Chapter 1
Introduction

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Chapter 1. Introduction

The Washington State Department of Natural Resources (Washington DNR) has developed the Aquatic Lands Habitat Conservation Plan (Aquatic Lands HCP) in response to the listing of several species of animals as threatened or endangered under the federal Endangered Species Act. The Aquatic Lands HCP is programmatic in nature, addressing multiple species and habitats, and encompasses submerged lands managed by Washington DNR—excluding those areas managed by port management agreements (Revised Code of Washington [RCW] Section 79.105.420).

Washington DNR's authority for state-owned aquatic lands is governed by a hierarchy of laws, regulations, and guidelines that begin with the assertion of ownership in the Washington State Constitution (Article XVII). The laws granting Washington DNR the proprietary authority to manage state-owned aquatic lands are codified under Title 79 of the Revised Code of Washington (RCW). The state legislature directs Washington DNR management activities under RCW 79, 43.12, and 43.30. To fill gaps in statutory directive, Washington DNR adopted the rules published under Chapter 332-30 of the Washington Administrative Code (WAC), as well as internal policy statements (Standard Practice Memoranda and Guidelines) to provide consistency in the agency's management practices. Uses of state-owned aquatic lands are authorized under the agency's general authority to issue leases (RCW 79.105.210(4)), as well as its authority to issue easements (RCW 79.110 and 79.36.355), aquaculture leases (RCW 79.135), and permits to use waterways (RCW 79.120.040).

The scope and conservation strategy of the Aquatic Lands HCP were designed within the context of Washington DNR's proprietary authority and the agency's obligation to provide a balance of public benefits for current and future citizens of the state. Management guidelines for state-owned aquatic lands are identified within RCW 79.105.030 to include:

1. Encouraging direct public use and access.
2. Fostering water-dependent uses.
3. Ensuring environmental protection.
4. Utilizing renewable resources.

Generating revenue in a manner consistent with guidelines (1) through (4) is considered a public benefit.

The Aquatic Lands HCP includes the following:

- An executive summary that provides an overview of the elements in the document.
- A statement of purpose outlining the intent of the Aquatic Lands HCP.
- A description of the relationship between the Endangered Species Act and the benefits provided under Section 10(a)(1)(B) of the act; a description and quantification of the lands included; the process used for selecting activities to be covered under the Aquatic Lands HCP; the species covered under this HCP and a description of the process used to select species included in this HCP (Chapter 1).
- The history of aquatic land management in Washington State; the relationship of the Aquatic Lands HCP to other Washington DNR HCPs; and the regulatory environment affecting the Aquatic Lands HCP (Chapter 2).

- A description of how the covered activities occur on the landscape, and quantification of the land encumbered by the activities (Chapter 3).
- A description of covered species' distribution within Washington State and their life history requirements; a discussion of the environmental factors associated with covered activities and their effects on covered species; the direct and indirect effects covered by the Aquatic Lands HCP; and quantification of the area potentially affected by covered activities (Chapter 4).
- Washington DNR's goals and objectives under the Aquatic Lands HCP; the operating conservation program for the HCP; the implementation process and funding; compliance and effectiveness monitoring; and the HCP's adaptive management program (Chapter 5).
- A description of alternatives to the Aquatic Lands HCP that were considered and the reasons for their rejection (Chapter 6). The Environmental Impact Statement that accompanies this HCP includes a detailed discussion of the alternatives considered.

1.1 Purpose of the plan

Washington DNR developed the Aquatic Lands HCP to ensure that legally authorized, planned, and mandated management actions may continue to occur on state-owned aquatic lands without risk of violating the Endangered Species Act or resulting in an unlawful *take*[1] of threatened and endangered species. The Aquatic Lands HCP is a contractual agreement between the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries), U. S. Department of the Interior, U.S. Fish and Wildlife Service and Washington DNR. This HCP specifies the goals, strategies, and conservation measures Washington DNR will use to both protect and contribute to the recovery of species that depend on aquatic habitat.

The Aquatic Lands HCP formalizes Washington DNR's efforts to conserve and enhance submerged habitats on state-owned aquatic lands and provides a stable management framework for agency staff and those using state-owned aquatic lands. The HCP is programmatic in nature and covers multiple species, habitats, and activities. It addresses the protection of species through proprietary requirements that are included in the legal instruments (leases, etc.) authorizing uses of state-owned aquatic lands.

Generally stated, the goals for the Aquatic Lands HCP are to:

- Avoid and minimize effects to covered species and habitats.
- Improve and restore habitat conditions on state-owned aquatic lands.
- Identify and protect important habitats on state-owned aquatic lands.

1.1.1 Benefits

An aquatic HCP will help DNR protect sensitive, threatened, and endangered species that are native to Washington State and depend on aquatic habitat. An aquatic HCP will also ensure that activities authorized by DNR, such as leasing for marinas and aquaculture, can continue while avoiding and minimizing impacts to endangered species. By committing to the conservation

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[1] Section 3 (18) of the Endangered Species Act defines *take* as "…to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."

strategies in the aquatic HCP, DNR and entities that lease state-owned aquatic lands will receive federal assurances of compliance with the ESA.. The HCP will also provide assurances that authorized uses of state-owned aquatic lands may continue without jeopardizing covered species or their habitat. The citizens of the state will benefit from Washington DNR's continued ability to provide the balance of public benefits mandated by state law (RCW 79.105.030) and generate revenue managing state-owned aquatic lands. Other benefits include the potential to:

- Develop streamlined permit processes through applicable Aquatic Lands HCP conservation strategies.
- Minimize impacts from private residential docks through implementation of a management strategy (covered in Chapter 5, Section 2.4 of this document).
- Protect aquatic vegetation and forage fish spawning habitat (Chapter 5, Section 2.2).
- Conserve and restore important habitats (Chapter 5, Section 2.2).
- Develop landscape plans for identified priority landscapes (Chapter 5, Section 5.1).
- Increase understanding of the interactions between species, their habitats, and Washington DNR's activities through the HCP's monitoring and research commitments (Chapter 5, Section 4).
- Enhance Washington DNR management activities through implementation of the HCP's adaptive management process (Chapter 5, Section 4).

1.1.2 Term of the plan

Washington DNR is seeking an incidental take permit from NOAA Fisheries and U.S. Fish and Wildlife Service for a term of 50 years to run concurrently with the Aquatic Lands HCP. This term ensures that Washington DNR will be able to implement the defined conservation strategies and monitoring efforts for all activities covered by the HCP that currently exist on state-owned aquatic lands. At the termination of the permit, Washington DNR and the federal agencies may consider renewal of the permit with additional or amended conditions that reflect future circumstances and public involvement.

1.2 Endangered Species Act and assurances

The Endangered Species Act provides for the designation and protection of plants and animals that are in danger of becoming extinct and provides a means to conserve the ecosystems on which such species depend. Section 2(b) of the act defines its purpose as providing ". . . a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species."[2] The act prohibits the take of threatened or endangered species under Section 9(a) making it unlawful to take a species that is listed as endangered or threatened[3] without a permit from U.S. Fish and Wildlife Service, NOAA Fisheries, or both of these agencies that share responsibility for

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[2] Endangered Species Act, 16 U.S.Code § 1531-1544, 87 Stat. 884, as amended.
[3] *Endangered species* are defined as those species in danger of becoming extinct throughout all or a significant portion of their range, with threatened species defined as species that are likely to become endangered in the foreseeable future.

administering the Endangered Species Act. Generally, U.S. Fish and Wildlife Service—acting on behalf of the secretary of the U.S. Department of the Interior—is responsible for terrestrial and freshwater aquatic species, while NOAA Fisheries—acting on behalf of the secretary of the U.S. Department of Commerce—is responsible for marine species and anadromous fish.

Under Section 10(a)(1)(B) the U.S. Fish and Wildlife Service or NOAA Fisheries may permit any taking otherwise prohibited by section 9(a)(1)(B) if such taking is incidental to, and not the purpose of, the carrying out of otherwise lawful activities. In order for such an incidental take permit to be issued, the applicant must submit a habitat conservation plan that specifies:

- The impact which will likely result from such taking (addressed in Chapter 4, Section 4.2 of this document).
- What steps the applicant will take to avoid, minimize and compensate for the impacts (Chapter 5, Section 5.2.) and the funding that will be available to implement the specified steps (Chapter 5, Section 5.3).
- What alternatives the applicant considered and why those alternatives are not acceptable (Chapter 6).
- Such other measures or conditions that the secretary of the interior and the secretary of commerce may require as being necessary or appropriate for purposes of the plan.

1.2.1 Issuance criteria

When the U.S. Fish and Wildlife Service or NOAA Fisheries (or both agencies, as appropriate) determine that all criteria for a habitat conservation plan have been met and there has been an opportunity for public comment, an incidental take permit shall be issued if the applicant meets the following criteria (16 U.S.C. 1539(a)(2)(B)):

- The taking will be incidental.
- The applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking.
- The applicant will ensure that adequate funding for the plan will be provided.
- The taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.
- Such measures that the secretary of the interior and the secretary of commerce may require as being necessary or appropriate to meet the purposes of the plan.

Providing the activities comply with the permit conditions, issuance of an incidental take permit allows the holder to conduct otherwise lawful activities in the presence of listed species without being liable for criminal or civil penalties that may result from an unauthorized taking.

1.2.2 Section 7

Section 7(a)(2) of the ESA requires all federal agencies to consult with the U.S. Fish and Wildlife Service and NOAA Fisheries to ensure that ". . . any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification . . . " of designated critical habitat.[4] If the action is determined to have incidental take, agency actions will include the issuance of an incidental take permit, after the U.S. Fish and Wildlife Service and NOAA Fisheries conduct an intra-agency Section 7 consultation. The regulations implementing Section 7 (50 CFR 402) require, among other things, a biological consultation to analyze the direct and indirect effects of the proposed action; the cumulative effects of other activities on listed species; and where applicable, the effects of the action on critical habitat. For the Aquatic Lands HCP, an effects analysis on covered, unlisted species is required and a statement of incidental take is required for all covered (listed and unlisted) species. Information in the Aquatics Lands HCP and the associated environmental impact statement will assist the U.S. Fish and Wildlife Service and NOAA Fisheries in their consultation process.

For the purpose of Section 7, agency actions also include permits issued by a federal agency for construction or development of a single project such as building a dock. These single project consultations narrowly address avoidance, minimization, and compensation for the construction or development activities associated with the specific project; the Aquatic Lands HCP will not eliminate this requirement. In contrast, a Section 7 consultation conducted for a habitat conservation plan addresses avoidance, minimization, and compensation for take associated with an ongoing program of operation; the approved habitat conservation plan must address long-term monitoring and contributions to the recovery of listed species.

1.2.3 No surprises and unforeseen circumstances

No surprises

The federal government provides the No Surprises assurances through the section 10(a)(1)(B) process to non-federal landowners. Through No Surprises, if unforeseen circumstances arise, the U.S. Fish and Wildlife Service and NOAA Fisheries will not require the commitment of additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources beyond the level agreed to in the habitat conservation plan without the consent of the permittee. The federal government will honor these assurances as long as a permittee is implementing the terms and conditions of the habitat conservation plan, permit, and other associated documents in good faith [No Surprises Rule, 63 Fed. Reg. 8859 (Feb. 23 2998), codified at 50 C.F.R. § § 17.22, 17.32 and 222.307(g)] .

Unforeseen circumstances

Unforeseen circumstances are those affecting either a species or the geographic area covered by the Aquatic Lands HCP that result in a substantial and adverse change in the status of a covered species and could not have been reasonably anticipated by Washington DNR or the permitting agencies at the time of developing and negotiating this HCP. In negotiating unforeseen circumstances, U.S. Fish and Wildlife Service and NOAA Fisheries will not require the

[4] Section 3(5)(A) of the Endangered Species Act defines *critical habitat* as specific areas occupied by a species at the time of its listing that contain the physical or biological features essential to the conservation of the species, and which may require special management considerations or protection.

commitment of additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources beyond the level otherwise agreed upon for the species covered by the conservation plan without the consent of the Washington DNR. Consistent with those limitations, if additional conservation and mitigation measures are deemed necessary to respond to unforeseen circumstances, the U.S. Fish and Wildlife Service and NOAA Fisheries may require additional measures of the Washington DNR. Additional measures may be applied when the conservation plan is being properly implemented, but only if such measures are limited to modifications within conserved habitat areas, if any, or to the conservation plan's operating conservation program for the affected species.

The original terms of the conservation plan will be maintained to the maximum extent possible. The U.S. Fish and Wildlife Service and NOAA Fisheries will have the burden of demonstrating that unforeseen circumstances exist, using the best scientific and commercial data available. These findings must be clearly documented and based upon reliable technical information regarding the status and habitat requirements of the affected species. U.S. Fish and Wildlife Service and NOAA Fisheries will consider, but not be limited to, the following factors:

- Size of the current range of the affected species.
- Percentage of range adversely affected by the conservation plan.
- Percentage of range conserved by the conservation plan.
- Ecological significance of that portion of the range affected by the conservation plan.
- Level of knowledge about the affected species and the degree of specificity of the species' conservation program under the conservation plan.
- The likelihood that survival and recovery of the affected species in the wild would be appreciably reduced if additional conservation measures were not adopted.

1.2.4 Changed circumstances

Changed circumstances are those affecting a species or the geographic area covered by this HCP that can reasonably be anticipated and that were taken into account by Washington DNR and U.S. Fish and Wildlife Service and NOAA Fisheries during the course of developing this HCP. Such changes include listing, delisting, or extirpation of a species; natural events such as floods or seismic events; introductions or increases in invasive species; global climate change; and spills of hazardous substances. Additionally, minor changes in the area of state-owned aquatic lands may occur through adjudication, sale, acquisition, or exchange. The incidental take permit will authorize the incidental take of covered species under ordinary circumstances and under changed circumstances, as long as Washington DNR is operating in compliance with this HCP and its associated documents.

Change in species status

Over time, species status under the Endangered Species Act may change and additional species may be listed as threatened or endangered, delisted, declared extinct, or critical habitat for a species may be designated.

Listing of species not covered by this HCP

When aquatic or aquatic-dependent species that occur within, or rely on, state-owned aquatic lands for significant portions of their life history become listed under the Endangered Species Act, the U.S. Fish and Wildlife Service and NOAA Fisheries will determine if there is a potential for incidental take of the species to occur as a result of the activities covered under the Aquatic Lands HCP. In instances where the U.S. Fish and Wildlife Service and NOAA Fisheries determine that there is the potential for take, Washington DNR can request that the newly listed species be added to the incidental take permit and amend the HCP or prepare a separate HCP to address the needs of that species. Under either circumstance, the U.S. Fish and Wildlife Service and NOAA Fisheries and Washington DNR will enter into discussions to develop the appropriate standards, programmatic strategies and activity-specific conservation measures to meet ESA Section 10(a) requirements for incidental take coverage.

Delisting of covered species

If a species covered by this HCP is delisted (regardless of whether it has become extinct or is recovered), Washington DNR will evaluate whether it is in the best interest of the public to continue implementation of the standards, programmatic strategies, and activity-specific conservation measures designed to benefit the delisted species. If it is determined to continue with conservation strategies specific to the delisted species, Washington DNR will document the rationale, develop a plan for the species, and provide specific goals for public record.

Extirpation of covered species

If there appears to be local extinction (extirpation) of a covered species from a distinct and isolated fragment of suitable habitat, Washington DNR, the U.S. Fish and Wildlife Service, and NOAA Fisheries will determine the appropriate study and survey protocols for evaluating the circumstances. If the study and survey conducted under the agreed-upon protocols show that the species is extirpated and that natural repopulation is unlikely, Washington DNR will evaluate whether it is in the best interest of the public to continue implementation of the standards, strategies, and measures designed to exclusively benefit the extirpated species in that area. If it is in the public interest, Washington DNR may continue implementation and, if feasible, may consider relocation of species from other habitat areas. Otherwise, Washington DNR will discontinue implementation of all standards, strategies, and measures that benefited only the extirpated species.

Designation of critical habitat

When a critical habitat is designated for a listed species, whether covered by the HCP or not, the U.S. Fish and Wildlife Service and NOAA Fisheries will determine if there is a potential for critical habitat to be adversely modified as a result of the activities covered under the Aquatic Lands HCP. In instances where the U.S. Fish and Wildlife Service and NOAA Fisheries determine that there is this potential, Washington DNR can request that the covered lands be excluded from critical habitat designation. During the development of the rules for critical habitat, the U.S. Fish and Wildlife Service and NOAA Fisheries will take the request for exclusion into consideration based on the merits of the HCP's conservation strategy.

Adjudication of ownership

The extent of state ownership may become more certain over the term of this HCP as the result of judicial decisions that particular freshwater lakes or rivers are, or are not, navigable for state title (see Section 1.3, Lands Covered). Rather than addressing changing conditions, such decisions correct erroneous assumptions about ownership; while Washington DNR can litigate the matter, the judicial courts make the final determination. If the question of navigability is fully litigated and a final decision is rendered by the court that aquatic land previously claimed by the state is actually owned by another entity, the Aquatic Lands HCP will no longer apply to the area litigated. If the court's final decision is that aquatic land not previously claimed by the state is actually state-owned, Washington DNR will apply the appropriate HCP standards, programmatic strategies, and activity-specific measures to the newly acknowledged lands.

Sale, acquisition, and exchange of aquatic land

Washington DNR may sell, acquire, or exchange aquatic lands during the term of the Aquatic Lands HCP. Such conveyances are unlikely to result in significant changes to the land base of 2.6 million acres unless the legislature takes the unusual step of granting the agency substantially more discretion in conveyance of lands. The limitations on Washington DNR's authority to convey lands have been approximately the same for more than 40 years and are based on the classification of land as bedlands, tidelands, or shorelands (Section 1.3.1, Statutory Classification). The agency currently has no authority to convey bedlands; the agency does have the authority to sell shorelands and tidelands near cities to public entities for public purposes (RCW 79.125.200, 79.125.700 and 79.125.710). The agency may also sell shorelands to upland owners if the shorelands are more than two miles from cities and the sale is not contrary to the public interest (RCW 79.125.450). Washington DNR may exchange tidelands and shorelands with both private and public entities if the exchange is in the public interest (RCW 79.105.400) and can accept gifts of aquatic lands (RCW 79.105.410). Outright land purchase requires legislative approval and appropriation. Port districts can obtain management authority over state owned aquatic lands under RCW 790.125.420.

As directed by the legislature, Washington DNR will continue to consider the public interest when evaluating proposed sales, acquisition, or exchange of aquatic lands; the agency regards furtherance of the goals of the Aquatic Lands HCP to be in the public interest. When considering offers made to the state for purchase or exchange of lands owned by others, the agency will use the landscape planning process to identify lands most in need of acquisition and protection. Washington DNR will apply the appropriate HCP standards, strategies, and measures to the newly acquired lands. Washington DNR will avoid authorizing the use of aquatic lands that would be considered a conservation priority based on the Aquatic Lands HCP's land planning process unless the receiving entity commits to continued management in conformance with this HCP (Section 5.2.2, Programmatic Strategies).

