft 3, these activities are permitted “provided they do not require structures, grading, fill, draining, or dredging”, but, in a change from Draft 2, the proposed rules no longer specify that the exemption “does not include constructing new roads, or trails, vegetation clearing, or collection of plants or animals”.

I urge that the language governing new roads, etc. cited above from Draft 2 should be reinstated in the final CAO because these activities are highly damaging to fragile habitats and the plants and animals that depend on them. The construction of roads and trails in particular is harmful, as these activities compact soils, change drainage patterns, fragment habitat and facilitate predator access.

In Note 1 to Table 19.70.235E, new language in Draft 3 would allow for a reduction in required buffer widths for wetlands that score 6 points or more for habitat (such as Cannery Pond and SHIP) from high intensity (300 feet) to moderate intensity (225 feet) under certain conditions. Given the importance and scarcity of high-quality wetlands in Anacortes, I do not believe any reduction in buffer width should be permitted in those areas. I suggest the language be amended as follows (or to similar effect):

“Except for designated Habitats and Species of Local Importance, for wetlands that score 6 points or more for habitat function, buffer widths for high intensity may be reduced to moderate intensity if...”

Please note that the language in Note 1 to Table 19.70.235E does not make sense as it stands—it says “...if both of the following criteria are met:” but then has only one subclause a. Where is the second criterion b., and what does it say?

I would like to thank you for the opportunity to submit comments and for all the work you and your colleagues have put into the CAO project.

Sincerely,



April 20,2021

Tess Cooper, Senior Planner
tessc@cityofanacortes.org
City of Anacortes
Planning, Community & Economic Development Department
PO Box 547
Anacortes, WA 98221

RE: Anacortes Critical Areas Regulation draft #3 19.70.335 Fish and Wildlife Habitat, Great Blue Herons

Dear Tess,

Thank you for the opportunity to provide further input on the Critical Areas Regulation (CAR) draft #3 regarding Great Blue Herons. Skagit County is home to the greatest concentration of nesting herons in the Salish Sea. Critical nesting and foraging habitat, including that of the March Point mega-colony, lie within the City of Anacortes boundaries.

Skagit Land Trust compliments the City for the CAR draft #3 for herons and heron nesting areas (heronries) and their associated habitat. The regulations are science-based and incorporate WA Fish and Wildlife guidance appropriately as they pertain to heronries and their associated habitat.

We recommend one clarification in 19.70.335 C 2a. Specific Standards for other FWHCAs, City-Designated Habitats and Species of Local Importance, March Point Heronry, Purpose. Currently the first bullet (a) reads as “ Proposed activity within 1000 feet, or that is likely to impact the colony, must provide a critical area assessment report and habitat management plan that follows at a minimum the guidelines provided by WDFW’s Management Recommendations for Washington Priority Species (March 2012) and link. (The current link appears defunct and should be <https://wdfw.wa.gov/publications/01371>).

This is overall excellent wording, and we appreciate that the City provides the link to the WA Fish and Wildlife document. We recommend adding a small clarification (see bolded text) to the above as follows: “Proposed activity within 1000 **from the outer boundary of the nesting colony**, or that is likely to impact the colony.... (continuation of paragraph)....”. Since this is a notification area and not a “buffer”, details of how to measure the 1000-foot distance are not covered in Washington Department of Fish and Wildlife management recommendations for Great Blue Herons. However, finding the outer boundary of the nesting colony is something the CAR describes well as it is needed for measurements of buffers. Thus this should not be an extra burden on the City or a permit applicant.

Thank you very much for the opportunity to comment and for your good work in this area. Please let me know if you have questions or would like to discuss the above suggestions.

Sincerely,

Molly Doran

Molly Doran (mollyd@skagitlandtrust.org)

PO Box 1017 Mount Vernon WA, 98273

From: [Anne Winkes](#)
To: [Cooper, Tess](#)
Subject: incorrect link in the CAO March Point heronry section
Date: Friday, April 16, 2021 9:27:52 AM

Hi Tess,

I want to alert you to an incorrect link in the CAO March Point heronry section on pg 68. Here is the section containing the link that takes the reader to a page that is now nonexistent:

"Purpose. Because Skagit County is home to the greatest concentration of nesting Great Blue Heron in the Salish Sea, March Point being the largest, the City has identified the March Point Heronry as a habitat of local importance.

a. Proposed development activities within 1,000 feet, or that is likely to impact the colony, must provide a critical areas assessment report and habitat management plan that follows at a minimum the guidelines provided by WDFW's Management Recommendations for Washington's Priority Species (March 2012).

https://wdfw.wa.gov/publications/00026/abbreviated_great_blue_heron.pdf."

I thought you could perhaps correct the link at this time so that in the future anyone reading the CAO and seeking WDFW's heronry management recommendations could, with a "click", go directly to the right document.

The correct link is [Priority Habitats and Species Management Recommendations: Great Blue Heron | Washington Department of Fish & Wildlife](#)

Thanks,

Anne

From: [Anne Winkes](#)
To: [Cooper, Tess](#)
Subject: comment on draft 3 of the Critical Areas Regulations
Date: Thursday, April 22, 2021 9:43:20 AM

Dear Tess,

I am emailing you to comment on draft 3 of the Critical Areas Regulations (CAR) update.

As a Skagit Land Trust volunteer citizen science observer of the Samish Island heron colony at the time of its abandonment in 2017, I became acutely aware of the need to protect great blue heron nesting sites from disturbance if our resident great blue heron population is to thrive. I have been observing the March Point heronry throughout the breeding and nesting season for the past three years. I applaud your recognition of the March Point heronry in draft 3 of the proposed updates to the CAR as the greatest concentration of nesting Great Blue Herons in the Salish Sea and your identification of the March Point nesting colony as a habitat of local importance that must be protected.

I commend your incorporation of WDFW's Management Recommendations for great blue heron nesting colonies, recommendations based on the best available science, into draft 3 of the CAR. These guidelines through the use of year round and seasonal buffers will protect the courtship, nesting and foraging habitat needed by Great Blue Herons.

You have wisely assigned a 984 feet year round buffer for the March Point colony in acknowledgment of its unique status as a megacolony, its documented sensitivity to human intrusion, and its limited room for expansion.

Additionally you have included in the proposed update of the CAR a requirement that proposed development activities within a 1,000 feet, or likely to impact the colony, provide a critical areas assessment report and habitat management plan based at a minimum on WDFW's management guidelines. I agree with the recommendation in Skagit Land Trust's 4/20/21 email to you that this excellent requirement should include a clarification that the 1,000 feet be measured from the outer boundary of the nesting site, a boundary established by following WDFW's instructions for mapping the nesting colony's buffers.

Thank you so much for all your work on strengthening the CAR so that it provides the best possible protection for our community's beloved Great Blue Herons.