1.2.5 Other methods of ESA compliance pertinent to state-owned aquatic land

Section 7 of the Endangered Species Act

When a person or entity proposes an action on state-owned aquatic lands, the action may have a federal connection or nexus as a result of 1. issuance of a United States Army Corps of Engineers permit for in-water construction or for discharge of materials into the waters of the United States; 2. actions by the federal government; 3. actions carried out with federal funding; or 4. when federal environmental health and safety laws such as oil spill response and occupational safety are at issue. Where there is a federal nexus, the proposed action is subject to Section 7 of the Endangered Species Act (see Section 1.2.2) and a federal consultation is required to ensure that the proposed action does not jeopardize listed species or adversely modify critical habitat. This HCP does not replace this means of ESA compliance or relieve entities of the duty to consult under Section 7. Rather, Washington DNR will use the standards defined in the HCP as minimum conditions for new proposals occurring on state-owned aquatic lands.

Section 4(d) Rules of the Endangered Species Act

For some activities on state-owned aquatic lands, compliance with the ESA may be achieved under rules promulgated by the secretary of the interior or secretary of commerce as necessary for the conservation of threatened species per Section 4(d) of the Endangered Species Act.. NOAA Fisheries has defined rules addressing habitat restoration as part of a watershed restoration plan; routine road maintenance activities; forestry activities; and select development/redevelopment for fourteen evolutionarily significant units (ESUs) of salmonids (65 CFR 132, 42422 to 42481; 50 CFR 223). U.S. Fish and Wildlife Service has defined rules for the accidental hooking or catching of bull trout. Under this particular 4(d) rule, bull trout hooked or caught and released by anglers that are fishing in compliance with state fishing regulations will not represent a violation of take prohibitions under Section 9 of the Endangered Species Act.

1.3 Lands covered

The Aquatic Lands HCP covers those lands directly owned by the state of Washington and managed by Washington DNR that underlie navigable freshwater, marine, and estuarine waters within the state of Washington. Under federal law, Washington received title to those lands upon statehood[5] and the State asserted ownership in Article XVII, Section 1 of the Washington State Constitution. This HCP does not cover areas managed under port management agreements, or aquatic lands sold into private ownership, managed by agencies other than Washington DNR, or under waters that are not navigable for the purpose of establishing state title.

Waters that are navigable for the purpose of establishing state title are those lands that are capable of serving as a highway for commerce in their natural and ordinary condition, using customary

[5] See *Pollard's Lessee v. Hagan*, 44 U.S. (3 How.) 212 (1845).

modes of travel and trade on water.[6] Washington DNR presumes ". . . all bodies of water meandered by government surveyors . . ." to be navigable for the purpose of establishing state title unless declared otherwise by a court (WAC 332-30-106(41)). If there is a dispute about whether a water body is navigable for the purpose of vesting title in the state, the judiciary makes the final determination.

While state ownership in saltwater is well established, the extent of state-owned aquatic lands underlying freshwater is less established because the navigability of some water bodies has yet to be analyzed or adjudicated. In addition, because state ownership, and thus Washington DNR's management authority, generally follows gradual changes in the boundary of the water body caused by natural accretion, erosion, and reliction, the location of water bodies managed by Washington DNR may change over time.[7]

The state manages approximately 2.6 million acres of submerged land (Figure 1.1), and the associated biological communities, such as submerged aquatic vegetation and *infauna* (animals or invertebrates that live within sediment). State-owned aquatic lands extend 5.6 kilometers (3 miles) waterward into the Pacific Ocean and includes:

- Submerged lands and resources to the center of the Strait of Juan de Fuca, Haro Strait, Boundary Pass and the Strait of Georgia.
- Aquatic lands and resources surrounding the San Juan Archipelago.
- Lands and resources underlying Puget Sound and Hood Canal.
- Navigable rivers and lakes across the state.[8]

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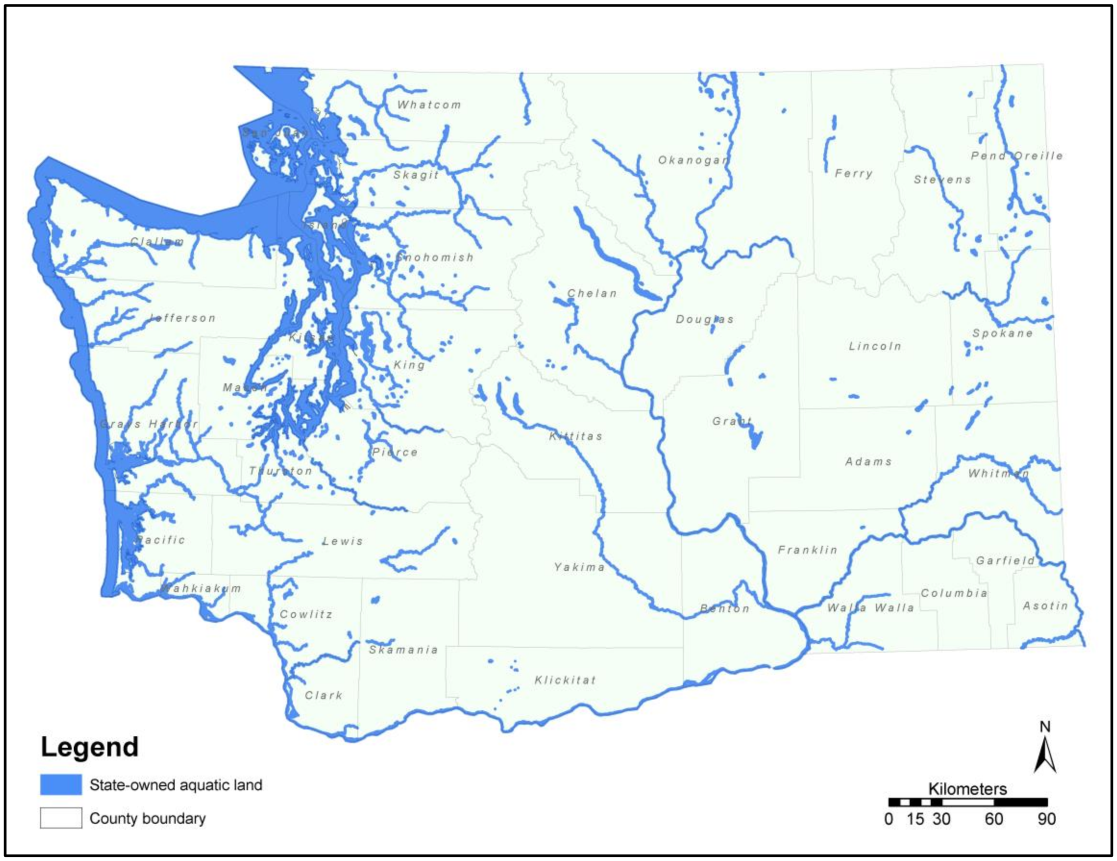
6 *Brewer-Elliott Oil & Gas Co. v. U.S., 260 U.S.* 77, 43 S. Ct. 60, 67 L. Ed. 140 (1922); U.S. v. Holt State Bank, 270 U.S. 49, 55-56, 46 S. Ct. 197, 70 L. Ed. 465 (1926); U.S. v. Utah, 283 U.S. 64, 75, 51 S. Ct. 438, 75 L. Ed. 844 (1931).

7 See *Smith Tug & Barge Co. v. Columbia-Pacific Towing Corp*., 78 Wn.2d 975, 482 P.2d 769 (1971).

8 The federal *Submerged Lands Act* of 1953 grants states title to the natural resources located within three nautical miles of their coastline, with natural resources defined as minerals and marine animal and plant life.

Figure 1.1. Distribution of state-owned aquatic lands.



1.3.1 Statutory classification

Washington has three primary statutory classifications for aquatic lands: tidelands, shorelands, and bedlands (RCW 79.105.060). These lands are further classified as harbor areas or waterways, depending on the special uses to which the land is subject. Of the lands originally granted to the state by the federal government, nearly all freshwater and marine bedlands, approximately 30 percent of the tidelands, and 70 percent of the shorelands of the navigable lakes and rivers in the state remain in state ownership. Table 1.1 illustrates the approximate current distribution of state-owned aquatic lands by statutory classification.

Table 1.1. Approximate distribution of aquatic lands by statutory classification.

Statutory Classification	Acreage		Percent State-owned
	State-owned	Total	
Bedlands			
Lacustrine	144,776	151,619	95%
Marine	2,162,158	2,163,243	100%
Riverine	174,977	207,506	84%
Subtotal	2,481,910	2,522,368	98%
Shorelands			
Lacustrine			
First Class	48	1,534	3%
Second Class	11,324	16,958	67%
Unclassified	-	71	0%
Subtotal	11,372	18,563	61%
Riverine			
First Class	21,831	22,064	99%
Second Class	21,831	27,049	81%
Unclassified	-	439,906	0%
Subtotal	43,663	489,019	9%
Tidelands			
First Class	6,895	23,307	30%
Second Class	127,665	264,073	48%
Unclassified	-	1,065	0%
Subtotal	134,561	288,444	47%
Harbor Areas	10,129	10,147	100%
Waterways	1,760	1,770	99%
Other[9]	578	3,883	15%
Total	**2,683,973**	**3,315,631**	**81%**

[9] Includes abandoned tidelands, shorelands and canals.

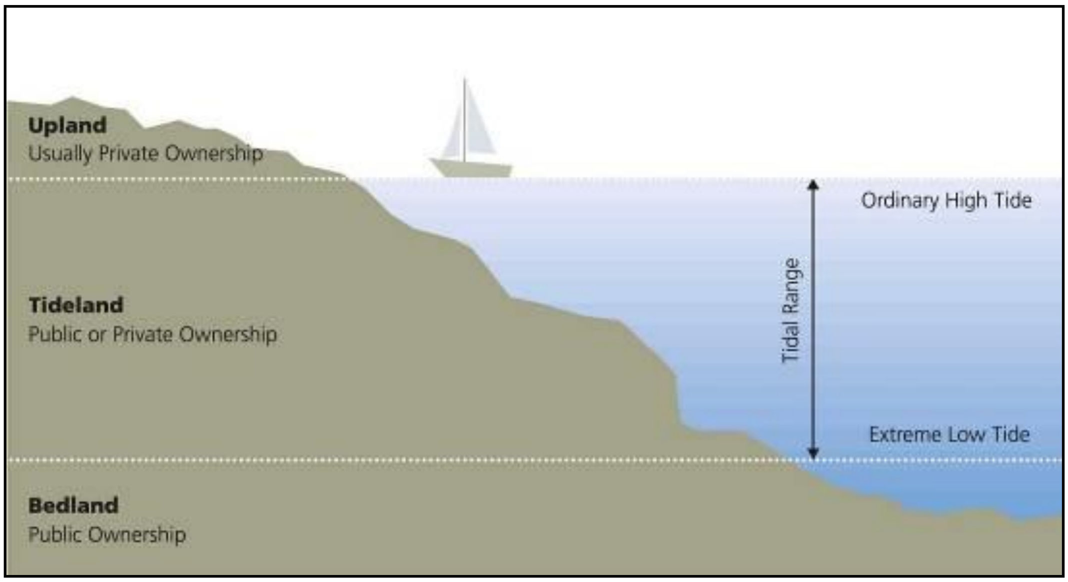
Tidelands

Tidelands are those marine and estuarine waters affected by the ebb and flow of tides and located between the ordinary high tide and extreme low tide line (Figure 1.2).

State law defines first-class tidelands as " . . . the shores of navigable tidal waters belonging to the state, lying within or in front of the corporate limits of any city, or within one mile of either side and between the line of ordinary high tide and the inner harbor line; and within two miles of the corporate limits on either side and between the line of ordinary high tide and the line of extreme low tide" (RCW 79.105.060 (4)). Second-class tidelands are defined as " . . . the shores of navigable tidal waters belonging to the state, lying outside of and more than two miles from the corporate limits of any city, and between the line of ordinary high tide and the line of extreme low tide" (RCW 79.105.060 (18)).

As city limits change, the classification of a given area of state-owned tideland may also change. Besides location, the most important difference between first- and second-class tidelands is that the owners of terrestrial lands abutting first-class tidelands have a preference right, or right of first refusal, for use of the submerged lands adjacent to their property.

Figure 1.2. Marine tidelands and bedlands.



Graphic: Luis Prado, DNR

Shorelands

Shorelands are generally submerged lands associated with navigable rivers and lakes not affected by the ebb and flow of tides. For purposes of ownership, shorelands are statutorily defined as lands located between the line of ordinary high water[10] and the line of navigability (Figure 1.3). The *line of navigability* is the ". . . measured line at a depth sufficient for ordinary navigation as

[10] Ordinary high water is determined either by the line of permanent terrestrial vegetation along the shore, or by a line impressed upon the soil by the action of the water over many years.

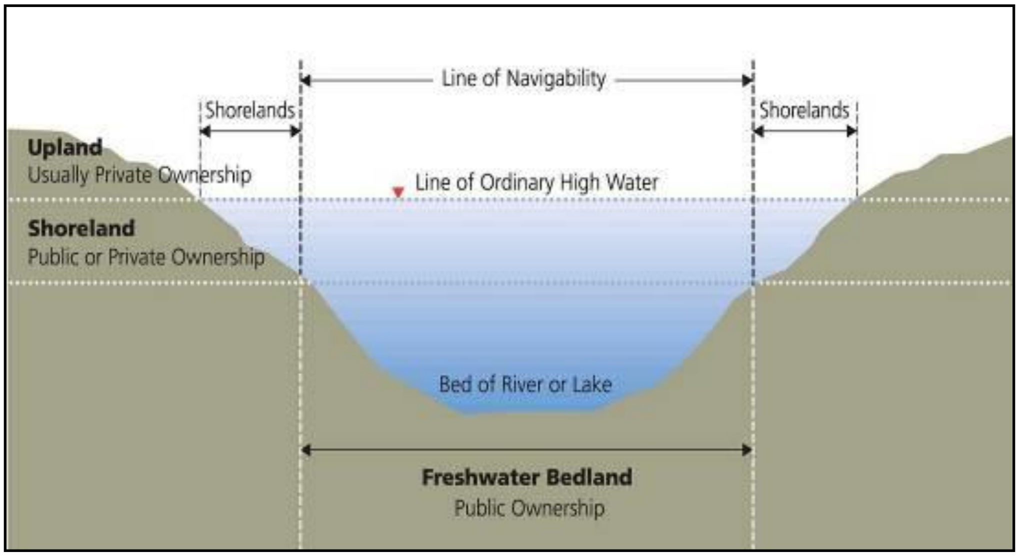
determined by the board of natural resources for the body of water in question" (WAC 332-30-106(33)).

State law defines *first-class shorelands* as ". . . the shores of a navigable lake or river belonging to the state, not subject to tidal flow, lying between the line of ordinary high water and the line of navigability, or inner harbor line where established and within or in front of the corporate limits of any city or within two miles of either side" (RCW 79.105.060 (3)).

Second-class shorelands are defined as ". . . the shores of a navigable lake or river belonging to the state, not subject to tidal flow, lying between the line of ordinary high water and the line of navigability, and more than two miles from the corporate limits of any city" (RCW 79.105.060 (17)).

Similar to the legal definitions for tidelands, the classification of state-owned shorelands may change as city limits change, with owners of abutting terrestrial lands having a preference right for authorized uses of first-class shorelands.

Figure 1.3. Freshwater shorelands and bedlands.



Graphic: Luis Prado / DNR

Bedlands

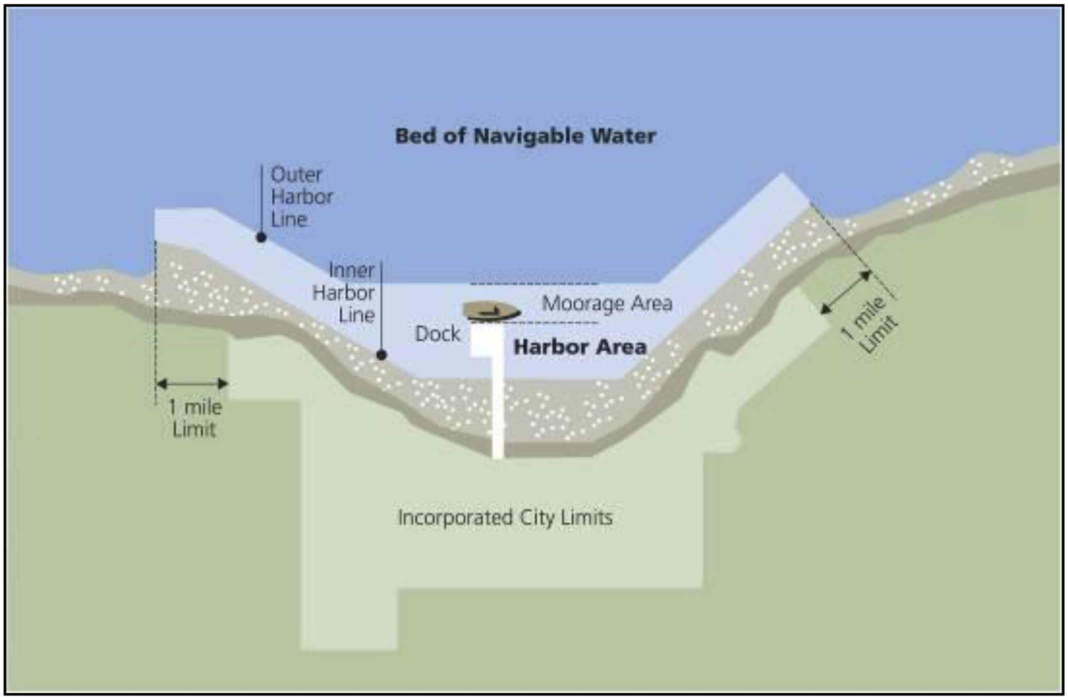
Bedlands, or *beds of navigable waters* (RCW 79 105.060 (2)), are submerged lands that lie waterward of adjoining tidelands or shorelands and below the line of extreme low tide or the line of navigability (see Figures 1.2 and 1.3).

Harbor Areas

Under Article XV, Section 1 of the Washington State Constitution, *harbor areas* are ". . . forever reserved for landings, wharves, streets, and other conveniences of navigation and commerce." Harbor areas may extend up to one mile along the shoreline beyond incorporated city limits and are delimited by both an inner and outer harbor line (Figure 1.4). The state is prohibited from giving, selling or leasing lands beyond the outer harbor line. Washington DNR assists the Board of Natural Resources in its constitutional role as the Harbor Line Commission to locate and establish harbor lines.

Proposals to establish, relocate, and re-establish inner and outer harbor lines are submitted to the Washington DNR Aquatic Resources program. Staff reviews the proposals in accordance with specific procedures, forwarding both the proposal and staff recommendations to the Harbor Line Commission for final review and approval. Since 1890, the Harbor Line Commission has established 31 harbor areas (26 marine and tidal, and 5 freshwater areas) and approved approximately 60 harbor line changes (Ivey, 2004).

Figure 1.4. Limits of harbor areas.



Graphic: Luis Prado / DNR

Waterways

Waterways are lands reserved for public access between terrestrial lands and open water. Their purpose is to provide public navigation routes between deep water and the land inside of the inner harbor line (RCW 79.120.010). Waterways are planned and platted as part of a harbor area designation; some state designations may overlap or adjoin waters where federal pierhead lines have been established to create a federal waterway (RCW 79.120.040) State law prohibits permanent structures that interfere with navigation and commerce in waterways, (RCW 79.120.010), except in areas where a boundary of a state waterway is landward of a pierhead line for a federal waterway (RCW 79.120.040). There are 102 state waterways adjoining 23 harbor areas throughout Washington State, with additional waterways owned and established by counties and cities, port districts, and commercial waterway districts pursuant to authority granted by the legislature.

1.4 Habitats covered

Washington DNR's management authority for state-owned aquatic lands includes the sediments and their attached biological communities. This section defines those habitats and the processes upon which they depend.

1.4.1 Environmental setting

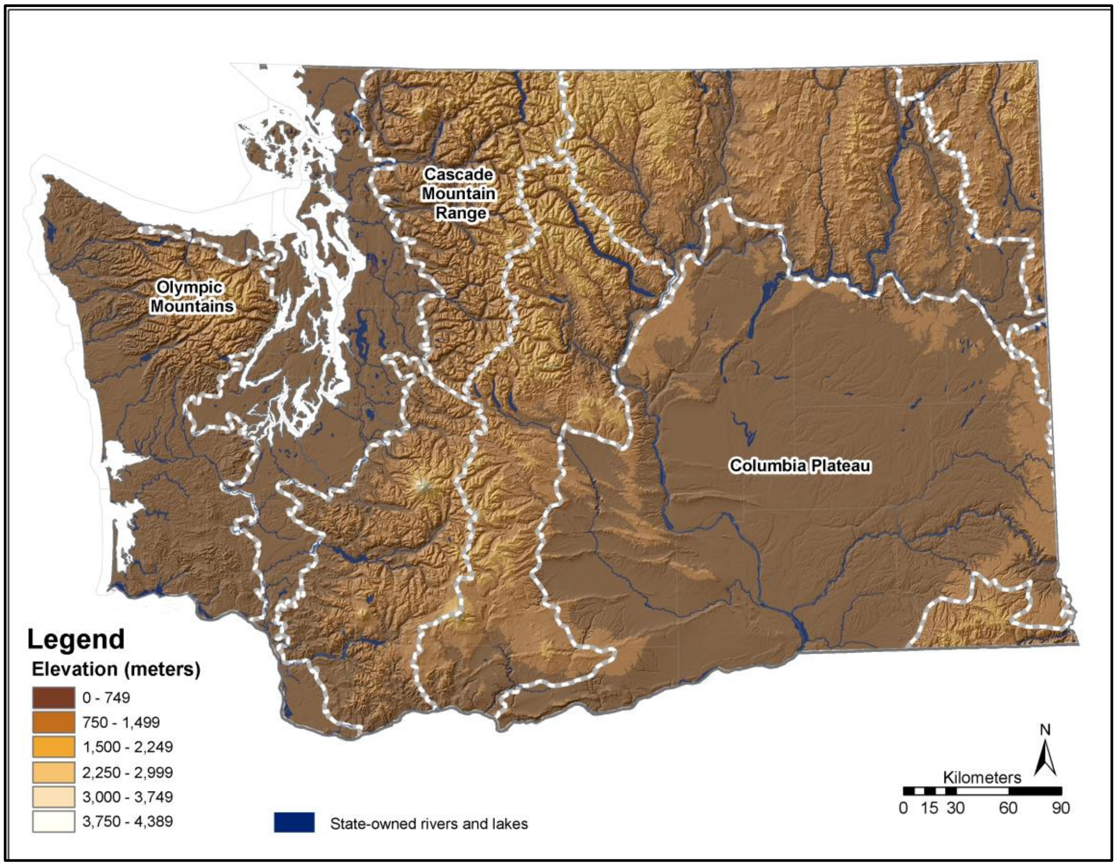
While individual water bodies have distinct biological, chemical, and physical characteristics, they can also be defined by commonalities in ecological and landscape patterns. This section defines and describes those commonalities and the condition of state-owned aquatic lands.

Topography

The Cascade Mountain Range (Cascade Range) runs north-south through the state and is considered the division between eastern and western Washington (Figure 1.5). The mountains are the dominant feature of central Washington and the highest elevations in the state are found here; the highest mountain is Mount Rainier at 4,392 meters (14,410 feet). Eastern Washington is dominated by the high desert of the Columbia Plateau and the valleys of the Columbia River and its tributaries.

West of the Cascade Range are the coastal lowlands of the Puget Trough and Puget Sound. Western Washington also contains the Olympic Peninsula and the Olympic mountains, which are part of the Pacific Coastal Mountain Range that extends from Alaska to California. The shoreline of the Pacific Ocean forms the western boundary of the state; the lowest elevations in the state occur here where the land meets the ocean.

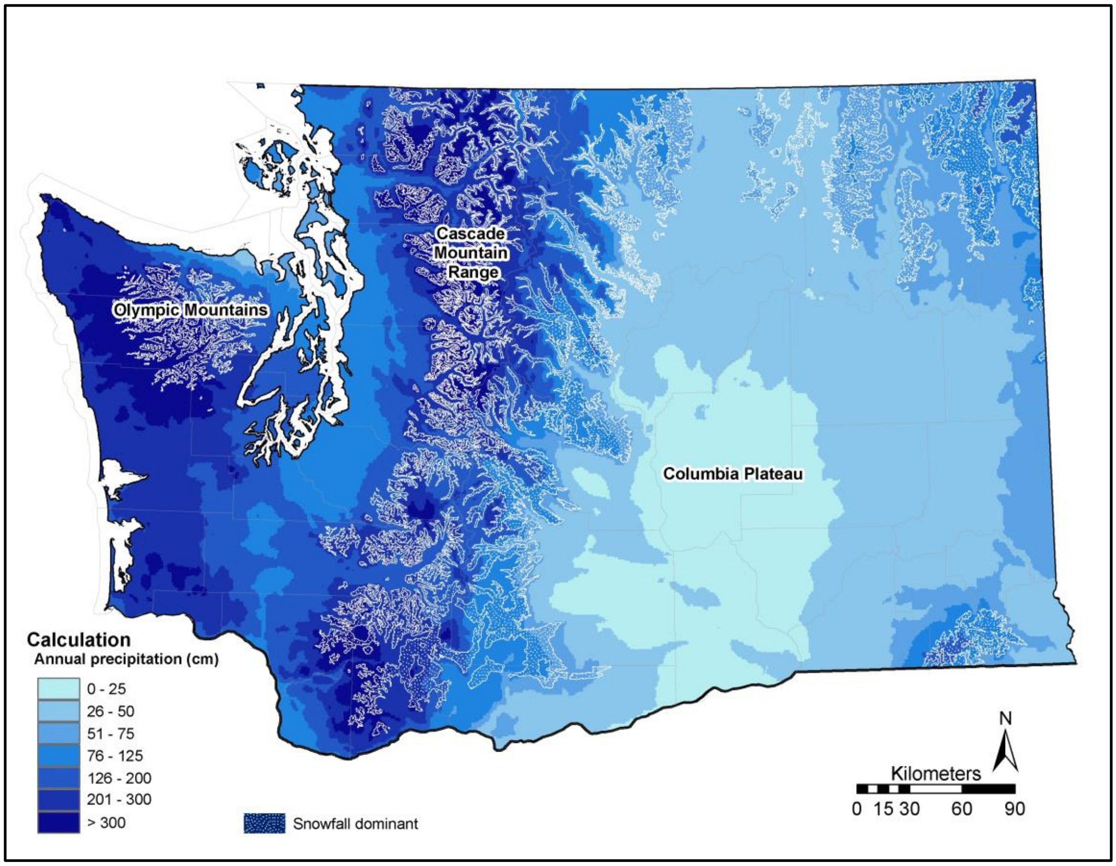
Figure 1.5. Topographic regions of Washington.



Climate

The influences of the Pacific Ocean and Cascade Range result in distinct climatic differences between the eastern and western sides of the state (Figure 1.6). Air currents coming off the ocean bring warm, moist air and abundant rainfall to western Washington and result in a temperate climate. These maritime-influenced parts of the state are frequently cloudy with considerable fog and long-lasting periods of rain. Summers are sunny and mild with average high temperatures near 21 degrees Celsius (70 degrees Fahrenheit). Washington's coastal region is one of the wettest areas in the United States, receiving up to 3.8 meters (12.5 feet) of rain per year at the highest elevations; the western slopes of the Cascade Range receive over 5 meters (16 feet) of snow annually. Precipitation anomalies due to the rain shadow effect of the northeast Olympic Peninsula result in some western Washington areas receiving an average rainfall of less than 0.51 meters (20 inches) per year. The Cascade Range hinders the eastward movement of the warm ocean air, resulting in a semi-arid climate in eastern Washington. This side of the state is drier and has greater extremes in seasonal temperatures and precipitation. In addition to warmer summers, winters are colder and there is less precipitation than in the western side of the state.

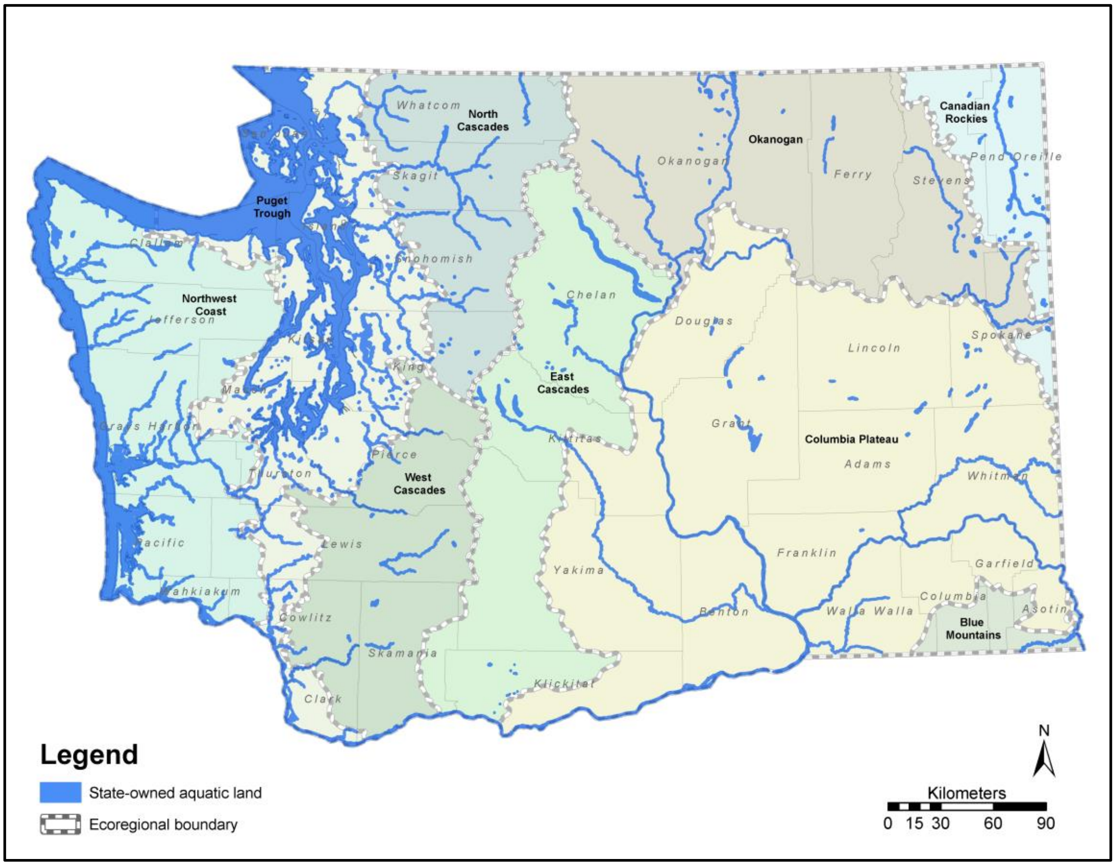
Figure 1.6. Climatic regions of Washington.



1.4.2 Ecoregional setting

The definition of an ecoregion includes biotic and abiotic factors within geographically distinct landforms. To reflect the diversity of habitat requirements of the HCP covered species, Washington DNR has chosen to report its conservation efforts using the Natural Heritage Program's defined ecoregions (Washington DNR, 2007a; Figure 1.7). The decision to use this system is primarily based on the resolution of the data and its compatibility with Washington DNR's leasing data, as well as its use by The Nature Conservancy for ecoregional assessments.

Figure 1.7. Natural Heritage program ecoregions.



Blue Mountains

The Blue Mountains ecoregion extends from adjacent Idaho and Oregon into the southeast corner of Washington and includes the Grande Ronde and Snake River canyons. Annual precipitation varies from less than 25 centimeters (9.8 inches) in the Grande Ronde River canyon to more than 127 centimeters (50 inches) in the Wenaha-Tucannon Wilderness Area. While much of the region's precipitation occurs as snow, fall and spring rains frequently lead to floods. Approximately 1 percent of Washington is within this ecoregion.

Canadian Rockies

The majority of this ecoregion occurs in adjacent British Columbia and Idaho; only 4 percent of Washington lies within this ecoregion. Annual precipitation ranges from 50 centimeters (20 inches) along the Columbia River to about 200 centimeters (79 inches) in the Salmo-Priest Wilderness Area. Heavily influenced by forming and retreating glaciers, this ecoregion is dominated by ice-carved valleys and isolated mountain peaks.

Columbia Plateau

The hottest and driest ecoregion in Washington, the Columbia Plateau lies in the rain shadow of the Cascade Range and is bounded by the Cascade, Okanogan, Blue and Rocky mountains. Annual precipitation increases west to east from about 10 centimeters (4 inches) along the Columbia River's Hanford Reach to 63 centimeters (25 inches) in the Palouse Hills. The region's canyons and broad valleys were carved by glaciers; the coulees and scablands were formed by flood events associated with Lake Missoula and Lake Columbia. Approximately one-third of the state lies in this ecoregion.

East Cascades

Influenced by alpine glaciers, steep mountain ridges, and broad valleys, this ecoregion lies east of the Cascade crest, from Sawtooth Ridge near Lake Chelan south to the Oregon border. The climate is wetter and colder in the western portion of the region and along the Cascade crest, and hotter and dryer in the foothills. Precipitation falls from November through April, with totals ranging from 51 to 305 centimeters (20 to 120 inches) annually and snow pack accumulating at higher elevations. Approximately 10 percent of Washington is included within this ecoregion.

North Cascades

The North Cascades ecoregion includes the Cascade Range north of Snoqualmie Pass and west of the crest; elevations range between 152 meters and 3,048 meters (499 to 10,000 feet). Precipitation occurs as snow and rain from October through April, with totals ranging from 150 to 400 centimeters (59 to 157 inches) annually. Small streams and rivers originating in the mountains feed the larger systems in the Puget Trough; lakes are common in the region's glacial depressions. Approximately 10 percent of the state lies in this ecoregion.

Northwest Coast

Approximately 11 percent of Washington's area occurs within the Northwest Coast ecoregion. The ecoregion is dominated by the Olympic Mountains, Pacific Ocean, coastal plain, and the Willapa Hills. Annual precipitation ranges from 150 to 600 centimeters (59 to 236 inches), with fog and cool temperatures common year-round. Streams and rivers typically begin in steep mountain drainages, forming large flat river systems on the coastal plain with natural lakes occurring in glacial depressions.

Puget Trough

This ecoregion is nestled between the Cascade Range and Olympic Mountains and includes Puget Sound and the lowlands south to the Columbia River. Roughly 8 percent of Washington, and the bulk of the state’s human population, is within this ecoregion. Precipitation primarily falls as rain in the winter, with annual totals ranging between 50 and 180 centimeters (20 to 71 inches). Large, low-gradient rivers begin in the adjacent mountains and flow through this ecoregion; freshwater lakes are common in the glaciated portions of the ecoregion.

Okanogan

The Okanogan region of Washington extends from the Cascade crest in the northern Cascade Range east to the Selkirk Mountains; the southwestern border follows Sawtooth Ridge northeast of Lake Chelan. Annual precipitation ranges from less than 0.3 meters (1 foot) in the Okanogan Valley to between 130 and 230 centimeters (51 to 91 inches) in the Cascade Range. Approximately 14 percent of Washington is within this ecoregion.

West Cascades

The West Cascades ecoregion extends west from the Cascade crest and Snoqualmie Pass southward to the Oregon border; elevations range from 15 meters (49 feet) in the Columbia River Gorge to over 4,392 meters (14,410 feet) at the summit of Mt. Rainier. Climate in the region is wet and relatively mild. Annual precipitation occurs as rain and snow and ranges from 140 to 350 centimeters (55 to 138 inches). This ecoregion consists of highlands modified by montane glaciers and associated river valleys. Small, steep-gradient streams typically feed major rivers to the west; the region’s lakes were formed by glacial processes and landslides. Approximately 8 percent of the state is within in this ecoregion.

1.4.3 Ecosystems present

As with ecoregions, ecosystem definitions include biotic and abiotic factors but tend to be broader geographically, occurring across ecoregional boundaries. The Aquatic Lands Habitat Conservation Plan defines four general aquatic ecosystems: lacustrine, riverine, saltwater nearshore,[11] and saltwater offshore. These ecosystem categorizations are founded on scientifically based and commonly used classification systems (Cowardin, 1979; Dethier, 1990). The hierarchies were simplified to improve their utility in a statewide analysis and to accommodate the coarse spatial resolution of Washington DNR’s leasing data layer. Because of the complexities associated with defining the geographic limits of estuaries and the fact Puget Sound is frequently classified as an estuary, it is difficult to define the geographic limits of tidal influence. As a result, estuaries and tidally influenced rivers have been included as part of the saltwater-nearshore ecosystem. Table

[11] Includes tidally influenced rivers.

1.2 illustrates the approximate distribution of state-owned aquatic lands by the ecoregions and ecosystems used within the Natural Heritage program. Table 1.3 summarizes the distribution of each defined ecosystem.[12] Appendix A summarizes habitat types and characteristics for each ecosystem.

Table 1.2. Approximate distribution of state-owned aquatic lands by Natural Heritage program ecoregion and defined ecosystem.