Anne Winkes

PO Box 586

Conway, WA

98238-0586

Critical Areas Regulations Update

Draft 3 Public Comment Summary

Updated 04/26/2021

Below is a brief summary of public comments received up until April 23, 2021, and staff responses. Comments have been grouped by theme/ issue. Complete written public comment letters can be viewed [here](https://www.anacorteswa.gov/DocumentCenter/Index/1267) (<https://www.anacorteswa.gov/DocumentCenter/Index/1267>) and should be consulted for full details and context.

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
General Comments not associated with a specific section			
Maps	Comment points out that known landslide areas along Guemes Channel Trail have not been included in the map.		Noted, recent local information is not included in the data used to generate the map, but it is the idea to update draft maps along the way as new data is collected.
Protection for natural environments	Comment is concerned with protecting Anacortes’ natural environments and supports Evergreen Islands comments.		Noted, thank you for your comment.
Protection for ecosystems	The Comment discusses the intent of the critical area regulations to protect, maintain, and restore functions of ecosystems and is disappointed that the CAO has provisions for developers with loopholes such as mitigation, reasonable use, and variance.		There are many laws, regulations, and codes at the federal, state, and local level that protect the environment and ecosystems. The purpose of the Critical Area Ordinance is to specify what protections are required in relationship to development and construction permitting.
General protection	Comment is in support of protecting our treasures and supports Evergreen Islands recommendations.		Noted, thank you for your comment.
Evergreen Island	A letter was received in support of the Evergreen Islands recommendations		Noted, thank you for your comment.
Section: General Provisions			
Passive Recreation	Commenter mentions horses on trails with wet-lands is not such a good idea, maybe remove horseback riding.	19.70.040	The management of trails and trail uses is not relevant to the code, this will be regulated elsewhere in Park/ACFL Policy and AMC. This Exempt Activity language just means that use of the existing trails (by any use) is not regulated by the Critical Area Ordinance.
Passive Recreation	Comment is concerned that the language has changed from “does not include constructing new roads, or tails, vegetation clearing, or collection of plants or animals” to “provided they do not require structures, grading, fill, drainage, or dredging”. Prefers the previous language.	19.70.040	Noted, thank you for your comment. The new language preventing grading is expected to be more restrictive than excluding new roads. Additionally, this section only describes the fact that recreational activities using existing facilities do not require a critical area development permit. Any building of roads or new facilities would have to meet the standards for roads and new facilities.

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
Protections	The comment acknowledges that the protections are improved for new development but is concerned that the act of conversion of wetlands to landscaping in existing development is not protected.	19.70.015	“Conversion” is a regulated alteration or development in and of itself. Therefore, even if no new construction is occurring, conversion of a natural area to something different would be considered development and covered under this regulatory body. However, staff suggests we add the word ‘conversion’ to the applicability statement in 19.70.015 A.
Identification, classification	Comment suggests that to ensure that buffer encroachments do not lead to reduced buffer delineations at a later date the CAO needs to explicitly state that buffer requirement must be based on the pre-violation habitat condition of the wetland.	19.70.020	The commenter made this recommendation previously and it was already added to Draft 3 in 19.70.020 C.2.
Goals	Comment suggest that critical area baseline dates are signific and should incorporated into the text the Goals section should be expanded to read “Goals and Baseline Dates”.		Further analysis of the necessity of this suggestion is needed. Staff does not see a functional purpose. Baseline dates change with each new adoption for establishing legally existing non-conforming uses and structures.
Maps	The comment shares knowledge of previous adopted map nomenclature and adoption status, and expresses concern that establishing the burden of proof for wetland conditions previous to activities should be on the applicant/owner.	19.70.020	Noted, thank you for your comment. The adoption of maps is for informational purposes only and can not be used for project approval or enforcement action because wetland conditions, sizes, and locations change over time, only actual site conditions govern official actions and will be dictated by current onsite delineations that must be reassessed every 5 years to capture “natural” changes in site conditions. Additionally, staff has taken the advice of this commenter previously and added language in to specify the burden of proof is on the property owner. 19.70.035 C.
	Additionally, the comment suggests looking at flooding and stormwater integration as well as transfer of development rights to avoid impacts due to reasonable use variances.		These are great suggestions and we will do more research to be prepared to include these in the next Update required in 2024 (3 years). These topics are more complicated then can be integrated at this time.
Section: Critical Areas Review Procedures			
Section: Wetlands			
Regionally significant wetlands	Commenter is concerned with the loss of protection for SHIP. While the ACFL and March Point Heronry have increased protections important bird habitat in SHIP may have less protections.	19.70.215	It is staff and Ecology’s position that the removal of Regionally Significant Wetlands results in an INCREASE in protection for wetlands such as SHIP. The previous code designated them as special in name but actually reduced the protections by lowering

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
			the buffer designation. Removing this restores the protection for these wetlands to the correct rating level and buffer designation. Additionally, SHIP and the other named wetlands have been added by name to a second section of Critical Area regulations under Fish and Wildlife Habitat Conservation Areas, therefore receiving a second and separate level of special protections for their “Habitat” value over and above wetland function. If as the comment suggests that there is a new Heron Rookery in SHIP the Heron nests would receive a 3 rd level of protection specific to “Great Blue Heron nesting and breeding areas” 19.70.335 D.2.c.
17.70.340	The comment is concerned that that changes from Chapter 17 to the proposed draft changes wetland categories and reduces buffers.	19.70.235 C.	Wetland categories have not changed – both systems use the Washington State Wetland Rating system. Wetland buffer ranges are increasing to a max buffer of 300’, whereas chapter 17 only had a max buffer of 225’, resulting in an increase in buffer sizes.
Isolated wetlands	The comment brings attention to an error between Draft 2 and Draft 3 the intended correction to small isolated wetlands was not captured correctly as discussed by PC.	19.70.230	Thank you we will correct sections 19.70.230 B.3.d and B.4.
Wetlands	The comment is concerned with the lack of clarity for the definition of Buffers and Wetlands and the implications that this can have on property rights resulting in worthless property and regulatory takings.	19.70.220	Thank you for your comment, staff has ensured allowances to prevent regulatory takings. The criteria for determining wetlands as prescribed by the US Army Corps of Engineers is comprehensive and includes the presence of water as well as hydrophytic vegetation and hydric soils long enough during the growing season. When all 4 conditions are present then the area is considered a wetland.
Category I wetlands	Comment expresses concerns about the protections for Category I wetlands like SHIP and the City’s proposed Phase II of the Guemes Channel Trail. Commenter is in support of the recommendations from Kyle Loring/Evergreen Islands.	19.70.215	Noted, thank you for your comments.
SHIP	The comment feels that the protections for SHIP have been weakened by being added to the Habitats of Local Importance provisions, and because the rating done by Ecology for SHIP drops the classification from a Class I to a Class II wetland.	19.70.215	While chapter 17 assigned SHIP a Class I rating it also specifically assigned the Class I wetland a Class II buffer. So there was no functional extra protections at all for SHIP. Ecology strongly defends the position that their rating system synthesizes very technical scientific information into the proper wetland rating and that this assigned rating is the better method for protecting wetlands. Since SHIP previously had a Class II buffer and now continues to have a Class II rating and buffer under the new code, there is NO diminished protections under wetland specific