		Acreage		Percentage	
Ecoregion	**Defined Ecosystem**	**State-owned**	**Statewide**	**State-owned[13]**	**State Ownership[14]**
Blue Mountains	Lacustrine	356	381	94%	
	Riverine	1,333	1,632	82%	
	Total	1,689	2,013	84%	0.1%
Canadian Rockies	Lacustrine	15,541	22,067	70%	
	Riverine	0	147	0%	
	Total	15,541	22,214	70%	1%
Columbia Plateau	Lacustrine	95,437	220,771	43%	
	Riverine	4,332	13,418	32%	
	Total	99,769	234,190	43%	4%
East Cascades	Lacustrine	55,171	70,448	78%	
	Riverine	1,506	6,606	23%	
	Total	56,677	77,054	74%	2%
North Cascades	Lacustrine	5,894	31,875	18%	
	Riverine	4,856	10,221	48%	
	Total	10,751	42,096	26%	0.4%
Northwest Coast	Lacustrine	16,579	25,158	66%	
	Riverine	4,861	23,103	21%	
	Saltwater	226,990	295,742	77%	
	Saltwater	528,013	528,123	100%	
	Total	776,443	872,126	89%	30%
Okanogan	Lacustrine	14,416	114,867	13%	
	Riverine	3,865	8,512	45%	
	Total	18,281	123,380	15%	1%
Puget Trough	Lacustrine	48,435	66,374	73%	
	Riverine	8,926	20,812	43%	
	Saltwater	225,537	375,975	60%	
	Saltwater	1,315,955	1,316,479	100%	
	Total	1,598,854	1,779,640	90%	62%

[12] Discrepancies in the estimated acreage of legal and ecological classifications are attributable to differences in the data layers used.
[13] *Percentage State-owned* is calculated by dividing *State-owned Acreage* by *Statewide Acreage*
[14] *Percentage State Ownership* is calculated by dividing total *Ecoregion Statewide Acreage* by total *State-owned Acreage.*

		Acreage		Percentage	
Ecoregion	Defined Ecosystem	State-owned	Statewide	State-owned[13]	State Ownership[14]
West Cascades	Lacustrine	8,211	43,611	19%	
	Riverine	1,839	11,849	16%	
	Saltwater -	2,394	2,437	98%	
	Total	12,753	58,206	22%	0.5%

Table 1.3. Approximate distribution of state-owned aquatic lands by defined ecosystem.

	Acreage		Percentage	
Defined Ecosystem	State-owned	State-wide	State-owned	State Ownership
Lacustrine	260,042	595,552	44%	10%
Riverine	37,892	128,063	30%	1%
Saltwater Nearshore	452,527	671,717	67%	17%
Saltwater Offshore	1,843,968	1,844,602	100%	71%
Total	**2,594,428**	**3,239,935**	**80%**	

Lacustrine

The lacustrine ecosystem, or lakes, is defined as a standing body of water located in a topographic depression that is not directly connected to the sea (Johnson *et al.*, 1985). Lakes are distinguished from rivers by the presence of relatively still waters (Horne & Goldman, 1994) and from saltwater ecosystems by the absence of ocean derived salt (Cowardin *et al.*, 1979). Of Washington's 7,800 lakes, ponds, and reservoirs (Sumioka & Dion, 1985), approximately 70 lakes are currently considered to include state-owned aquatic land.

Physical properties

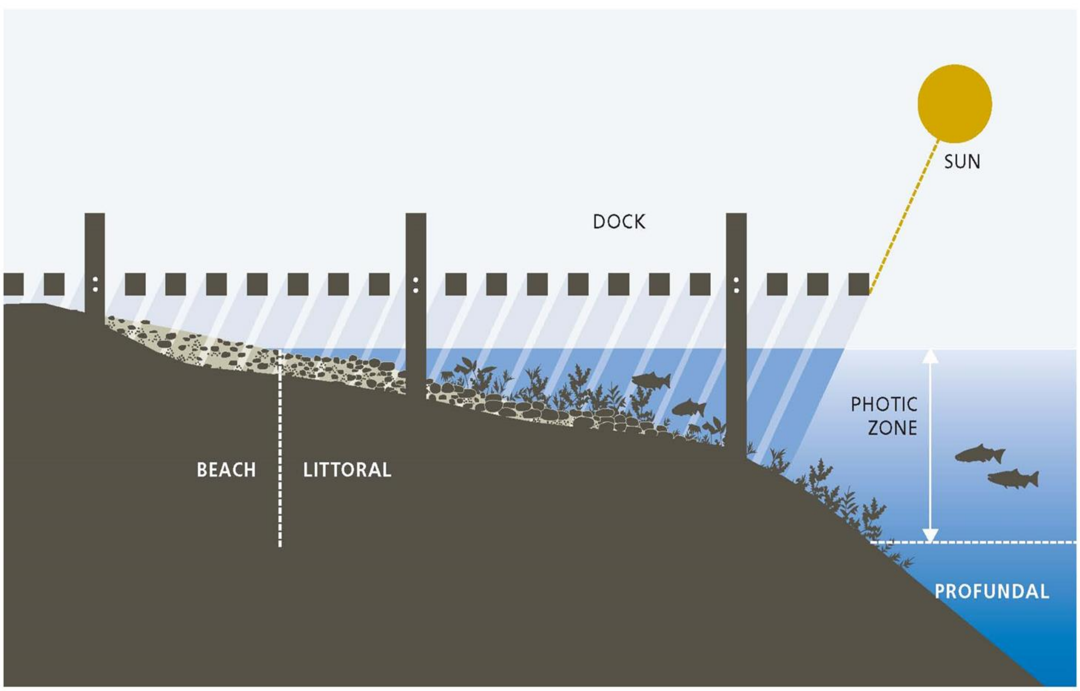
The geology of naturally occurring lakes is largely a product of tectonic, volcanic or glacial processes. Lakes formed by tectonic processes generally result from convergent fault blocks uplifting or slipping and creating a depression that fills with water. Volcanic lakes typically form through catastrophic events (caldera lakes) or through lava dams. Glacial lakes typically form by one of two processes: the scouring action of advancing glaciers, or by deposition of material forming dams across valleys and topographic depressions. While less frequent, lakes may also be formed by other processes, such as landslides, river migration (oxbow lakes), and animal activities (beaver dams) (Johnson *et al.*, 1985). Man-made lakes, or reservoirs, are the result of impounding rivers for power generation, water supply, flood control, irrigation, or recreation (Horne & Goldman, 1994).

Wave action is an important physical process in maintaining the diversity of lake habitat types. The height and velocity of waves are determined by water depth, the distance of open water over which the wind blows (fetch), and both the speed and duration of the wind. Wind is also responsible for currents, upwelling, and most lake oscillations (Wetzel, 2001). Combined, these conditions can generate substantial wave energy; the direction of littoral currents will determine whether wave energy will result in erosion or sediment deposition for a particular section of the shoreline (Herdendorf *et al.*, 1992).

In addition to the generation of waves, wind is the physical force responsible for currents, upwelling, and most lake oscillations (seiches). These processes may influence aquatic organisms in a variety ways, by facilitating mixing in the water column and nutrient exchange, which in turn influences primary production. For very large lakes, changes in water levels resulting from seiches may influence the distribution of aquatic vegetation in the littoral zone and along the shoreline. Seiches may also influence the distribution of fish (Levy *et al.*, 1991; Herdendorf *et al.*, 1992) and amphibians due both to wave energy and changes in water temperature that result from the water mixing during the seiche.

Lake benthos can be divided into two general classes (Figure 1.8): littoral and profundal. The littoral (nearshore) zone consists of shallow waters where sunlight reaching the benthos is sufficient to support the growth of submerged vegetation (Cowardin *et al.*, 1979; Mitsch & Gosselink, 1999; Wetzel, 2001). While substrate composition is largely the result of the formative processes of the lake (for example, glacial deposits or landslides), particle size is generally related to wave energy and currents (Herdendorf *et al.*, 1992); the size of the particles typically becomes smaller with increasing distance from shore. The array of species found in the littoral zone is generally more diverse than in the open water (limnetic) or profundal zones, which can be attributed to the variety of habitat substrates and vegetation types (Herdendorf *et al.*, 1992; Horne & Goldman, 1994). In addition to vegetative species, the littoral zone provides habitat for a variety of attached microbes (periphyton), infauna such as worms, invertebrates (crayfish, shrimp, insects), and both juvenile and adult fish.

Figure 1.8. Lacustrine ecosystem zones.

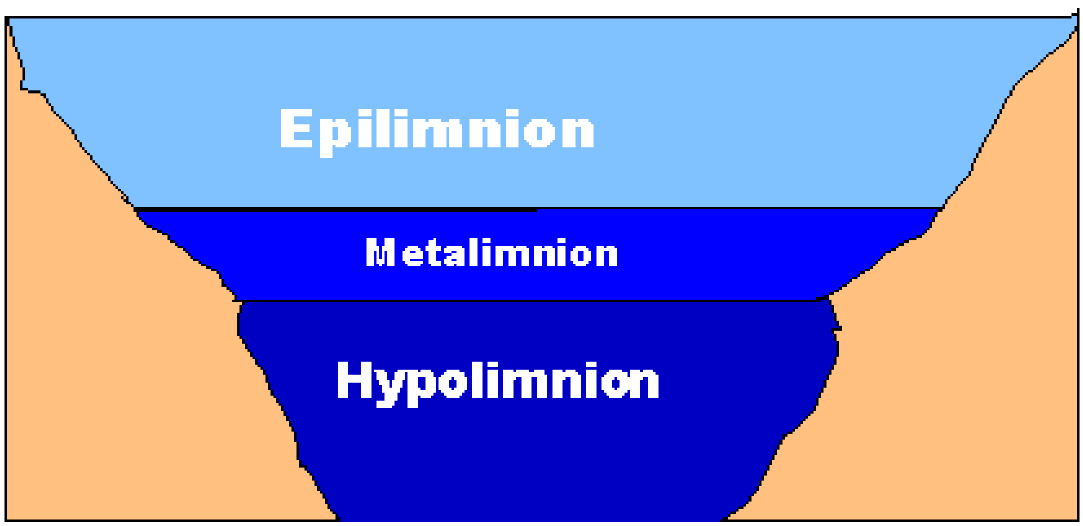


The profundal zone is below the maximum depth to which light penetrates in the water column and consists of benthic habitats that lack attached vegetation (Wetzel, 2001). The absence of high-energy disturbances in this zone leads to the deposition of finer-grained sediments. The resulting physical and chemical homogeneity allow species adapted to these conditions to competitively exclude other species. Consequently, the species present in the profundal zone are generally from one of four major groups: oligachaete worms, amphipods, insect larvae, and sphaerid (fingernail) and unionid clams (Horne & Goldman, 1994). Fish presence in the profundal zone is influenced by factors such as dissolved oxygen, both chemical and thermal stratification.

Water properties

While the surface temperature of a lake can be influenced by changes in ambient air temperatures, lacustrine thermal regimes are affected to a much greater degree by seasonal changes in solar radiation and physical properties such as water clarity and density. Lakes are generally thermally stratified and comprises three layers: an upper layer called the *epilimnion*, a lower layer called the *hypolimnion*, and a transitional middle layer known as the *metalimnion* (Figure 1.9). Thermal stratification occurs as a function of the density of water at different temperatures, with colder and denser water in the hypolimnion and warmer, less dense water in the epilimnion. As surface water temperatures equilibrate with ambient air temperatures, stratification may become less pronounced and may result in mixing, or turnover, of the lake's waters. Thermally stratified lakes may also be chemically stratified. Both stratification and the frequency of mixing events influence nutrient cycling and dissolved oxygen levels.

Figure 1.9. Lake layers.



Thermal stratification also influences the distribution of species within the water column. For example, cutthroat trout in Lake Washington were found in or below the metalimnion during the summer months when surface water temperatures were high, but were concentrated in shallow littoral habitats within the epilimnion when the lake was mixed and surface water temperatures were low (Nowak & Quinn, 2002). It is important to note that many windswept shallow lakes may never become thermally stratified.

Lake clarity is affected by materials that are suspended or are dissolved by wind and wave action, and by inputs of material from rivers, streams and the surrounding land mass. Clarity is generally lowest during warmer months when phytoplankton and zooplankton production is highest, and when stream runoff and overland flow is high.

Dissolved oxygen concentrations in the water column are controlled by gas exchange with the atmosphere through diffusion and wave action, production of oxygen by plants through photosynthesis, and consumption as a result of decomposition and respiration. Oxygen depletion and stratification is common in highly productive lakes where the demand from decaying phytoplankton may consume virtually all of the oxygen in the hypolimnion (Horne & Goldman, 1994).

Productivity

Biological productivity in lakes is referred to as the lake's trophic status and is measured as the amount of organic material produced by algae and plants (primary production). Productivity is determined based on three primary factors: the transparency of the water column when measured with a Secchi disk, the concentration of chlorophyll in the water column, and the concentration of nitrogen and phosphorous in the water column. The productivity of a lake is related to land use practices, hydraulic residence time, atmospheric deposition, and soil characteristics and is generally limited by the availability of nitrogen and phosphorous in the lake (Birch *et al.*, 1980; Dillon, 1975; Horne & Goldman, 1994). Nitrogen is principally derived from the atmosphere, whereas phosphorous is derived from the soils or anthropogenic sources. Four primary classes are used to define trophic status (Carlson, 1977)

- *Oligotrophic*: Lakes that have low phosphorous and nitrogen inputs and, as a result, are characterized by low primary production rates and high dissolved oxygen concentrations.
- *Mesotrophic:* Lakes with moderate phosphorous and nitrogen inputs, primary production rates, and dissolved oxygen concentrations.
- *Eutrophic*: Lakes with an abundance of nutrients, high primary production rates dominated by cyanobacteria, and low dissolved oxygen concentrations.
- *Hypereutrophic:* These lakes are covered by dense mats of surface algae, are generally anoxic, and may frequently experience fish kills.

The biological characteristics of water bodies within each trophic classification vary with site-specific factors such as substrate, morphology, energy associated with water movement, precipitation, and climate. Small, shallow lakes generally tend to have higher rates of productivity than large, deep lakes because they have a greater proportion of their surface area in the photic zone (Herdendorf *et al.*, 1992). Increases in nutrients from human activities, however, may also lead to increases in production in oligotrophic and mesotrophic lakes; this process is known as cultural eutrophication.

Table 1.4. Relationships between trophic status and index values.

Trophic Index	Trophic Status	Secchi Depth (meters)	Phosphorous (mg/L)	Chlorophyll (mg/L)
< 40	Oligotrophic	> 4	< 12	< 2.6
40 to 50	Mesotrophic	4 to 2	12 to 24	2.6 to 7.3
50 to 70	Eutrophic	2 to 0.5	24 to 96	7.3 to 56
> 70	Hypereutrophic	< 0.5	> 96	> 56

Aquatic habitat types

Aquatic bed (littoral)

These habitat units are differentiated from other habitat units by the presence of aquatic vegetation that is attached to the substrate, or is floating at the surface. The surface area of the substrate in these habitat units primarily comprises algal beds, rooted vascular plants, and floating vascular plants.

Rocky shore (littoral)

Rocky shore habitat units typically occur in high-energy areas of the littoral zone and are characterized by the dominance of exposed bedrock and rubble substrates resulting from exposure to wind and wave erosion.

Unconsolidated shore (littoral)

These habitat units occur in the littoral zone and comprise small particles, scant vegetative cover, and varying degrees of periodic inundation.

Rocky bottom (littoral, profundal)

These habitats are characterized by substrates comprising primarily stones, boulders, or bedrock and typically lack vegetative cover due to wind and wave energy. Rocky bottom habitat units are typically inhabited by organisms that employ attachment strategies such as hooks or suction devices in response to the high-energy environment (Cowardin *et al.*, 1979). These habitat units are similar to the rocky shore habitat units; however, rocky bottom habitat units also includes the profundal zone whereas rocky shore habitat units includes only the littoral zone.

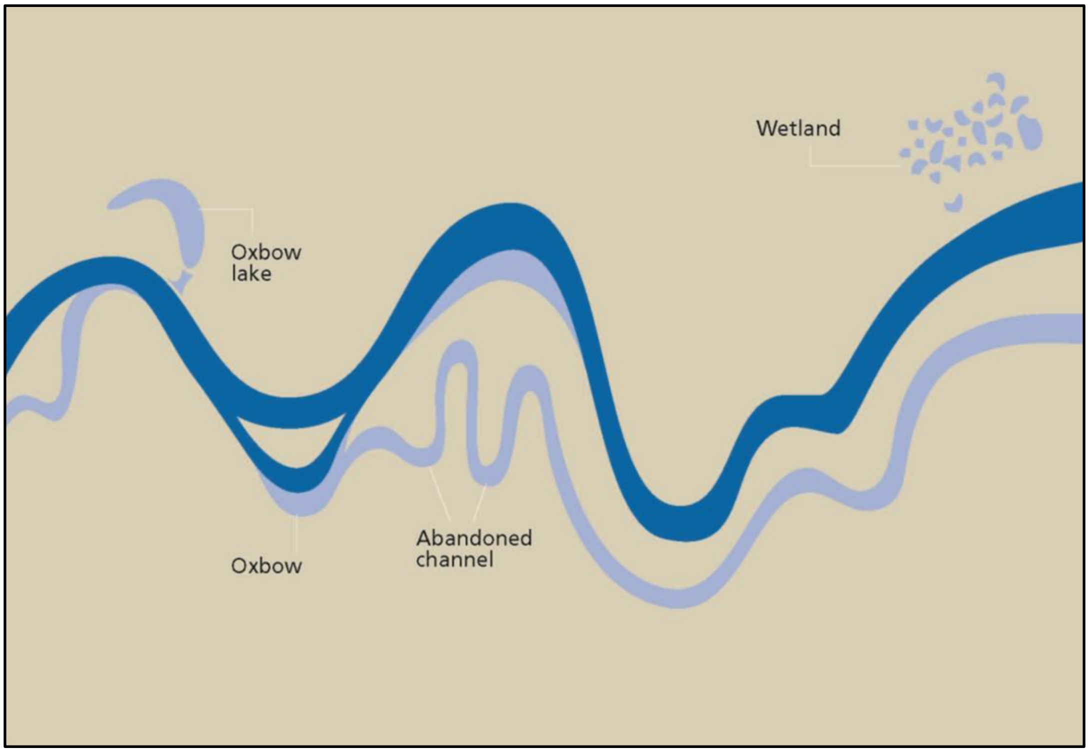
Unconsolidated bottom (littoral, profundal)

Characterized by mud, sand, or gravel substrates, unconsolidated bottoms are common in the profundal zone of eutrophic lakes, where light penetration is insufficient for plant growth and dissolved oxygen levels are low.

Riverine

Riverine habitat units includes stream channels, associated floodplains, and riparian areas found within the meander zone (Figure 1.10). This ecosystem is defined by the flow of water from higher to lower elevations, with the flow terminating in tidally influenced environments or in a lake. Riverine systems are essentially interconnected linear networks comprising patterns and processes that occur across their longitudinal, lateral, and vertical dimensions (Stanford & Ward, 1993; Townsend, 1996).

Figure 1.10. Riverine meander zone and features.



Graphic: Luis Prado / DNR

The longitudinal dimension refers to structural and functional changes that occur between headwater channels and the downstream reaches. The amount of water carried within the channel (discharge) typically increases with increasing drainage area. Other properties of rivers, such as width, depth, and velocity, also vary as a function of discharge and thus drainage area (Leopold & Maddock, 1953). Rivers typically decrease in gradient with longitudinal distance downstream.

In addition to the predictable changes in linear physical characteristics, some biological characteristics are also predictable in the longitudinal dimension (Vannote *et al.*, 1980). Changes in the type and quantity of biologically available energy sources increase with distance downstream, resulting in distinct behavioral and morphological adaptations in the species present. For example, small streams derive most of their energy from terrestrial sources; primary production is a small proportion of the total energy budget of these streams. As flow increases, litter from terrestrial vegetation comprises a smaller proportion of the energy budget and fine particulate organic matter becomes an increasingly important component of the food web, resulting in a change in the composition of species and functional feeding groups. In small streams, a high proportion of the total biomass is comprised of organisms adapted to directly consume leaf litter and its associated microbes. In large rivers, organisms are adapted to utilize smaller particles of decomposed material.

The lateral dimension of riverine ecosystems typically refers to patterns and processes that occur perpendicular to the direction of flow and, as defined above, includes only riverine wetlands. Seasonal changes in discharge influence the width of the river, however, the likelihood that the margins of this zone will be inundated decreases as elevation and the distance from the low flow channel increase. Similar to changes in species composition along the length of the river, the organisms present along the lateral dimension reflect the magnitude, intensity, and duration of flood disturbances (Gregory *et al.*, 1991).

In the forests of the Pacific Northwest, vegetation within the active channel may consist only of flood-tolerant grasses and herbs, while the vegetation adjacent to the active channel generally consists of deciduous shrubs and younger stands of trees. With increasing distance from the channel, forest stands may increase in age and the proportion of flood-tolerant species decreases. Junk *et al.* (1989) and Bayley (1995) suggest that seasonal flood pulses that inundate the floodplains of large rivers facilitate the exchange of key nutrients, enhance productivity, and maintain biological diversity. Because of the high number of species that use riparian zones for all, or a portion of their life history, researchers have identified these areas as key to the conservation of biodiversity (Gregory *et al.*, 1991; Naiman *et al.*, 1993).

The vertical dimension refers to the connection between ground and surface water and is commonly referred to as the hyporheic zone. Stanford and Ward (1993) suggest that the aquatic invertebrate species that inhabit the hyporheic zone are uniquely adapted to utilize dissolved materials and the organic and inorganic matter in the spaces between sediment particles. The vertical dimension is of critical importance for a number of species, with upwelling playing a role in redd site selection for both Chinook and chum salmon (Geist & Dauble, 1998; Reub, 1987). Groundwater seeps or springs may also provide important thermal *refugia* for salmonids in streams that would otherwise be too warm for prolonged exposure (Torgersen *et al.*, 2001).

Physical properties

Tectonic processes such as uplift, subduction, the characteristics of local rock formations, and climate history together affect the distribution of bedrock types, surface deposits, and topography; these in turn control geomorphic processes and stream channel response (Montgomery & Buffington, 2001; Montgomery, 1999). Regional geology also determines sediment supply and the gradient and sediment transport capacity of the stream. Regional geology may also influence the composition of plant communities and stream chemistry. Hillslope processes, such as landslides, slumps and earthflows, and debris avalanches and torrents, are also important mechanisms for the delivery of sediment and large woody debris to stream channels and in the creation of new land forms (Swanston, 1991).

A number of factors related to topography influence the structure of riverine networks, including basin size and shape, drainage density, the number of connecting streams, and the geometry of the connections (Benda *et al.*, 2004). Ultimately, the structure and variability of in-channel habitat is a function of channel slope, which is largely determined by topography (Montgomery, 1999). The type, frequency, and intensity of disturbance regimes depend on channel size and location within the watershed, which in turn vary with topography (Reeves *et al.*, 1995). Disturbances in the adjacent floodplain are characterized by seasonal inundation; bed mobility, and shifts in channel location are influenced by topography and the type, frequency, and intensity of the inundation.

Climatic regimes influence riverine habitat types on a number of scales; however, within Washington, climatic influences are generally related to the most recent glacial period, and seasonal variability in precipitation. Glacial deposits are generally responsible for the variety of river channel patterns observed in the Puget Lowlands, with some rivers for example the Nisqually, cutting multiple braided channels with islands in Pleistocene glacial deposits. Rivers created by sub-glacial runoff, such as the Snoqualmie River, are more contained and have single-thread channels that may be higher in elevation than the surrounding valley floor (Collins *et al.*, 2003). In eastern Washington, the advance of the continental ice sheet caused the formation of a large inland lake known as Glacial Lake Missoula. The ice dam that formed this lake breached episodically throughout the last ice age, causing massive floods with flows more than 10 times the combined flow of all the other rivers in the world (U.S. Geological Survey, 2005).

The interaction between moist air from the Pacific and the region's mountain ranges drives the annual variability in the quantity and timing of streamflow patterns in Washington. As moisture-laden air cools and passes over topographic barriers such as mountains, a phenomenon known as orographic lifting creates condensation and precipitation. Orographic lifting is most prevalent on the western side of mountain ranges within Washington; the eastern side of the mountains experiences a reversal of the process as the air mass loses elevation and becomes warmer resulting in a rain shadow effect. Within the rain shadow, snow is the dominant form of precipitation and is most prevalent at the higher elevations. Consequently, much of the mean annual discharge for streams and rivers within the rain shadow comes from snowmelt. Peak flows in these basins occur during the spring and summer months and do not necessarily coincide with precipitation events. Hydrographs for streams and rivers on the western side of the mountains (especially those at lower elevations) are driven by rainfall events, with peak precipitation occurring from fall through spring.

Precipitation patterns also influence vegetation patterns. Western Washington is generally forested at all elevations; the eastern side of the state is forested in higher and moister mountain elevations. As a result, both the quantity and type of organic matter delivered to river channels also varies west to east.

Research indicates that aquatic communities are structured by the magnitude, timing, frequency, duration, and rate of change of instream flows (Richter *et al.*, 1996). Aquatic and terrestrial organisms have anatomical, morphological, behavioral, and physiological adaptations that capitalize on the seasonal changes in flows (Junk *et al.*, 1989; Poff & Allen, 1995).

Water properties

River temperatures are strongly correlated with air temperatures and vary with both season and time of day (Wetzel, 2001). River temperatures are also strongly influenced by the presence or absence of vegetative shading, solar radiation, and other hydrologic inputs such as groundwater, tributary inflow, and overland flow (Welch *et al.*, 1998). In the Pacific Northwest, a number of rivers are fed by glaciers and they tend to be cooler year-round as a result. While rivers rarely experience temperature stratification, benthic regions are generally cooler due to groundwater inputs and depth.

Like temperature, river clarity or transparency varies spatially and temporally. Clarity is strongly influenced by the amount of suspended sediment present and the ability of both suspended and dissolved matter to absorb light. Rivers with high sediment loads—those originating from glaciers and those either flowing through fine-grained materials or in watersheds with significant erosion—are less transparent than those with lower sediment loads or flowing through bedrock.

Washington's rivers generally have low concentrations of macronutrients such as phosphorous and nitrogen. As a result, they have low rates of primary productivity (Welch *et al.*, 1998). Naturally occurring inputs are the result of decomposition of organic material and they support the growth of attached algae, and submerged, emergent, and riparian plants. Unlike lakes, however, riverine nutrients are concentrated in detritus rather than in living plant or algal material; dissolved material is continually washed downstream (Welch *et al.*, 1998).

As in other aquatic ecosystems, dissolved oxygen is a critical factor in determining the types of organisms present in rivers. In addition to being influenced by site-specific conditions such as stream velocity, algal and plant respiration, and water chemistry, dissolved oxygen is also affected by daily and seasonal variation in water temperature. Dissolved oxygen levels are highest in fast, cool waters and forested reaches; slower and warmer reaches have lower levels.

Habitat types

Riverine habitats are an interconnected continuum (Figure 1.11). Their biological communities shift with changes in flow, temperature, gradient, and organic inputs. In general, smaller and steeper gradient streams are dominated by organic input from terrestrial sources such as leaf litter, invertebrate communities that shred the detritus, and fish that consume the invertebrates. As flows increase and gradients decrease, primary energy sources move to algae; invertebrate communities shift to species that collect algae, and fish communities shift to species that either collect algae or consume invertebrates and other fish. Large rivers continue to be dominated by algal productivity, invertebrate collectors, and fish that consume invertebrates and other fish. Fish species that graze on algae become less common in large rivers and are replaced by fish that consume plankton. Five benthic habitat types have been defined for riverine systems: cascade, plane-bed, pool-riffle, and low-gradient valley.

Cascade

For this classification system cascade stream reaches are defined as those with gradients greater than 8 percent. These reaches are characterized by beds comprised of large boulders and channels typically confined by valley walls (Montgomery & Buffington, 2001). Movement of bed material is rare in cascade habitats due to the large size of the dominant substrate and the relatively shallow water depths.

Step-pool

Morphology of step-pool reaches is characterized by alternating sequences of relatively deep stream sections with flat, non-turbulent flow, and shallow, steep sections with turbulent flow. Pools are typically formed by a cluster of large boulders that restrict the flow of water, resulting in a backwater upstream of the restriction and a substantial drop in elevation downstream of the restriction. Step-pool gradients range between 4 and 8 percent.

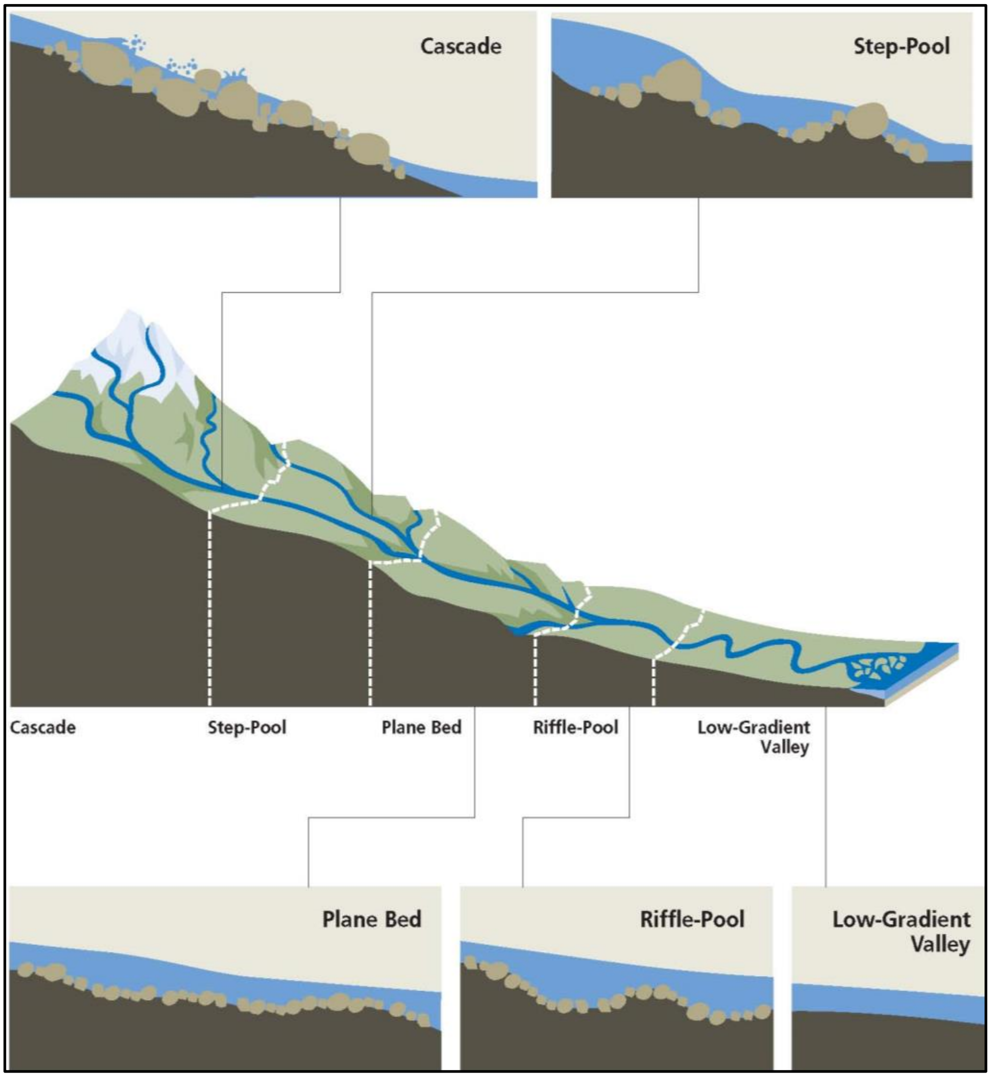
Plane-bed

Stream reaches with gradient between 2 and 4 percent are plane-bed habitats. Plane-bed reaches are typically composed of intermediate substrate sizes (gravel to cobble) and lack the characteristic steps that are common in step-pool and cascade stream reaches.

Pool-riffle

Comprised of alternating sequences of pools, gravel bars, and riffles, these habitats typically have moderately low gradients (0.1 to 2 percent) and are sinuous Pools in these reaches generally form on alternating banks of the channel and are created by scour resulting from the convergence of flow. Sediment deposition occurs either between pools in the riffles, or adjacent to the pools on

Figure 1.11. Riverine ecosystem longitudinal profile.



Graphic: Luis Prado, DNR

bars. Particle sizes in pool-riffle reaches are typically smaller than those observed in higher-gradient reaches comprised of gravel and cobble.

Low-gradient valley

Low-gradient valley is the most common riverine habitat found on state-owned aquatic lands. These river sections typically have slopes less than 0.1 percent and occur in watersheds where sand supply is abundant. Stream beds consist of a series of mobile sand dunes whose length and height depend on the velocity of the river. Where sand supply is absent, the dominant bed material may be small gravel. Low-gradient valley channels commonly have multiple threads and the supply of sediment is typically greater than the river's sediment transport capacity.

Riverine habitats can also be described as two general classes of hydrodynamic units: fast water and slow water. Fast water can be further divided into turbulent and non-turbulent habitats. Fast turbulent water is characterized by emergent substrate and may include cascades, riffles, and pocket waters; non-turbulent fast water is characterized by sheet flow over broad flat areas. Slow water can be further divided by its formative mechanism: dammed pools result from hydraulic controls such as bedrock weirs (a row of boulders); debris dams and scour pools formed by erosive processes associated with woody debris, bedrock or boulders.

In large river systems, habitat features on the lateral margins of the channel and primary floodplain can be especially important for juvenile salmonids (Beechie *et al.*, 2005). These edge unit types include the stream banks, the lateral margins of exposed bars, backwater side channels, and valley-wall tributaries. Low-energy areas such as backwater side channels, deltas at tributary confluences, and pools on slow-moving streams often support the development of aquatic vegetation which provides refuge and forage opportunities for a wide variety of aquatic species (Cowardin *et al.*, 1979).

Saltwater — common properties and processes

Washington's saltwater environments extend 5.6 kilometers (3 nautical miles) off the Pacific Coast (Neah Bay to the Columbia River), covering more than 9,800 square kilometers (3,784 miles^2) (Lanzer, 1999) with the total shoreline of the many islands, inlets and sub-estuaries along the Pacific Coast and in Puget Sound about 4,935 kilometers (3,066 miles) in length (Washington DNR, 2002). Saltwater habitats in the state are commonly classified by using Cowardin *et al.* (1979) and Dethier (1990), with both schemes providing significant detail in terms of the numbers of habitat types. While the classification system presented here incorporates many of the elements in both Cowardin and Dethier, it has also been simplified to reflect the coarseness of the leasing data available for Washington's state-owned aquatic lands.

Saltwater systems in the Pacific Northwest are influenced by mixed semidiurnal tides (two high and two low tides each lunar day with unequal amplitude). Within Puget Sound the tidal range increases from north to south, with tidal ranges in the north Sound less than 3 meters (10 feet) and more than 5 meters (16 feet) near Olympia. On the Pacific coast, the maximum tidal range is about 4 meters (13 feet), with an average range of approximately 2 meters (6 feet) (Komar, 1997).

Locally, tidal currents and wind events also affect inland circulation patterns. In Puget Sound wind flow is predominantly from south-southwest during the winter, before gradually reversing direction in the spring (Williams *et al.*, 2001). Highest net speeds are in the range of 6 to 9 meters per second (13 to 20 miles/hour) and wave conditions are generally mild, with both wave height and period limited by fetch (Williams *et al.*, 2001). Wind significantly influences the oceanography of interior waters by generating surface waves, mixing surface waters and forcing surface drift currents (Thomson, 1994).

In Puget Sound, stratification is greatest during the summer because of the combined effects of solar heating and river discharge, and lowest in the winter because of seasonal cooling and increased wind-induced mixing from storms (Thomson, 1994). Many of the deeper regions of Puget Sound exhibit persistent density stratification based on salinity and temperature (Williams *et al.*, 2001). In comparison, seasonal stratification in the Strait of Juan de Fuca is relatively uncommon and the waters are well-mixed vertically.

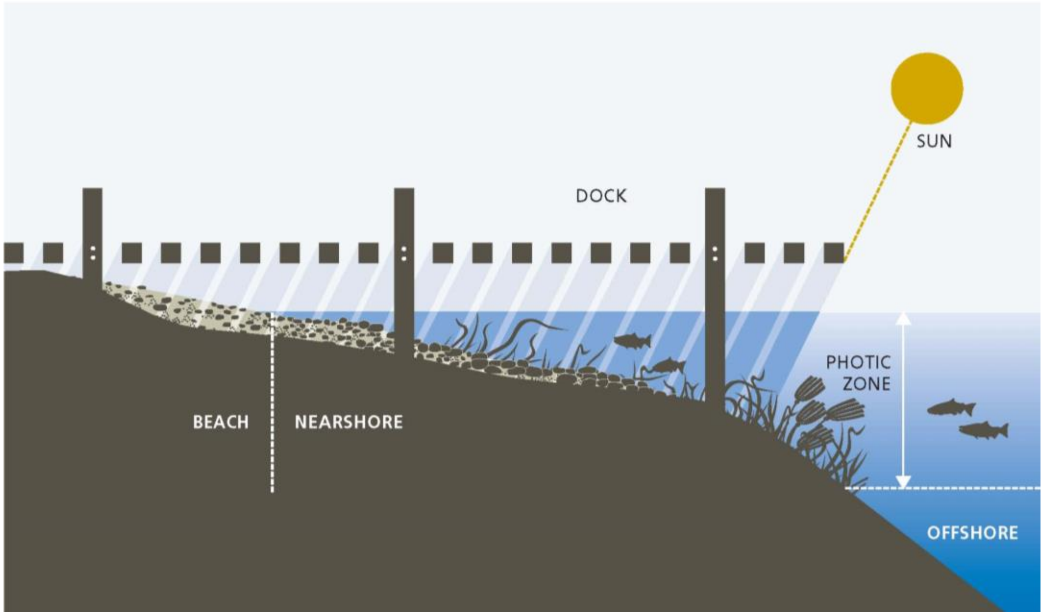
Saltwater — nearshore

The saltwater-nearshore ecosystem extends inland from the offshore area boundary (20 meters or 66 feet in depth) to the shoreline at extreme higher high water (Figure 1.12), and includes estuarine and tidally influenced riverine habitat. Resource cycling in this ecosystem is fueled primarily by energy from benthic and terrestrial vegetation; the type and source of vegetative inputs influence both the species present and their ecological function (Simenstad & Wissmar, 1985; Valiela, 1984). While benthic habitats in the nearshore generally lie within the photic zone, the lower depth of light penetration is highly dependent on water clarity.