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
			regulations – even though it lost the special and arbitrary Class I rating. Because staff agrees with the public that SHIP provides exceptional ‘habitat function’ over and above its basic wetland functions staff has added SHIP and the other removed regionally significant wetlands as Habitats of Local Importance under FWHCA provisions. Thereby giving these wetlands a second layer of special protections over and above wetland protections. There is no longer a statewide accepted and prescribed critical area type for ‘wetlands of local importance’ and therefore no specific guidance or protections. On the other hand, ‘Habitats of Local Importance’ remain a state recognized critical area with specific provisions and protections. This is clearly an increase in protection for SHIP and other wetlands.
March Point Heronry	Comment appreciates the work and improvements to the March Point Heronry provision and suggests one small clarification to the language to read “from the outer boundary of the nesting colony”.	19.70.335 C.2.a	Noted. Thank you for your comment we agree this is a good suggestion.
March Point Heronry	The comment notified staff that the link provided to the WDFW great blue heron pdf is no longer correct and provided us with the correct link.	19.70.335 C.2.a	Noted. Thank you for your comment we will be sure to fix this.
Hérons	The comment commends us for our work to improve the protections for Herons and the March Point Heronry.	19.70.335 C.2.a	Noted. Thank you for your comment.
Section: Fish & Wildlife Habitat Conservation Areas			
Streams	Comment is concerned with the removal of stream names and believes 50’ buffers are in adequate.	19.70.330	The stream names do not have any scientific value for functional regulations. The regulated streams remain the same, the names remain on the map just not in the text of the regulations. Streams are now classified and regulated by their state designated water typing which has more scientific value. The stream buffers have not changed between chapter 17 and the update, they are both 50’ which is supported by our Best Available Science Report. The confusing and contradictory separate section for riparian areas and buffers has been removed from the text, but riparian areas, biodiversity areas, and wildlife corridors remain protected as a state listed priority habitat under regulated Fish and Wildlife Habitat Conservation Areas. The buffers for these areas are variable and dependent on specific needs based on science from an individual habitat assessment report and not an arbitrary buffer prescribed by code as provided for in 19.70.325 D.1. The majority of stream

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
			lengths within city limits do not have adjacent riparian area and larger buffers would result in unfair and overprotective regulations for certain stream reaches.
Wildlife Corridors	A verbal comment during the Hearing expressed concern that wildlife corridors are not included or protected in Draft 3 but are a very important habitat that should be protected.	19.70.315 A.8.a	Agreed! Staff apologizes that the word ‘Corridor’ was accidentally omitted from the drafts – thank you for bringing this error to our attention - it will be corrected. The draft currently reads a. Biodiversity areas; it should read a. Biodiversity areas and Corridors. Wildlife corridors are still functionally protected in this CAO because it is a specified terrestrial habitat that is protected as a State Priority Habitat under Fish and Wildlife Habitat Conservation Areas in section 19.70.315 A.8. The description of Biodiversity Areas and Corridors as protected in Draft 3 under 19.70.315 A.8.a can be found on page 255 of the State Priority Habitats and Species found here .
ACFL	The comment expresses concern that the ACFL doesn’t have a stronger buffer requirement.	19.70.335 C	Noted, thank you for your comment.
Streams	The comment is concerned with the provision to allow stream relocation and setbacks from roadside ditches.	19.70.330	Noted, thank you for your comment. Also keep in mind that many of the streams within the urban environment are modified and artificial constricted channels, relocation includes moving these into a more natural channel location and configuration, further away from urban impacts and essentially functioning as a stream restoration project. Relocation just to move it out of a project’s way is not likely to meet the other requirements necessary to be approved.
March Point & ACFL	Comment notes the improvement to these sections and supports these changes		Noted, thank you for your comment.
Section: Geologically Hazardous Areas			
Section: Critical Aquifer Recharge Areas			
Section: Frequently Flooded Areas			
Section: Definitions			

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
Evergreen Islands Suggestions:			
“Assess the potential impacts to the critical area and determine if they can be avoided or minimized.”	Assess the potential impacts to the critical area and determine if they can be avoided or minimized. <u>In reviewing the impacts and the applicant’s critical area report, the City may engage an independent qualified expert at the applicant’s expense.</u>	19.70.030.B.3.	Staff recommends considering this beneficial change.
“Restoration or replacement of a structure that is damaged by fire, natural disaster or other calamity when:”	Restoration or replacement of a structure that is <u>where up to 75% of its square footage has been</u> damaged by fire, natural disaster or other calamity when:	19.70.035.C.4	Staff recommends referring this suggestion to legal for review.
“Provided they do not require structures, grading, filling, draining, or dredging except as provided herein or authorized by a Critical Area Permit: Passive Outdoor Activities, including fishing, birdwatching, hiking, boating, biking, horseback riding, swimming, canoeing, and similar activities with limited environmental impact are exempt activities.”	Provided they do not require structures, grading, filling, draining, or dredging except as provided herein or authorized by a Critical Area Permit: Passive Outdoor Activities, including fishing, birdwatching, hiking, boating, biking , horseback riding, swimming, canoeing, and similar activities with limited environmental impact are exempt activities.	19.70.040.F Table 19.70.040(A) Exempt Activities (no review)	Staff does not recommend this change as it would not accomplish any functional change to these development regulations. The use of bicycles on trails if more appropriately regulated elsewhere in AMC and City management plans.
“Maintenance, operation, repair, modification, or replacement of existing Non-Motorized trails, and existing facilities within public improved recreation areas....”	Maintenance, operation, repair, modification, or replacement of existing <u>Non-Motorized</u> trails, and existing facilities within public improved recreation areas....	19.70.040.F Table 19.70.040(B) Exempt Activities (Letter of Exemption)	Staff does not recommend this change as motorized trails are already permitted in some areas and maintenance, operation, and repair is necessary for these trails.
“Where trail relocation is the preferred method of repair, trail relocation further away from the Critical Area is not to be considered a new trail but is included in the exemption for operation, maintenance, repair, or replacement.”	Where trail relocation is the preferred method of repair, trail relocation further away from the Critical Area is not to be considered a new trail but is included in the exemption for operation, maintenance, repair, or replacement.	19.70.040	Staff incorporated this provision as it is a benefit to relocate existing trails further away from the critical areas.

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
“ Applicability. An applicant may seek an alteration of a critical area and/or critical area buffer through a permitted alteration when application of the standards renders compliance with these provisions infeasible and the proposed development meets the specific terms of this section and can be considered a reasonable use.”	Applicability. An applicant may seek an alteration of a critical area and/or critical area buffer through a permitted alteration when application of the standards <u>in this chapter would result in the denial of all reasonable and economically viable use of the property renders compliance with these provisions infeasible</u> and the proposed development meets the specific terms of this section and can be considered a reasonable use.	19.70.045.A.	Staff recommends considering this change.
“Public services” include, but are not limited to, water supply, sewer and stormwater management facility, electric power, telephone, cable television, gas, and transportation for persons and freight.”	“Public services” include, but are not limited to, water supply, sewer and stormwater management facility, electric power, telephone, cable television, gas, and transportation <u>by city road</u> for persons and freight.	19.70.045.F.	Staff recommends considering this change.
“ New to Table Anacortes Community Forest Lands. Given the unique qualities of the community forest, all properties designated as ACFL have been nominated as a regulated critical area. Any and all new uses and development of new facilities within the ACFL must meet the requirements of the Conservation Easements/Deed Restrictions of the land, Anacortes Comprehensive Plan, the ACFL Comprehensive Plan, AMC 19.70 Critical Areas, and AMC 12.18 ACFL.”	Recommend striking this entirely from the table	19.70.045.F.	This is an important distinction for the administration of the ACFL as a regulated critical area, it must remain in order to protect the ACFL. We can clarify that “in addition to the provisions in this chapter under 19.70.335(C)(1.) the proposal must also meet the requirements of the Conservation Easements”... etc.
“ Category II, III and IV Wetlands. Development activities that result in alteration of Category II, III or IV wetlands may be permitted upon demonstration, through a critical areas report meeting the requirements of this Chapter, that:....	Category II, III and IV Wetlands. Development activities that result in alteration of Category II, III or IV wetlands may be permitted upon demonstration, through a critical areas report meeting the requirements of this Chapter, that:.... [this subsection B and its paragraphs must be deleted]	19.70.230.B.	This would result in a regulatory taking.

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
report meeting the requirements of this Chapter, that:....”			
Category IV 50 40 25	Category IV 50 40 25 <u>40</u>	19.70.235.C.1.	Staff recommends the buffers as reviewed and recommended in correspondence with Ecology.
Category IV 50 40 25	Category IV 50 40 25 <u>40</u>	19.70.235.C.2.	See above
Category III 80 60 50-40 Category IV 50 40 25	Category III 80 60 50-40-60 Category IV 50 40 25 <u>40</u>	19.70.235.C.3.	See above
“Averaging buffer widths... b. The buffer averaging does not reduce the functions or values of the wetland, either through preservation of total buffer area or enhancement of buffer areas... e. The buffer width at its narrowest point is not reduced to less than 75% of the standard width, for Category I and II. No less than 50 percent or 35 feet for Category III and 15 feet for Category IV, whichever is greater.”	Averaging buffer widths... b. The buffer averaging <u>improves</u> does not reduce the functions and <u>and</u> or values of the wetland, either through preservation of total buffer area or enhancement of buffer areas... e. The buffer width at its narrowest point is not reduced to less than 75% of the standard width, for Category I and II. No less than 50 percent or 35 feet for Category III and 15 feet for Category IV, whichever is greater.	19.70.235.B	Staff recommends considering this change.
Reducing Buffer Widths.	Reducing Buffer Widths. <u>[this subsection D and its paragraphs must be deleted]</u>	19.70.235.D.	This provision is here to allow flexibility in highly urban/developed environments when no functional buffer exists and there is documented zero impact by doing so but rather greater buffer function can be obtained on a site from incentivized restoration of buffer. This provision is not applicable to natural functioning buffers. Staff’s position is that this provision is integral to regulating an urban environment. (Improving a paved paradise if you will).
“Setbacks from buffers. Buildings, structures, paving, and other hard surfacing must be set back a minimum distance of 10 feet from the edge of the wetland buffer, or edge of the wetland if no buffer is required, unless otherwise determined by the Decision	Setbacks from buffers. Buildings, structures, paving, and other hard surfacing must be set back a minimum distance of 10 feet from the edge of the wetland buffer, or edge of the wetland if no buffer is required, unless otherwise determined by the Decision maker <u>Decision maker</u> that a smaller distance would meet the intent of this subsection.	19.70.235.H.	Staff has no recommendation on this change.

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
makerDecision-maker that a smaller distance would meet the intent of this subsection.”			
“Uncovered decks, roof eaves and overhangs, unroofed stairways and steps;”	Uncovered decks, roof eaves and overhangs, unroofed stairways and steps;	19.70.235.H.2.	These types of items are generally exceptions to all setback types, and have been included for consistency. Staff has no recommendation on the change.
“3. Waters of the State, including streams as classified in WAC 222-16-030;”	3. Waters of the State, including streams as classified in WAC 222-16-030, including but not limited to Whistle Creek, Happy Valley Stream, Ace of Hearts Creek, Beaver Brook, Cranberry Creek, Clyde Creek, Anaco Bourn, Morrison Run, Cedar Springs, Weaverling Rill, Miller Creek, Aqua Creek, Howard Creek, Sumit Creek, and March’s Run.	19.70.315	Staff has made a lot of effort to condense and eliminate non-functional filler text, stream names were removed from the text because they have no functional scientific relevancy to the regulations. Staff has no recommendation on the change.
“FWHCA’s or their buffers may be altered only if the proposed alteration of the habitat or the mitigation proposed does not degrade the functions and values of the habitat.”	<u>Alterations of FWHCA’s or their buffers is prohibited except as otherwise allowed by this chapter and may occur</u> only if the proposed alteration of the habitat or the <u>and any associated</u> mitigation does not degrade the functions and values of the habitat.	19.70.325.A.	Staff recommends considering this change.
“Access roads and utilities serving a proposed subdivision may be permitted within the FWHCA and associated buffers only if the applicant’s qualified professional(s) demonstrate, and the Decision- maker determines, that no other feasible alternative exists, all unavoidable impacts are fully mitigated, and the use is consistent with this chapter.”	Access roads and utilities serving a proposed subdivision may be permitted within the FWHCA and associated buffers only if the applicant’s qualified professional(s) demonstrate, and the Decision- maker determines, that no other feasible alternative exists, all unavoidable impacts are fully mitigated, and the use is consistent with this chapter. <u>This paragraph does not authorize new access roads and utilities in FWHCAs and associated buffers for existing subdivisions.</u>	19.70.325.F.	Staff recommends considering this change.
Type F 50 feet Type Np 50 feet Type Ns 50 feet	Type F 50 feet <u>1 Site Potential Tree Height</u> Type Np 50 feet <u>1 Site Potential Tree Height</u> Type Ns 50 feet <u>1 Site Potential Tree Height</u> [WDFW’s map of Site Potential Tree Heights for Anacortes would apply]	19.70.330.B.2. Stream Buffers	Staff does not recommend this change. Chapter 17 regulated streams and stream buffers differently than riparian areas and buffer – even for riparian areas along streams. Staff has maintained this separation in regulating the stream/stream buffer and the Riparian area/riparian buffer. As Mr. Loring noted Riparian Management Zones are listed as WDFW Priority Habitats and therefore is its own protected critical area under Fish and Wildlife Habitat Conservation Areas in Draft 3. Staff’s