Within the nearshore ecosystem, the coastal region extends south from Cape Flattery along the outer coast to the mouth of the Columbia River; the inland region is comprised of the Strait of Juan de Fuca, the San Juan Archipelago north to the Canadian border, all of Puget Sound including Hood Canal, and the Columbia River from its mouth to the Bonneville Dam.

Physical properties

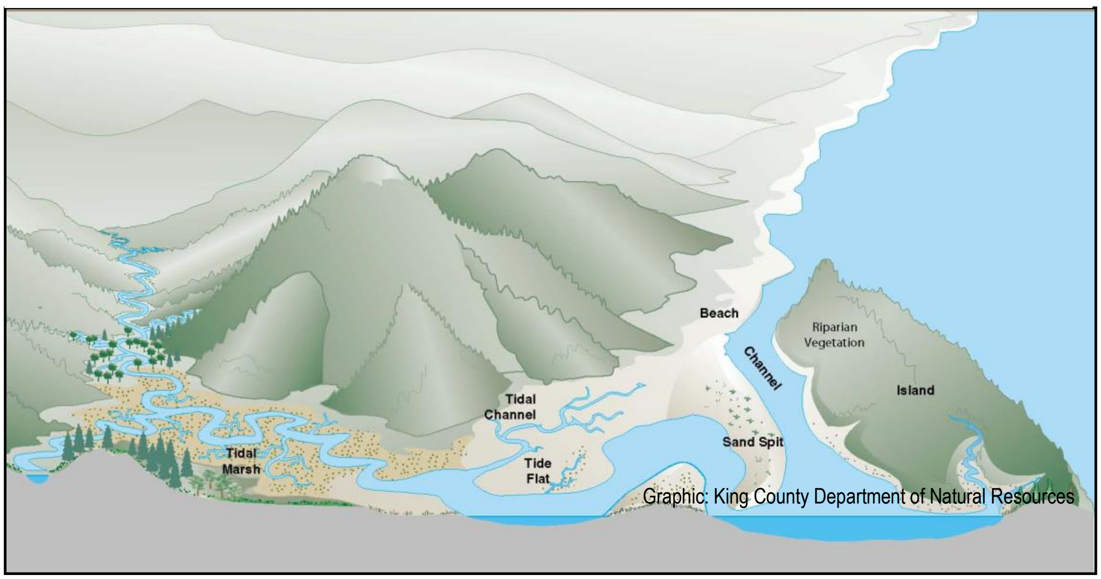
Figure 1.12. Saltwater ecosystem.



Graphic: Luis Prado / DNR

The bathymetry of the nearshore ecosystem varies with the characteristics of the surrounding landscape (Figure 1.13). In Puget Sound, much of this ecosystem is a narrow fringe along the edge of the steep-sided fjord that is interspersed with shallow inlets and back-bay areas. The

Figure 1.13. Nearshore landscape characteristics.

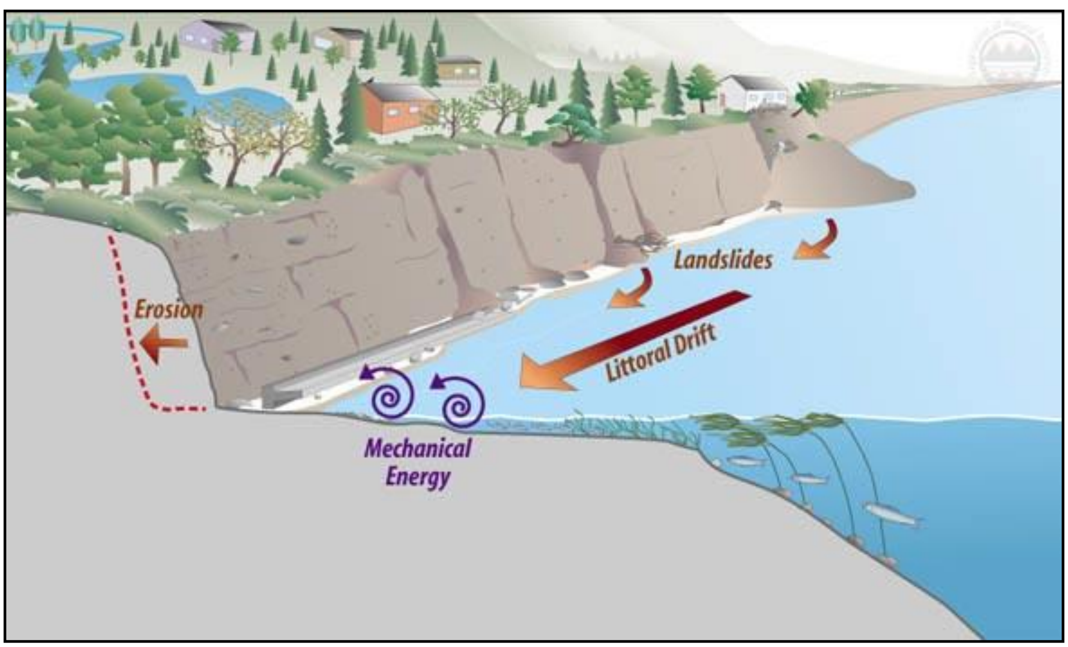


Graphic: King County Department of Natural Resources characteristics of these shallow areas vary from north to south. Estuaries and tidally influenced rivers are concentrated in the north (for example, Bellingham, Skagit, and Port Susan bays); inlets predominate at the southern end of Puget Sound (including Henderson, Budd, and Hammersley inlets) (Washington DNR, 2005a).

Water circulation and local bathymetry have a significant influence on the character of the nearshore system. Because of the proximity of the continental shelf, strong seasonal upwelling occurs along the coast of Washington and results in the movement of nutrient-rich waters into the photic zone and the nearshore ecosystem. This stimulates phytoplankton growth and thereby provides habitat and food for zooplankton. Tidal exchange also transports these highly productive waters into tidally influenced rivers and shallow embayments, providing foraging and refuge habitat for juvenile salmonids and other fish (Emmett *et al.*, 2000). During periods of low circulation, or stratification, the nearshore is most affected by the upper water column, which is generally warmer and nutrient poor in the summer and is less saline in the winter due to increased river flows.

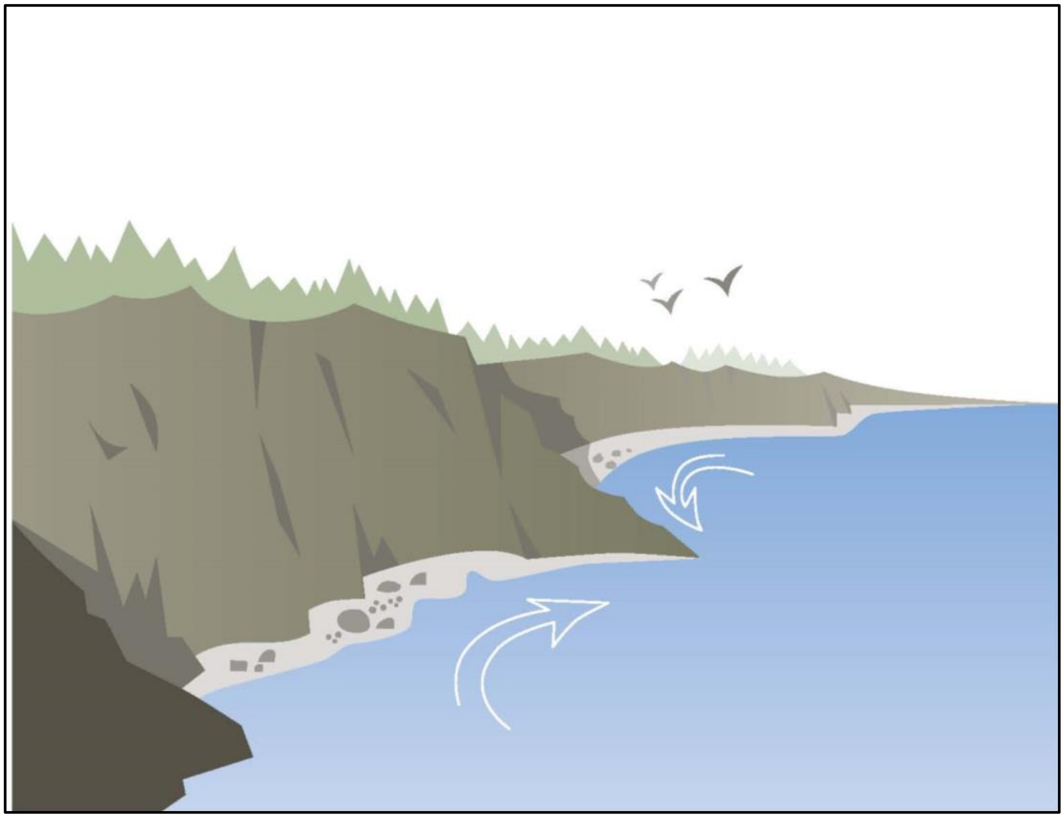
Glaciation shaped the general geomorphology of aquatic basins in Puget Sound, however, the morphology of the Northwest Coast ecoregion is largely the result of tectonic forces (Burns, 1985). Present-day sediment processes are responsible for forming and maintaining unconsolidated nearshore features such as dunes, marsh plains, and unvegetated beaches. Sediment transport in the nearshore is generally the result of waves and wave currents. Wave approach patterns determine the type of currents and resulting sediment movement (Figure 1.14). When waves approach the beach parallel to the shoreline, a series of rip currents develop causing erosion in pockets along the beach, while waves approaching at an angle form a longshore current or littoral drift (Figure 1.15). These currents can move along the shore for hundreds of miles; the direction of the prevailing winds determines the direction that the sediment is transported (Komar, 1997). Within the Puget Sound nearshore, sediment transport processes vary in their predominant direction and intensity, and are influenced by the complexities of tidal currents, wind-influenced wave patterns, and shoreline geomorphology.

Figure 1.14. Nearshore sediment transport processes.



Graphic: King County Department of Natural Resources.

Figure 1.15. Sediment drift process illustration.



Graphic: Luis Prado / DNR

Water properties

Saltwater-nearshore temperature varies dramatically both seasonally and spatially. Solar energy heats the water and intertidal substrate at low tides, which results in a dramatic seasonal variation in water temperature. Saltwater-nearshore temperatures generally range from 6 to 9 degrees Celsius (43 to 48 degrees Fahrenheit) during winter and 16 to 19 degrees Celsius in summer (61 to 66 degrees Fahrenheit) (Thom and Albright, 1990). Summer temperatures in shallow embayments with restricted circulation reach 20 to 25 degrees Celsius (68 to 77 degrees Fahrenheit) during warm sunny days. Infrequent, long, cold periods can drive temperatures to as low as 2 degrees Celsius (36 degrees Fahrenheit), especially in shallow systems, and very shallow water will occasionally freeze.

River and stream flows can also affect temperature in the nearshore. Typically, warming of freshwater during summer will increase water temperature in the nearshore where flows impact the beach. In winter, freshwater flows can cool nearshore water temperatures. Winds that blow offshore cause vertical mixing of the water column and can create upwelling, which brings colder, deeper water from offshore into the nearshore environment. Stratification of the water column in the nearshore typically results in a warm surface layer during summer and a cold surface layer in winter. The most protected water and shallowest sites show the greatest extremes in temperature, whereas sites most exposed, deep and open to circulation (such as the outer coast) show the least extremes. The greatest range in water temperatures between winter and summer can occur during strong El Niño periods.

Salinity varies seasonally and spatially in the saltwater nearshore. Salinity is determined by the relative amounts of freshwater inputs from rivers and streams and saline ocean water. Winds and currents cause vertical and horizontal mixing of fresh and salt water. Nearshore areas along the outer coast that are not affected by freshwater typically have salinity levels that approximate open ocean conditions (30 to 35 parts per thousand).[15] Nearshore areas dominated by rivers can have periods of very low salinity. In central Puget Sound, salinity observations at the mouths of rivers can vary between about 15 parts per thousand in winter-spring to about 31 parts per thousand in late summer and early autumn. In the Columbia River estuary, extreme freshets[16] induced by high levels of precipitation and runoff can temporarily flush any salinity from the estuary.

Inorganic nutrients in the nearshore typically include the macronutrients nitrate, nitrite, ammonia and phosphate. These arrive in the nearshore by ocean inputs through upwelling, and freshwater inputs through overland flows of rainwater, rivers and streams. These macronutrients are important to the support of phytoplankton, seaweed, seagrass, and marsh plant growth in nearshore areas; low macronutrient concentrations can limit productivity. An overabundance of one or more of these nutrients can result in abnormal abundances of phytoplankton or seaweeds, the decay of which can create areas of low dissolved oxygen, also known as hypoxia. Plant use and uptake also affects the seasonal concentrations of nutrients. Nitrate concentrations in central Puget Sound vary from a high of about 35 micromoles per liter in winter to a low of less than 5 micromoles per liter in early summer (Thom & Albright, 1990).

Remineralization of nutrients from dead organic matter in the saltwater nearshore can also contribute to nutrient concentrations. In the summer, nutrient concentrations can become extremely low in shallow embayments with restricted circulation and no freshwater input, while open nearshore areas with upwelling and dynamic wave energies typically have much higher nutrient concentrations.

Dissolved oxygen concentrations in the saltwater nearshore are spatially and temporally variable. Because the water column is shallow, and often overlies very productive habitats, periods of high productivity can result in oxygen levels greater than 100 percent of the theoretical maximum oxygen concentration possible in water—this phenomenon is called supersaturation. In central Puget Sound, nearshore dissolved oxygen concentrations are typically greatest and most variable in spring and summer (11 to 16 milligrams per liter); the least variation occurs in autumn and winter (7 to 9 milligrams per liter; Thom & Albright, 1990). Oxygen demand by sediment-associated microbes and chemical processes can be great in embayments with low circulation (where sediments are high in organic matter concentration) and in areas with very high densities of large infauna such as clams.

Habitat types

As in freshwater systems, the saltwater nearshore is home to many species of planktonic invertebrates and fishes and is responsible for much of the primary production in nearshore and offshore waters. Water column phytoplankton communities can be divided into three main groups: dinoflagellates, diatoms, and microflagellates. Diatoms are typically the most abundant group, particularly during algal spring blooms. Dinoflagellates are more common in calmer, low-energy environments (Strickland, 1983). Zooplankton consume phytoplankton and form the prey base for many species of fishes that inhabit the nearshore water column, particularly juvenile salmon.

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[15] Parts of salt per thousand parts seawater, or grams of salt per kilogram of seawater.
[16] A flood resulting from heavy rain or a spring thaw.

Other species that feed primarily on zooplankton include juvenile and adult Pacific herring (*Clupea pallasi*), southern euchalon (*Thaleichthys pacificus*), stickleback (*Gasterosteus* spp.), sand lance (*Ammodytes hexapterus*), juvenile salmon (*Onchorhynchus* spp.), Pacific cod (*Gadus macrocephala*), Pacific hake (*Merluccius productus*), walleye pollock (*Theragra chalcogramma*), lingcod (*Ophiodon elongatus*), sablefish (*Anoploploma fimbria*), and spiny dogfish (*Squalus acanthias*) (Williams *et al.*, 2001). Several species of mammals and birds also depend on the nearshore water column, including harbor seals (*Phoca vitulina*), killer whale or orca (*Orcinus orca*), grey whales (*Eschrichtius robustus*), river and sea otters (*Lontra canadensis* and *Enhydra lutri* respectively) loons (*Gavia* spp.), grebes (Podicipedidae), cormorants (*Phalacrocorax* spp.), gulls (Laridae), and several species of ducks (Long, 1982).

Benthic nearshore habitats are divided into two general types: consolidated[17] and unconsolidated.18 The specific nature of the habitat and its associated communities are influenced by the substrate and the vegetation present (Dethier, 1990; Williams & Thom, 2001).

Consolidated habitats

Rocky shore assemblages

Rocky shores include those areas of the intertidal and shallow subtidal zone that are dominated by bedrock or boulder substrates. This habitat type is generally defined by relatively large-sized or abundant taxa dominated by kelp beds and other seaweed, or benthic invertebrates.

Seaweed assemblages

Seaweeds are macroscopic algae that occur in the sea and are included within three taxonomic subgroups based on their dominant photosynthetic pigmentation: red, green and brown algae. Seaweeds occur throughout the photic zone, reaching their greatest abundance in areas where salinity is routinely above about 15 parts per thousand, with the greatest numbers of species occurring at salinities in the range of 31 to 35 (Thom, 1980).

Kelp (Laminariales) and other seaweeds that grow attached to rock generally dominate consolidated habitats in areas of bedrock and boulders. The distribution of these seaweeds occurs along a vertical-depth gradient and is controlled by a variety of species-specific factors, such as light requirements, tolerance for desiccation, thermal and physical stress (such as, log bashing, wave action and currents), competition with other native and non-native plants, and life-history strategies. Red algae are often found in the deepest waters because of their ability to use the wavelengths and energy levels of light that are found at these depths.

Floating kelps, such as bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis integrifolia*), can form extensive canopies at or near the surface of the ocean and are most common in high-energy environments. In Washington, floating kelp beds are found on approximately 11 percent of the shoreline, primarily in the Northwest Coast ecoregion (Washington DNR, 2002). Kelp beds are used by sea otters and a variety of fishes and invertebrate species for rearing, feeding and predator avoidance. In some areas, herring may lay eggs on kelp fronds. Benthic diatoms are also an important photosynthetic component of rocky consolidated habitats and their primary productivity rates can be as high as that in beds of eelgrass (*Zostera marina*) (Thom *et al.*, 1989).

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[17] Coarse material includes boulders (rocks larger than 30.5 centimeters in diameter), bedrock, and consolidated clays (hardpan).
[18] Fine material includes cobble (7.5 to 30.5 centimeters in diameter), gravel (0.45 to 7.5 centimeters), sand (0.0075 to 0.45 centimeters), and mud (less than 0.0075 centimeters).

Unconsolidated habitats

Eelgrass meadows

In unconsolidated habitats, the primary vegetation is comprised of rooted flowering plants called seagrasses. Six species of seagrasses occur in Washington State; eelgrasses (*Z. marina* and the exotic *Z. japonica*) are the most widespread. Eelgrass is found in monotypic stands, or meadows, throughout much of Puget Sound and the San Juan Archipelago, areas along the Strait of Juan de Fuca, coastal estuaries, and in small areas in the outermost portion of the Columbia River estuary. These meadows harbor some of the richest assemblages of animals among all aquatic habitats in the state (Phillips, 1984). They provide important feeding and refuge habitat for salmonids, crabs , and birds, and provide spawning habitat for herring (Baldwin and Lovvorn, 1994; Holsman *et al.*, 2003; McMillan *et al.*, 1995; Phillips, 1984; Thom *et al.*, 1989); Wilson and Atkinson, 1995; McIntyre and Barr, 1997). While the vertical extent of eelgrass is controlled by light penetration and desiccation, it generally grows at depths of approximately plus 0.3 meters (0.9 feet) to minus 10 meters (33 feet) relative to mean lower low water (Thom *et al.*, 1998; Thom *et al.*, 2003).