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
			position is that applying standard 50’ buffers as prescribed in our BAS to the actual stream channels is good management. Because riparian areas within the city are so varied, we feel a code prescribed riparian buffer is not appropriate and removed that section from code now requiring that a Habitat Assessment will be required to assess the needs of each individual project site and prescribe a specific buffer for areas with important Riparian Management Zones. The WDFW BAS provided by Mr. Loring is great information and the recommended method of on-site potential tree height can be used as a guidance document for evaluating Habitat Assessments and Habitat Management Plans (Demonstration using the WDFW map). Staff does suggest inserting Riparian as item b. (moving the remainder items down one letter) under 19.70.315 (A)8 to make it more clear that riparian areas are regulated priority habitats. The list is not inclusive and riparian areas are regulated by default in this CAO regardless if it is actually listed under State Priority Habitats and Species. <i>(it is possible to add this method for assessing riparian buffers to the recommendations for FWHCA Buffer standards under 19.70.335 D.2)</i>
“Buffer Reduction Standards.....”	Buffer Reduction Standards..... [this subsection C and its paragraphs must be deleted]	19.70.330.C.	As discussed above, there are appropriate times to allow buffer reduction, for example when there is zero existing functional buffer on site and by requiring a buffer enhancement project that results in a net ecological gain for the site despite the actual size of the buffer.
“Building setbacks from stream buffers. Buildings, structures, paving, and other hard surfacing must be setback a minimum distance of 10 feet from the edge of the stream buffer unless otherwise determined by the Decision maker<u>Decision-maker</u> that a smaller distance would meet the intent of this subsection.”	Building setbacks from stream buffers. Buildings, structures, paving, and other hard surfacing must be setback a minimum distance of 10 feet from the edge of the stream buffer unless otherwise determined by the Decision maker<u>Decision-maker</u> that a smaller distance would meet the intent of this subsection.	19.70.330.D.	There are some highly developed segments of stream within the city with zero functional buffer, there is no ecological reason for requiring a setback from the buffer edge in those cases. The buffer itself is established for protection. <i>(Show example on map).</i>

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
“Uncovered decks, roof eaves and overhangs, unroofed stairways and steps;”	Recommend striking this exception.	19.70.330.D.2.	These type of items are generally exceptions to all setback types, and have been included for consistency. Staff has no recommendation on the change.
“Type F and Type Np Streams Relocation....” “Type Ns Streams Relocation....”	“Type F and Type Np Streams Relocation....” “Type Ns Streams Relocation....” [these paragraphs 1 and 2 must be deleted]	19.70.330.F.1, and .F.2	As discussed above, stream relocation is sometime a beneficial action and should not be removed.
“B. Other Priority Habitats and Species.”	B. Other Priority Habitats and Species. [this section B and its paragraph 1 must be deleted]	19.70.335.B.	This change is not recommended as Priority Habitats and Species are a protected Critical Area. If we remove this paragraph here then what are the performance standards for these critical areas and buffers? This is the section that Riparian habitat and Wildlife Corridors are regulated under. Staff recommends considering revising the language as suggested by Mr. Loring in #5 below: language about altering FWHCAs should be revised to clarify that alterations are allowed only as identified in the critical areas ordinance.
“Fish and wildlife habitat – Buffer Width Averaging for All FWHCA’s. A. Approval Criteria. The Decision makerDecision-maker may allow the averaging of FWHCA buffer widths when the critical areas report demonstrates the following.”	“Fish and wildlife habitat – Buffer Width Averaging for All FWHCA’s <u>Other Than Those Designated by the City as Habitats and Species of Local Importance.</u> A. Approval Criteria. The Decision makerDecision-maker may allow the averaging of FWHCA buffer widths for FWHCAs other than those designated by the City as habitats and species of local importance when the critical areas report demonstrates the following.”	19.70.340.	Staff recommends considering this change.
“In-stream or buffer habitat functions, will be increased or maintained where native buffer vegetation is generally intact, or increased where existing buffer vegetation is inadequate to protect	In-stream or buffer habitat functions, will be increased or maintained where native buffer vegetation is generally intact, or increased where existing buffer vegetation is inadequate to protect functions and values; and”	19.70.340.A.1.	Staff recommends considering this change.

Issue / Key Words	Comments summary	Draft 3 reference	Staff Comments
functions and values; and”			
“The buffer width is not reduced in any location to less than 50 percent of the standard width or 35 feet, whichever is greater, on a case-by-case basis as a result of a habitat assessment pursuant to AMC 19.70.380 (B)(4); and”	“The buffer width is not reduced in any location to less than 75 50 percent of the standard width or 35 feet, whichever is greater , on a case-by-case basis as a result of a <u>habitat assessment pursuant to AMC 19.70.380 (B)(4); and”</u>	19.70.340.A.5.	While Ecology reviewed and approved the proposed buffer averaging/reduction standards, Staff recommends considering this change.
Mitigation success			Previous mitigation efforts were not generally successful because agency monitoring and tracking was non-existent. So old BAS says compensatory mitigation was failing. However, recent evidence on mitigation monitoring says that agencies who have thorough oversight and compliance monitoring programs have a much higher rate of mitigation success. Planning staff have attended the COMPENSATORY MITIGATION WEBINAR SERIES by the Association of State Wetland Managers , is creating a more robust mitigation compliance tracking system, and is seeking funding and approval for new permitting software to improve tracking and compliance efforts in Anacortes. Additionally, this update incorporates assurances for success such as performance bonds and notice on title.

Hunt, Marcia

From: Evelyn Adams <evelynannadams@gmail.com>
Sent: Sunday, May 2, 2021 9:47 PM
To: CityClerk
Subject: comment on Critical Areas Ordinance update

To the Mayor and Anacortes City Council:

We are writing to express our grave concern regarding the potential weakening of wetland protections in the Critical Areas Ordinance update.

We're especially alarmed to learn of the proposal to downgrade the Ship Harbor Interpretive Preserve wetland from a Class I to a Class II wetland, "with a reduction in buffer from 300 to 225 feet. Activities such as biking, canoeing, fishing, horseback riding and swimming would be allowed." (*Anacortes American*, 4/28/21)

We've lived on this island for 40 years now, and while grateful to see the protection afforded to our wild neighbors through the conservation of the ACFL, there have been far too many wild places destroyed for human activities. The pressure to persist in that destruction will only increase as our island becomes more and more attractive to those who'd flee areas besieged by drought, wildfires, and increasingly severe weather.

Wildlife is also migrating, if they can, to escape the pressures of an overheating world. Many are dying; scientists tell us that we're in the middle of a mass 6th extinction. According to the *2020 Living Planet Report*, wildlife populations have plunged by more than two-thirds in the last 50 years due to human activities. Here in our own backyard, the number of imperiled species in the Salish Sea nearly doubled in just four years (2008-2011).

We're in the midst of not only a climate crisis but also a biodiversity crisis, which requires us to do everything we possibly can to support wild populations. People can manage just fine without a bike trail through a wetland buffer. Wild species, however, depend on critical habitat for survival.

If anything, wetland and other critical wildlife area protections need to be strengthened, not weakened. At the very least, please ensure that existing protections will remain firmly in place.

Sincerely,
Evelyn and Gary Adams
1112 Haddon Lane
Anacortes



ANACORTES

Critical Areas Regulations Update

Draft 3 Public Hearing - May 3, 2021

Tonight:

- Review Comments and Discuss
- Additional Public Hearing / Testimony
- Close the Hearing (?)
- Council Final Thoughts

Current Process:



4/23/2021 – End of Public Comment Period



5/3/2021 – Review of Public Comments, CC Directions



5/10/2021 – How it Works – Example Case Studies



TBD – Review of Final Edits and associated documents – Final Decision



SHIP HARBOR WETLAND

Wetland name or number _____

RATING SUMMARY – Western Washington

Name of wetland (or ID #): Ship Harbor Date of site visit: 1/21/2020
Rated by: Chris Laerkens Trained by Ecology? X Yes ___ No Date of training: _____
HGM Class used for rating: Depressional Wetland has multiple HGM classes? Y X N

NOTE: Form is not complete without the figures requested (figures can be combined).
Source of base aerial photo/map: _____

OVERALL WETLAND CATEGORY _____ (based on functions _____ or special characteristics _____)

1. Category of wetland based on FUNCTIONS



Category I – Total score = 23 - 27

Category II – Total score = 20 - 22

Category III – Total score = 16 - 19

Category IV – Total score = 9 - 15

FUNCTION	Improving Water Quality			Hydrologic			Habitat			
Site Potential	(H)	M	L	(H)	M	L	(H)	M	L	
Landscape Potential	(H)	M	L	(H)	M	L	H	(M)	L	
Value	H	M	(L)	H	M	(L)	(H)	M	L	TOTAL
Score Based on Ratings	7			7			8			22

Score for each function based on three ratings (order of ratings is not important)

9 = H,H,H
8 = H,H,M
7 = H,H,L
6 = H,M,M
5 = H,L,L
4 = M,L,L
3 = L,L,L

2. Category based on SPECIAL CHARACTERISTICS of wetland

CHARACTERISTIC	CATEGORY
Estuarine	I II
Wetland of High Conservation Value	I
Bog	I
Mature Forest	I
Old Growth Forest	I
Coastal Lagoon	I II
Interdunal	I II III IV
None of the above	



D. *Regionally Significant Wetlands.* Pursuant to subsection (B)(1)(a)(iii) of this section, the following wetlands are designated as Category I wetlands:

1. Cannery Pond (West of the State Ferry Terminal);
2. Ship Harbor Interpretive Preserve (East of the State Ferry Terminal), except as to buffer widths which shall be as required for Category II;
3. Any otherwise regulated Category II wetland, as rated under subsection (B)(1)(b) of this section, that is within the watersheds of Little Cranberry Lake, Whistle Lake and Heart Lake and that drains by natural seasonal surface water connection into those lakes or their upstream associated wetland systems.

FUNCTION	Improving Water Quality			Hydrologic			Habitat			
Circle the appropriate ratings										
Site Potential	(H)	M	L	(H)	M	L	(H)	M	L	
Landscape Potential	(H)	M	L	(H)	M	L	H	(M)	L	
Value	H	M	(L)	H	M	(L)	(H)	M	L	
Score Based on Ratings	7			7			8			22

CURRENT CODE SHIP = 225' BUFFER

Table 17.70.340(1) BUFFER WIDTHS BY CATEGORY PROVIDED THE MEASURES IN TABLE 17.70.340(2) ARE TAKEN

Wetland Characteristics	Buffer Widths
Category IV wetlands	
Score for all 3 basic functions is less than 30 points	40 ft.
Category III wetlands	
Moderate level of function for habitat (score for habitat 20—28 points)	110 ft.
Not meeting above characteristic	60 ft.
Category II wetlands	
High level of function for habitat (score for habitat 29—36 points)	225 ft.
Moderate level of function for habitat (score for habitat 20—28 points)	110 ft.
High level of function for water quality improvement and low for habitat (score for water quality 24—32 points; habitat less than 20 points)	75 ft.
Not meeting above characteristic	75 ft.
Category I wetlands	
High level of function for habitat (score for habitat 29—36 points)	225 ft.
Moderate level of function for habitat (score for habitat 20—28 points)	110 ft.
High level of function for water quality improvement (24—32 points) and low for habitat (less than 20 points)	75 ft.
Not meeting above characteristic	75 ft.

Tables for translating function scores

Function scores	2004 Score Range	2014 Score Range
Habitat — High	29-36	8-9
Habitat — Medium	20-28	5-7 (July 2018 modified to 6-7)*
Habitat — Low	≤ 19	3-4 (July 2018 modified to 3-5)*
Water quality — High	24-32	8-9

*Based on a review of the rating system reference wetland data, Ecology adjusted the ranges for the habitat scores.

Also Note:

Cat I &
Cat II
Buffers are
Exactly the
same.