Flats

Mud or tidal flats consist of gently sloping lands that contain fine to coarse unconsolidated sediments. Deposition of fine material is largely influenced by riverine sediment load or by deposition of material eroded from the surrounding bluffs. Benthic diatoms are generally the major source of primary production in many flats; eelgrass, however, and other attached vegetation and drift seaweeds (ulvoids) may be present. Unconsolidated sediments provide habitat for a variety of infauna (worms, small crustaceans, and bivalves) that are important prey for shorebirds, fishes, and both marine and terrestrial mammals. These sediments are also home to recreationally and commercially important stocks of clams, crabs, sturgeon (*Acipenser* spp.) and flatfish (Pleuronectidae), including geoduck clam (*Panopea abrupta*), native littleneck clam (*Protothaca staminea*), and Dungeness crab, (*Metacarcinus magister*).

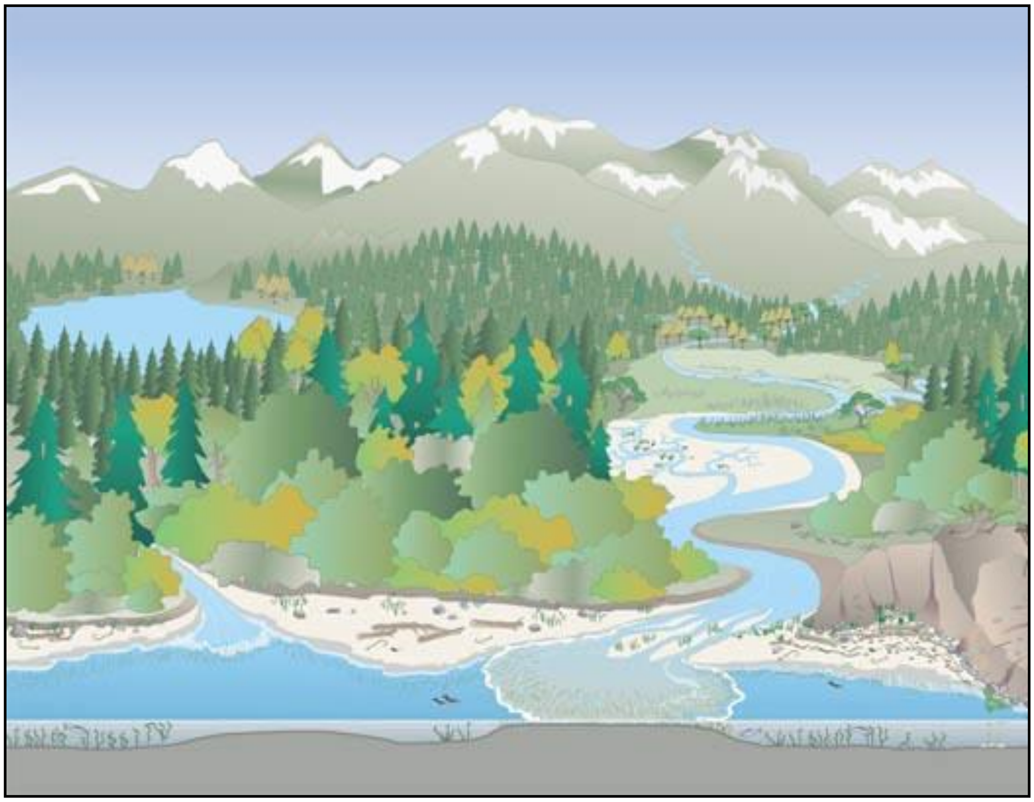
Sub-estuaries and tidally influenced rivers

Rivers and streams that enter into larger estuarine and tidal systems, such as Puget Sound, the Columbia River, and Willapa Bay, can form distinct sets of habitats (Figure 1.16). At their mouths, these tidally influenced waters form deltas, which include channels through the mud flats that may contain water even at the lowest tides. Sub-estuaries are characterized by salinity concentrations that vary with river flows; estuarine character extends up river to the limit of tidal influence. Sub-estuaries also contain riparian habitat, dune habitat, tidal marshes, seaweed assemblages, eelgrass meadows, and limited rocky shore habitat. Sub-estuaries and tidally influenced rivers provide the transition between freshwater and saltwater for migratory salmonids. Recent studies indicate that juvenile salmonids spend considerable time in these habitats as they migrate to the ocean (Beamer *et al.*, 2005).

Saltwater - riparian areas

Saltwater riparian habitat plays an important role in the structure and function of the nearshore ecosystem. This area is primarily under private ownership and is immediately landward of the intertidal zone; it is often naturally vegetated with shrubs and trees that sometimes overhang the intertidal zone (Williams *et al.*, 2001). As with freshwater riparian areas, saltwater riparian areas play a key role in nutrient cycling. These habitats filter and detain stormwater runoff, stabilize soils, reduce erosion rates, decrease temperature impacts on shallow water and beach habitats, and provide both structure (large woody debris) and insect prey for aquatic species (Brennan and Culverwell, 2004).

Figure 1.16. Sub-estuary and tidally influenced riverine habitats**.**



Graphic: King County Department of Natural Resources.

Saltwater - offshore

The offshore ecosystem (Figure 1.12) generally begins at water depths greater than 20 meters (65 feet) and is defined by levels of photosynthetically active radiation (wavelengths 400 to 700 nanometers) insufficient to support the long-term survival of attached submerged aquatic vegetation. As a result, the offshore ecosystem is primarily driven by energy derived from phytoplankton communities found in the water column.

The offshore ecosystem comprises a coastal and an inland region. The coastal region includes those areas along the outer coast of Washington from the mouth of the Columbia River to Cape Flattery. The inland region consists of the Strait of Juan de Fuca, the San Juan Archipelago north to the Canadian border, all of Puget Sound, and the Columbia River from its mouth to the Bonneville Dam.

Physical properties

Bathymetry strongly influences water circulation and water chemistry of offshore ecosystems. Submarine ridges, or *sills*, define the geometry of interconnected basins in Puget Sound, drive upwelling and currents along the outer coast, and strongly affect water exchange and biological conditions for both areas (Burns, 1985; Thomson, 1994). The offshore ecosystem comprises three major bathymetric and hydrodynamic features: Puget Sound, the Strait of Juan de Fuca, and the continental shelf on the outer coast. Puget Sound is defined at its northern end by the 65-meter sill at Admiralty Inlet and includes all of the marine waters south to Olympia, including Hood Canal. The Strait of Juan de Fuca connects Puget Sound to the Pacific Ocean. The Strait of Juan de Fuca's western end is affected by oceanic processes that create strong tidal currents; the eastern end is modified by intense tidal processes (Thomson, 1994). The continental shelf on the outer coast is wide and gently sloping, resulting in slower circulation and greater particle residence times (Hickey and Banas, 2003).

Water circulation has a significant influence on the character and biological productivity of this ecosystem. In the inland region, circulation is governed by the seaward movement of rainfall and snowmelt in the upper portion of the water column, and the landward inflow of saltwater in the lower water column (Thomson, 1994). In the coastal region, oceanic conditions influence seasonal fluctuations of upwelling and downwelling (Hickey and Banas, 2003). From late spring to early fall, northwesterly winds transport the upper 100 meters (328 feet) of the water column farther offshore (Thomson, 1994), enabling upwelling of relatively cold, high salinity, and nutrient rich waters. From late fall to early spring, coastal winds are primarily from the southeast, which causes a reversal of circulation patterns and results in downwelling.

Water flows and wave/current energies control sediment transport in the offshore ecosystem. In the inland region, flowing water is generally the most important process governing sediment transport; rivers and shoreline erosion represent the primary means of sediment transport (Burns, 1985). In the coastal region, large waves and strong ocean currents constantly erode and rebuild beaches, resulting in seasonal changes in sediment transport and substrate composition.

Water properties

Surface water salinity and temperature vary by season. In the summer, salinity typically ranges between 29 parts per thousand and 33 parts per thousand; temperatures range between 8 and 19 degrees Celsius (46–66 Fahrenheit). In the winter, salinity and temperature are influenced more by riverine flows; salinity may be as low as 13, and water within the top 10 meters (33 feet) of the surface may stratify (Newton *et al.*, 2002).

Water clarity is affected by plankton concentration and suspended sediments. Secchi depth, a measure of water clarity, varies between 4 meters (13 feet) and more than 11 meters (36 feet), with the clearest waters often occurring during calm periods in winter, and after the massive phytoplankton blooms in spring and summer have died off (Newton *et al.*, 2002). In addition to phytoplankton blooms, widespread reduction in water clarity can occur during storms from suspension of fine sediment particles, or plumes of turbid water from larger rivers.

Nitrogen and phosphorus in coastal waters come from three primary sources: upwelling of nutrient rich water, input from land sources, and recycling of nutrients in surface waters and sediments (Harris, 1986). As previously noted, the upwelling of nutrient-rich water from the Pacific Ocean is the major source of macronutrients to coastal offshore ecosystems. Rich, oceanic waters are also the primary source of nutrients for the inland region; anthropogenic sources are considered negligible in well-flushed basins (Williams *et al.*, 2001). Inland primary productivity rates are generally considered to be very high, relative to those in other temperate estuaries. Inland primary productivity rates are primarily affected by sunlight, stratification, and water residence time (Williams *et al.*, 2001). Because all of these factors are highly variable in time and space, primary productivity and abundance can occur in extremes, characterized by phytoplankton blooms. Intense blooms largely occur in the spring and fall, with smaller blooms in summer and sparse growth in the winter. Major types of phytoplankton present in Puget Sound include diatoms

(Bacillariophyceae), dinoflagellates (Dinoflagellata), and microflagellates (Protozoa) (Strickland, 1983).

Both inland and coastal offshore dissolved oxygen concentrations reflect the influence of dense, high salinity, naturally low-oxygenated oceanic waters (Newton *et al.*, 2002). Concentrations range between 5 and 3 milligrams per liter.

Habitat types

Many species that use the offshore ecosystem dwell within the water column or at the water's surface. In addition to free-floating plankton and pelagic fish eggs, these areas support a variety of fish larvae (for example, smelt (Osmeridae) and sculpin (*Artiedius* spp.); adult fish (such as spiny dogfish, Pacific herring, Pacific cod, and salmonids); and the marine mammals and birds that prey upon them (Long, 1982). At least 21 different species of marine mammals use the Strait of Juan de Fuca and northern Puget Sound alone for feeding and migration (Long, 1982). Large populations of birds, such as gulls (*Larus* spp.), loons (*Gavia* spp.), grebes (*Aechmophorus* spp.), and cormorants (*Phalacrocorax* spp.) also winter and feed in the offshore ecosystem.

As with the nearshore, there are two habitat divisions of inland and coastal offshore benthos—consolidated and unconsolidated.

Consolidated

Consolidated habitats are primarily found in scattered pockets off the coast of the Olympic Peninsula, in larger aggregations west and southwest of Willapa Bay, off of Cape Flattery, in the San Juan Archipelago, off the west coast of Whidbey Island and Admiralty Inlet, and in the Tacoma Narrows channel. High-energy, consolidated habitats are predominantly characterized by non-motile invertebrate species—such as anemones (*Metridium senile* and *Urticina* spp.), purple-hinged rock scallops (*Hinnites giganteus*), and giant acorn barnacles *(Balanus nubilus*) (Dethier, 1990)—and mobile species, such as sea urchins (*Strongylocentrotus* spp.), rockfish (*Sebastes* spp.), gobies (*Coryphopterus* spp.), lingcod (*Ophiodon elongatus*), and sculpin (*Artiedius* spp.). Low-energy, consolidated habitats are characterized by glass sponges (*Hyalospongia*), polychaete worms (*Serpulid* spp.), squat lobsters (*Munida quadrispina*), a variety of planktivorous invertebrates (e.g., anemones (*Urticina* spp.), orange cup coral (*Balanophyllia elegans*), rockfish, longfin sculpin (*Jordania zonope*) and gobies.

Unconsolidated

Unconsolidated, soft bottom is the predominant benthic habitat for both the coastal and inland region of the offshore system. The biological communities associated with high-energy, unconsolidated habitats are influenced by both substrate composition and size. Mixes of cobble and finer material, such as gravel, shell hash, and sand, are typically inhabited by horse mussels (*Modiolus modiolus*) and barnacles (*Balanus* spp.). Cobble substrates are generally dominated by sea urchins and rock scallops. Mixed-coarse substrates house a variety of infauna, including small bivalves—such as the hundred line cockle (*Nemocardium centifilosum*)—and amphipods such as the Bay ghost shrimp (*Callianassa californiensis*) and the stout coastal shrimp (*Heptacarpus brevirostris*). Sandy, unconsolidated habitats in high-energy regimes support small bivalves (for example, Tellina spp. and *Macoma* spp.), amphipods (including *Rhepoxynius abronius* and *Eohaustorius washingtonianus*) and polychaetes (such as *Maldane glebifex* and *Chaetozone setosa*) (Dethier, 1990). Low-energy, unconsolidated habitats typically support sea pens (*Ptilosarcus gurneyi*), sea whips (*Virgularia* spp.), tubeworms (*chaetopterid polychaetes*), many bivalve species, and mobile crustaceans, such as Dungeness crab and kelp crabs (*Pugettia* spp.) (Dethier, 1990).

1.5 Existing conditions

1.5.1 Water quality

Freshwater

Lacustrine

The Washington State Department of Ecology staff and volunteers assess water quality in lakes by measuring Secchi depth, temperature, pH, dissolved oxygen, and conductivity (Smith *et al.*, 2000; Bell-McKinnon, 2002). Of the 48 lakes assessed for phosphorus and trophic status in 1999, 12 percent exceeded the established criteria for the region. Table 1.5 illustrates trophic status and total phosphorous ranges (Bell-McKinnon, 2002).

Table 1.5. Trophic status and total phosphorous ranges for lakes assessed in 1999.

	Oligotrophic	Mesotrophic	Eutrophic
Trophic status assessed (number)	20	23	5
Exceed total phosphorous criteria (number)	2	4	
Total phosphorous range (micrograms/liter)	4.9–17.2	12.5–72.5	18.5–44.8

Riverine

The Washington State Department of Ecology's freshwater monitoring unit has monitored Washington's rivers and streams for more than 30 years. Monthly sampling occurs at 62 monitoring sites and 20 basins for the following 12 parameters: ammonia, nitrate+nitrite, total nitrogen, total phosphorus, orthophosphate, temperature, pH, conductivity, oxygen, turbidity, suspended sediment, and fecal coliform bacteria. Assessments of water quality are based on a comparison of the state's water quality standards (WAC 173-201A) to the data collected.

The 62 long-term monitoring stations are generally located near the mouths of major rivers and downstream of major cities. The basin stations are selected to address site-specific water quality issues. Because the basin stations are typically monitored for only one year and are located in known problem areas, the data associated with these stations are not representative of water quality conditions statewide.

The Washington State Department of Ecology uses the stream Water Quality Index[19] to compare trends across stations and basins (Hallock, 2006). An analysis of trends for 1996 to 2005 shows

[19] The Water Quality Index expresses results relative to levels required to maintain beneficial uses as defined in Washington's Water Quality Standards (WAC 173-201A). It is expressed as a unitless number between 1 and 100; higher numbers indicate better water quality.

that adjusting data for flow improved the Water Quality Index at 15 of the long-term monitoring stations; declines noted at 4 stations (Hallock and Parsons, 2006). An analysis of ecoregional trends for the same period showed a statistical improvement in 4 of the 6 regions where data were collected and a decrease in the Water Quality Index statewide (Table 1.6) (Hallock and Parsons, 2006).

Water Quality Index scores for 2005 were also assessed, with the scores grouped in categories used by the Environmental Protection Agency (EPA). For both the basin and the long-term monitoring sites, 4 percent were categorized as "highest concern," 49 percent as "moderate concern," and 46 percent as "lowest concern" (Hallock and Parsons, 2006). Additional results for 2005 per Hallock (2006) are as follows:

- Aquatic life and recreational use: all criteria were met by 24 percent of the long-term stations and 29 percent of the basin stations.
- Stream temperature: approximately 87 percent of the stations exceeded criteria for 2005.
- Bacteria: No reduction in bacteria counts were required for 97 percent of the long-term stations and 61 percent of the basin stations.

Table 1.6. Ecoregional trends in the Water Quality Index. Positive Z scores indicate improving water quality, with significant trends ($p<0.05$) shown in bold (adapted from Hallock and Parsons, 2006).

Ecoregion	Number of Stations	Trend in Monthly Water Quality Index Scores		
		Regional Z score	Probability of Significant Trend	Mean Annual Change Last 10 years (WQI units)
Northwest Coast	6	- 0.55	0.59	Not significant
Puget Trough	24	+ 5.40	<0.01	0.28
East Cascades	4	+ 5.21	<0.01	0.60
Columbia Plateau	22	+ 10.63	<0.01	0.85
Okanogan	6	+ 5.92	<0.01	0.61
Statewide	63	- 0.55	<0.01	0.51

In 2009, Washington Department of Ecology used data collected from 1994 to 2008 to assess trends in total nitrogen and nitrate+nitrite concentrations at 24 stations in Puget Sound area rivers. Total nitrogen concentrations were uniformly down; the Stillaguamish, Cedar, and Skokomish rivers displayed especially strong downward trends. The Cedar and Skokomish rivers also showed downward trends in annual nitrate+nitrite concentrations while the Deschutes and Elwha rivers showed upward trends. Summer nitrate+nitrite concentrations showed upward trends in the Snohomish, Green, and Deschutes rivers (Hallock, 2009).

Saltwater

The Washington State Department of Ecology has conducted annual marine water quality monitoring at stations in Puget Sound and in coastal areas (Grays Harbor and Willapa Bay) since 1967. The program collected data on dissolved oxygen, nutrients, and fecal coliform bacteria. The report, covered data from 1998 to 2000 (Newton *et al.*, 2002), were reported bi-annually by the

Puget Sound Action Team (Puget Sound Action Team, 2007). The following discussion is a synthesis of the material published by the Washington State Department of Ecology and the Puget Sound Action Team.