No more
protection
for Cat I

FUNCTION	Improving Water Quality			Hydrologic			Habitat			
Circle the appropriate ratings										
Site Potential	(H)	M	L	(H)	M	L	(H)	M	L	
Landscape Potential	(H)	M	L	(H)	M	L	H	(M)	L	
Value	H	M	(L)	H	M	(L)	(H)	M	L	
Score Based on Ratings	7			7			8			22



Low Land Use Intensity	Land use that includes the following uses or activities: low density residential (R1), forestry (cutting of trees only), low-intensity open space (such as passive recreation and natural resources preservation), <u>unpaved trails.</u>
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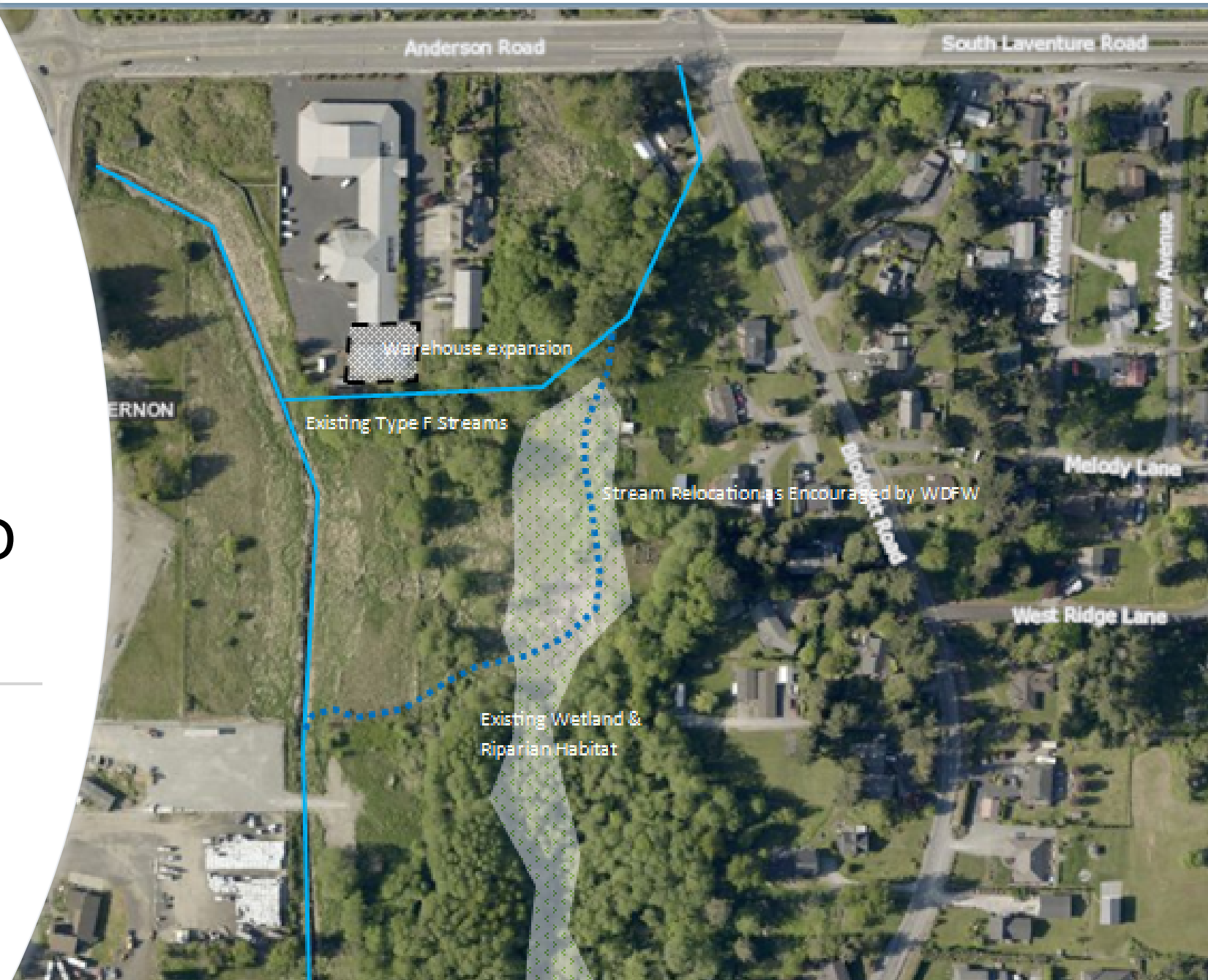
Wetland Category	Buffer Width (feet)		
	High Intensity	Moderate Intensity	Low Intensity
Category I	200 300	190 225	150 50
Category II	200 300	150 225	100 150
Category III	150	110	75
Category IV	50	40	25



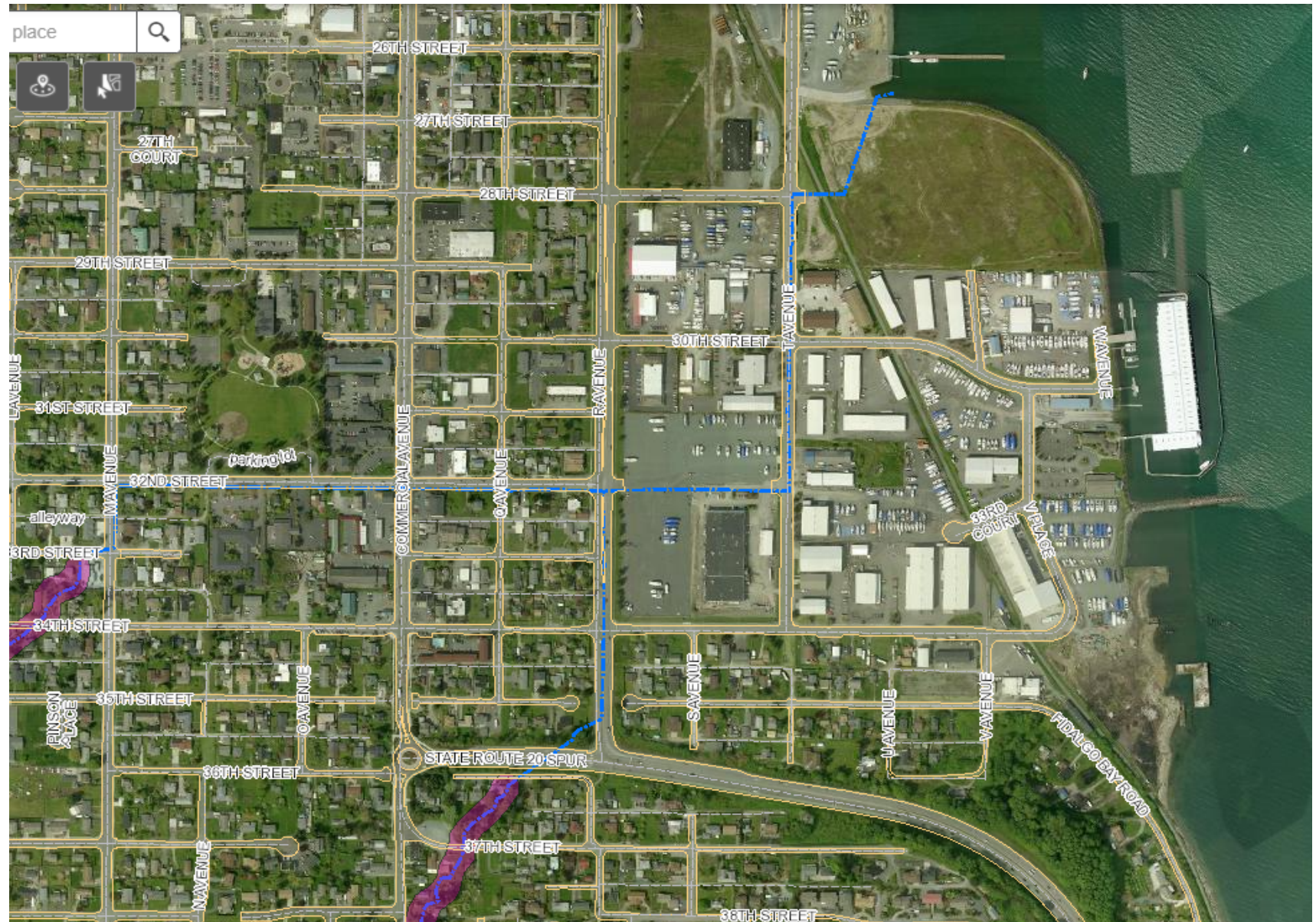
RELOCATION OF STREAMS – EXAMPLES OF WDFW SUPPORTED PROJECTS:



RELOCATION OF STREAMS – EXAMPLES OF WDFW SUPPORTED PROJECTS:



POTENTIAL???



FISH AND WILDLIFE HABITAT CONSERVATION AREAS:

19.70.315 FWHCA Designation:

A.8. State priority habitats and areas associated with State priority species defined and listed by the State Department of Fish and Wildlife in the [Priority Habitats and Species List Updated January 2019](#). Priority habitats and species known to be identified and mapped by WDFW(<http://apps.wdfw.wa.gov/phsontheweb/>) in Anacortes **include, but may not be limited to, the following:**

- a. Biodiversity areas & Corridors;
- b. Riparian Areas
- b. Bald eagle habitat protected pursuant to the Federal Bald and Golden Eagle Protection Act;
- c. Chinook/fall chinook salmon;
- d. Coho salmon;
- e. Great blue heron nest sites and breeding areas;
- f. Osprey nest sites;
- g. Peregrine falcon nest sites and breeding areas;
- h. Purple martin breeding areas;
- i. Resident coastal cutthroat trout;
- j. Winter steelhead trout;
- k. Waterfowl concentrations.

STREAM BUFFER VS. RIPARIAN BUFFERS AND WHY:

We propose to keep both stream buffers and riparian buffers as separate, and NOT to replace stream buffers with larger riparian buffers as suggested.

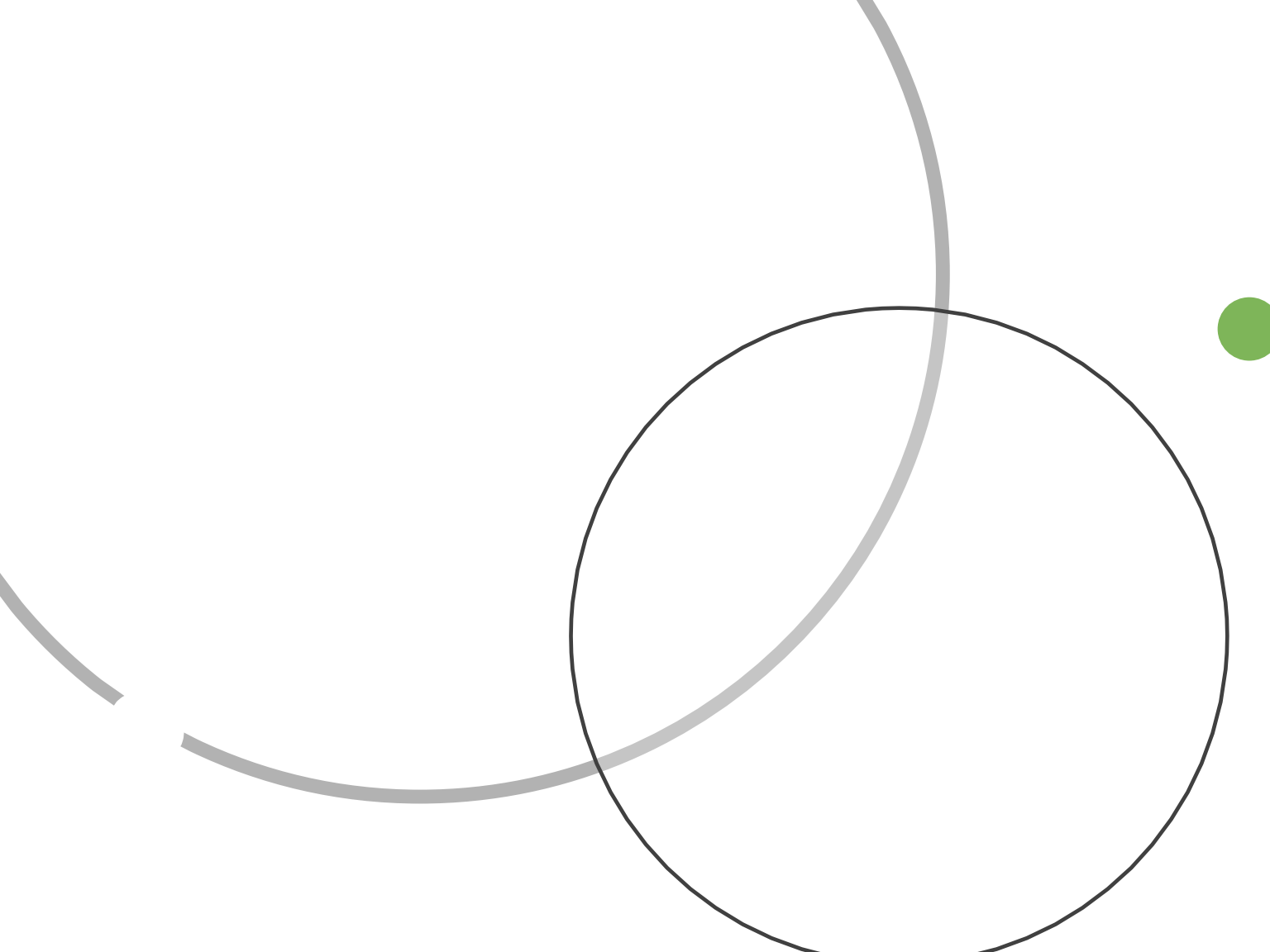
1. While a comment describes that the BAS for SPTH method is appropriate for 'urban areas'...
2. The map does not fully capture all of our streams accurately; some are even missing from the map;
3. Instructions describe use for forested ecoregions vs. common sense approach to our streams.

(Look at examples on the map)

Council Discussion:

A decorative graphic consisting of a thick green curved line that starts from the bottom left and curves upwards and to the right, ending with a small grey dot.

Additional Public Testimony:



Additional Discussion