While water quality varies seasonally and across years, general patterns in the levels of fecal coliform, nitrogen, ammonium, dissolved oxygen, and stratification can be used as indicators. For the 1998 to 2000 sampling period, the Washington State Department of Ecology reported that while water quality appeared to be generally good for the Puget Sound basin, several sites experienced decreases in overall water quality, including low dissolved oxygen, increases in fecal coliform bacteria, or a sensitivity to eutrophication based on stratification or nutrient conditions (Newton *et al.*, 2002). The eight areas of highest concern were southern Hood Canal, Budd Inlet, Penn Cove, Commencement Bay, Elliott Bay, Possession Sound, Saratoga Passage, and Sinclair Inlet. For the coastal estuaries, the primary water quality issue reported was chronic fecal coliform bacteria contamination in Grays Harbor and in Willapa Bay, adjacent to the Willapa River (Newton *et al.*, 2002). In 2005 all the sites sampled in Puget Sound were of concern for at least one parameter, with eight sites (Budd Inlet, South Hood Canal, Saratoga Passage, Possession Sound, Penn Cove, Commencement Bay, Elliott Bay, and Sinclair Inlet) considered "highest concern" due to exceedances of the standards for several or all parameters (Puget Sound Action Team, 2007). Bellingham Bay, Oakland Bay, Case Inlet, Discovery Bay, Strait of Georgia, Carr Inlet, Port Orchard, West Point, Skagit Bay and Port Susan were rated "high concern" due to exceedances of the standards for dissolved oxygen and fecal coliform bacteria (Puget Sound Action Team, 2007).

The Washington State Department of Ecology developed the Marine Water Condition Index (MWCI) in 2011 as a way to detect changes in water quality over time. The MWCI utilizes 12 variables to describe water quality conditions including temperature, salinity, nutrients, algae biomass and dissolved oxygen to assess local water quality and physical conditions in relation to broader oceanic water quality and natural variability. The NWCI trends show a continuing increase in nutrients, possibly due to the increase in population density since 2002, for the Puget Sound Central Basin, southern Hood Canal, Oakland Bay and Admiralty Inlet. Increases in population, particularly along Puget Sound's urbanized corridor correlate with increases in nutrient discharges from both point source and non-point sources in these areas (Washington State Department of Ecology, 2012).

303(d) Listed waters

In 2009, the Washington State Department of Ecology completed Washington State's Water Quality Assessment for 2007/2008. The results of the assessment were submitted to the Environmental Protection Agency as an integrated report to satisfy federal Clean Water Act requirements of sections 303(d) and 305(b). The assessment includes a list of the bodies of water in Washington known to be polluted. The list is available on the Department of Ecology's website and is included in the Environmental Protection Agency's Watershed Assessment, Tracking and Environmental Results System (WATERS) interactive database.

The report assesses 5 percent of the river and stream miles and 3 percent of the combined total number of lakes and gridded marine waters in Washington. Of the 26,000 segments assessed, 30 percent met all the tested water quality parameters (temperature, pH, dissolved oxygen, fecal coliform, total nitrogen, total phosphorous, total suspended sediment, and turbidity), 16 percent were designated as waters of concern,[20] and 14 percent were placed on the 303(d) list. The number of segments assessed as Category 5 (standards for one or more pollutants have been violated, and there is no Total Maximum Daily Load (TMDL) established for the segment) increased by 919 from 2005. Of the 2008 key parameter exceedances, 33 percent were due to temperature, 27 percent were due to fecal coliform bacteria, 24 percent were due to dissolved oxygen, 10 percent were due to pH, 2 percent were due to total phosphorous, and 4 percent were due to metals, toxics and “other” pollutants. The Washington State Department of Ecology’s Water Quality Program submitted the 2010 Candidate Assessment and 303(d) List to the Environmental Protection Agency in December 2011. Once approved, this list will replace the 2008 assessment and 303(d) list of impaired waters in Washington State.

1.5.2 Sediment quality

Freshwater

Washington State does not currently have sediment criteria for freshwater. The Washington State Department of Ecology is, however, engaged in establishing sediment quality values based on apparent effect thresholds for bioassay endpoints. In 1998, the U.S. Geological Survey published results pertaining to the Puget Trough from the National Water Quality Assessment Program showing that several riverine systems had levels of metals and toxins that exceed both Canadian probable effects levels and New York State freshwater sediment standards for sediment and fish tissue (MacCoy and Black, 1998).

Saltwater

Sediment quality plays an important role in the health and structure of *epibenthic* and *benthic* habitats, influencing food web dynamics, primary productivity, and species diversity and abundance. The Washington State Department of Ecology’s Marine Sediment Monitoring Team and the National Oceanic and Atmospheric Administration (NOAA) cooperatively collected sediment samples for 300 Puget Sound sites between 1997 and 1999. The data characterize the quality of sediments throughout Puget Sound, the concentration of toxins present, and describe the biological communities present (Long *et al.*, 2004).

The Sediment Quality Triad Index summarizes the data results by frequency of occurrence categories by basin/region (Table 1.7) and by total area within Puget Sound (Table 1.8) (Long *et al.*, 2004). Most samples assessed as degraded were collected in the Whidbey Basin (Everett Harbor), Central Sound (Elliot Bay and Commencement Bay), and South Sound (Budd Inlet) regions.

The station samples were also analyzed using five strata based on the major geographic features and degree of anthropogenic activity (including harbor, urban embayments, passage, deep basin, and rural embayments). The largest percentage of samples with degraded sediment quality was associated with the harbor and urban embayment strata; the samples with the highest sediment quality were found in passages, deep basins and rural embayments.

[20] Evidence of a water quality problem, but not enough to require production of a total maximum daily load.

Table 1.7. Sediment Quality Triad Index for Puget Sound basins (Long et al., 2004).

	Index Frequency (percent of samples)			
Basin	**High**	**Intermediate / High**	**Intermediate / Degraded**	**Degraded**
Strait of Georgia	70	25	5	0
Whidbey	61	13	5	21
Admiralty Inlet	100			
Central Sound	23	37	20	20
Hood Canal	61	19	10	10
South Sound	46	33	19	2

Table 1.8. Sediment Quality Triad Index for Puget Sound (Long et al., 2004).

	Stations	
Sediment Quality Triad Index	**Number**	**Percent**
High	138	46.0
Intermediate/high	85	28.3
Chemistry	13	4.3
Toxicity	68	22.7
Infauna	4	1.3
Intermediate/degraded	40	13.3
Chemistry	19	6.3
Toxicity	1	0.3
Infauna	20	6.7
Degraded	37	12.3

In 2005, the Puget Sound Ambient Monitoring Program (PSAMP) summarized 12 years of data from 10 long-term monitoring stations to establish a record of sediment conditions for a variety of habitats and geographic locations throughout Puget Sound (Partridge *et al.*, 2005). The data associated with grain size, total organic carbon content, and the composition and structure of benthic invertebrate communities were collected annually. Sediments were analyzed for more than 180 priority pollutant metal and organic contaminants: for example, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides. (Partridge *et al.*, 2005)

While many of these parameters were stable over time, changes associated directly with anthropogenic sources were found in urban embayments. Analysis of the chemical contaminant data set indicated that, in general, concentrations of metals in 2000 were lower than in 1989-1996 more often than they were higher, while the opposite was true of PAHs (Partridge *et al.*, 2005). The decrease in concentrations of metals may reflect a decreased discharge of metals into Puget Sound; the increase in PAH concentrations is likely attributable to increased suburban runoff. Overall, Sinclair Inlet had the highest concentration of metals; PAH concentrations at the Thea Foss Waterway station was one to two orders of magnitude greater than at any other station (Partridge *et al.*, 2005).

While not measured in either of the reports discussed here, it is likely that other environmental variables such as the availability of oxygen, nutrient flux between the sediments and water column, and unregulated pollutants—such as polybrominated diphenyl ethers (PBDEs), which are flame retardants— affect sediment conditions and food web dynamics. Taken up through the food chain, PDBEs have been documented in fish tissue studies and are known endocrine disruptors. As of this report, there are no monitoring planning efforts, water or fish standards for PBDEs (Washington State Department of Ecology, 2007).

1.5.3 Vegetation

Aquatic vegetation is important habitat in both fresh- and saltwater systems. Submerged and emergent vegetation provides structure to shallow water benthic habitats and reduces wave energy, which stabilizes the sediment and shoreline, and slows erosion (Fonseca & Cahalan, 1992; Van den Berg *et al.*, 1998). Aquatic vegetation also removes nutrients from the water column—thereby reducing algal blooms and associated decreases in dissolved oxygen—and converts carbon dioxide into oxygen in both the water column and the sediment (Findlay *et al.*, 2006; Hemminga and Duarte, 2000; Hietala *et al.*, 2004; Laskov *et al.*, 2006; Van den Berg *et al.*, 1998). Aquatic vegetation can also be a major source of food for herptofauna, birds, fishes, and invertebrates, which may consume the vegetation itself or consume species that shelter in the vegetation (such as zooplankton and larval and juvenile fishes). Aquatic vegetation also serves as a food source indirectly by contributing detritus and dissolved organic matter to the system (Alvarez and Peckarsky, 2005; Hilt, 2006; Moore *et al.*, 2004). Species may also use vegetation for egg attachment, nursery and rearing areas, and refuge from predation (Kendall and Mearns, 1996; Munger *et al.*, 1998; Shaffer, 2004; Webb 1991).

Freshwater

Washington's rivers and lakes contain a wide variety of vascular plants and freshwater algae. Freshwater aquatic plants can be categorized as rooted or unrooted. Rooted plants are further classified as submerged, emergent, or floating. Among the freshwater algae, stoneworts and brittleworts (Charophytes) achieve a size and structural complexity similar to vascular plants. Vegetative species include emergent species such as rushes (*Eleocharis* spp.) and arrowhead (*Sagittaria* spp.); floating species such as pond-lilies (*Nuphar* spp.), pondweed (*Potamogeton* spp.), pennywort (*Hydrocotyle ranunculiodes*), and duckweed (Lemnaceae); and submerged species such as western milfoil (*Myriophyllum hippuroides*), starworts (Callitrichaceae), hornworts (Ceratophyllaceae), and stoneworts (Characeae).

Freshwater vegetation is an important food web component. Species that directly consume freshwater vegetation include amphibian tadpoles, the western pond turtle (*Actinemys marmorata*), snails, insects, and a variety of birds and fishes. In turn, these primary and secondary consumers are a valuable food source for adult amphibians (such as Columbia spotted frog (*Rana luteiventris*)), birds, and both juvenile and adult fish, including white sturgeon (*Acipenser transmontanus).* Vegetation also provides refuge and breeding habitat for a variety of species such as amphibians and aquatic insects.

The Washington State Department of Ecology has documented an increase in the density of native plant growth in some lakes and rivers. This is most likely related to an increase in nutrients resulting from human sources, including fertilizer runoff and leaky septic systems. While moderate growth of aquatic plants is generally a benefit to aquatic systems, too much can cause detrimental impacts; exceptionally dense growth of native plants can potentially affect fish and other native wildlife (Hallock, 2006).

Riparian vegetation

In addition to shading the adjacent water body and helping to maintain cool water temperatures, riparian vegetation helps stabilize shorelines, thereby controlling erosion and sedimentation. Large diameter trees provide important perch sites for birds. Overhanging or partially submerged vegetation provides cover for fish and other aquatic species. The leaves, twigs, and insects that fall from the vegetation provide food and nutrients. Large trees that fall into lakes and rivers create cover and slow water habitats for spawning and rearing, and protection from predators. Large woody debris also helps form complex habitats by retaining gravel, contributing to floodplain development, and establishing pool/riffle sequences through transitional and depositional reaches. Understory riparian vegetation, soils, and the duff layer filter upland sediments and pollutants, which reduces detrimental inputs to aquatic systems. Vegetation also helps moderate stream volumes by reducing peak flows during flooding periods, and by storing and slowly releasing water into streams during low flows (Knutson and Naef, 1997).

Since the early 19th century, between 50 and 90 percent of Washington's riparian habitat has been lost or modified (Canning and Stevens, 1989; Knutson and Naef, 1997). The biologically productive lowlands have experienced an estimated 70 percent conversion of wetland and riparian areas; heavily urbanized areas experienced a 100 percent loss or severe alteration of wetland and riparian habitat (Canning and Stevens, 1989).

Invasive aquatic vegetation

The term *invasive* is used in this document as defined under RCW 79A.25.310(4). Since 1994, the Washington Department of Ecology has sampled 445 rivers and lakes for invasive aquatic weeds. Of the 44 percent found to have invasive weeds, Eurasian water-milfoil (*Myriophyllum spicatum*) was the most prevalent (found in 77 percent of the rivers and lakes with invasive species), followed by Brazilian elodea *(Egeria densa*; 13 percent) and parrot feather (*Myriophyllum aquaticum*; 8 percent) (Hallock, 2006).

Saltwater

Seagrasses

Seagrasses are rooted flowering plants that live partially or completely submerged in marine and estuarine waters. Of the six seagrass species occurring in Washington, the two eelgrasses (the native *Zostera marina* and the non-native *Z. japonica*) are the most widespread seagrasses: they are documented to occur along approximately 1,135 kilometers (705 miles) of shoreline (Washington DNR, 2002). North and central Puget Sound have the highest percentages of eelgrass; the southern end has the lowest percentage. Surfgrasses (*Phyllospadix* spp.) can also be found, but are generally less abundant than eelgrass and are restricted to the lower intertidal and shallow subtidal zone in high-energy (exposed), rocky, marine shorelines. Widgeon grass (*Ruppia maritima*) is even less common than the surfgrasses and inhabits the high intertidal in areas with brackish water.

Eelgrass meadows are a major source of carbon in the nearshore ecosystem and have one of the richest assemblages of animals among all aquatic habitats in the state. Eelgrass is used by a number of juvenile salmonids and other fish for foraging and refuge, by herring as a spawning substrate, and by a variety of crabs for feeding and refuge (Holsman *et al.*, 2003; McMillan *et al.*, 1995; Phillips, 1984).

As part of the Puget Sound Assessment and Monitoring Program (PSAMP),[21] Washington DNR's Submerged Vegetation Monitoring Project (SVMP) has been collecting data on the abundance and distribution of native eelgrass in greater Puget Sound since 2000. The study area is divided into five regions: central Puget Sound, north Puget Sound, San Juan Archipelago, Strait of Juan de Fuca, and the Saratoga-Whidbey Basin. More than a quarter of the total amount of eelgrass in Puget Sound is found in Padilla and Samish bays in the Puget Trough ecoregion.

Gaeckle *et al.*, (2009) provided recent data on eelgrass in Puget Sound, extending the overall data record to nine years (2000 to 2008). In Puget Sound overall, native eelgrass shows a pattern of slight decline; more sites display long-term decreases in eelgrass than increases; and more sites show one-year decreases in eelgrass than increases. However, this slight declining trend has not resulted in a decrease in the spatial extent of eelgrass across Puget Sound over the last nine years.

Sampling results from the Hood Canal region suggest that Hood Canal is showing the largest decline and is of highest concern for the decline in native eelgrass (*Z. marina*). The Strait of Juan de Fuca and central Puget Sound regions also show declining trends and are the second highest concern (Gaeckle *et al.*, 2009). In particular, several shallow embayments in the San Juan Archipelago have shown a pattern of sharp decline in eelgrass abundance, including some areas used as herring spawning sites (Dowty *et al.*, 2005). The Saratoga-Whidbey and north Puget Sound regions had the lowest frequency of change in eelgrass area—the number of decreasing sites matched the number of increasing sites—and this location is currently of low concern for native eelgrass decline (Gaeckle *et al.*, 2009).

While not the primary focus of the SVMP work, data on non-native eelgrass (*Z. japonica*) were also gathered. This introduced species tends to have a shorter growth form and different sheath morphology than the native species. Little is known, however, about differences in the ecological services of the two species. The non-native species tends to colonize shallower areas in upper intertidal zones and can co-occur with *Z. marina* (Dowty *et al.*, 2005). In 2009, *Z. japonica* was observed at 18 sites in all regions. Since 2000, non-native eelgrass has been observed at 68 different sites in Puget Sound (Gaeckle *et al.*, 2009).

[21] Formerly the Puget Sound Ambient Monitoring Program.

Seaweeds

Seaweeds are macroscopic marine algae (macroalgae). Macroalgae are divided into three taxonomic subgroups based on their dominant photosynthetic pigmentation (red, green, and brown algae). These algae occur throughout the nearshore in saline waters where light levels are great enough to support their growth. Although most seaweed species grow attached to consolidated substrates, some seaweeds, such as ulvoids (flat green seaweeds) can live unattached to the bottom. The vast expanses of rocky shores along the Strait of Juan de Fuca, and rocky outcrops on the outer coast of Washington support many of the 633 species that occur throughout the Pacific Northwest (Gabrielson *et al.*, 2000). Central Puget Sound supports approximately 160 species; south Puget Sound supports only a few species (Thom *et al.*, 1976).

Along many rocky shores in Washington, the upper intertidal band of seaweeds consists of low growing turf and crust-forming species. Below this is a band of the fucoid brown seaweed (*Fucus* spp.), usually followed by a diverse mix of red, green, and brown seaweeds. In the shallow subtidal zone, larger brown algae can dominate and form an assemblage comprised of an understory of smaller species associated with large dominant species. As the photic zone deepens, the brown algae will give way to the more low-light tolerant red algae and invertebrates.

One group of brown algae includes all of the order Laminariales, commonly known as kelp. Kelp attach to the substrate by root-like holdfasts and are categorized into floating and non-floating kelp. Bull kelp and giant kelp are floating kelp that can form extensive canopies at or near the surface of the ocean. These beds are most common in rocky, high-energy marine environments. In Washington state, floating kelp beds are found on approximately 11 percent of the shoreline, primarily on the northwest coast of the Olympic Peninsula (Washington DNR, 2002). Washington DNR's Nearshore Habitat program has been monitoring the areal extent of kelp bed populations along the Strait of Juan de Fuca and the Olympic Peninsula coast annually since 1989 to evaluate natural variation and changes related to human impacts (Dowty *et al.*, 2005). Annual variability is high: The overall extent of kelp fluctuated between a high of 11,832 acres in 2000, and a low of 4,722 acres in 1989.

Sargassum muticum is a non-native brown alga from Asia that has been established in Washington for decades. *Sargassum* occurs in lower intertidal and shallow subtidal rocky habitats and displaces native macroalgae. This species is found most often along the shorelines of Hood Canal, the San Juan Archipelago and the Strait of Georgia, and is least common along the outer coast. Data collected by the ShoreZone Inventory program (Washington DNR, 2002) show that *Sargassum* is present along 18 percent of the state's shorelines.

Marine riparian vegetation

While marine riparian areas generally receive less attention and study than freshwater riparian areas, an assessment of relevant literature by Brennan and Culverwell (2004) indicates that both freshwater and marine riparian systems serve almost identical functions for supporting biota and the integrity of nearshore/littoral habitats. Their assessment also indicates that a lack of attention to marine riparian areas and poor protective standards associated with shoreline development have resulted in substantial loss and degradation of marine riparian and nearshore ecosystems.

Recent work illustrates the value of saltwater riparian buffers: areas with less vegetation have decreased invertebrate diversity and decreased survival of surf smelt embryo (*Hypomesus pretiosus*) due to higher beach temperatures and lower humidities (Sobocinski, 2003; Rice, 2006).

Areas with older, more complex riparian vegetation provide more complex backshore structure, further stabilizing the bank (Tonnes, 2008).

Invasive aquatic vegetation

Marine species of cordgrass (*Spartina* spp.), are aggressive weeds, severely disrupting estuarine ecosystems by outcompeting native vegetation. In some areas, these species have become well established and are rapidly raising tidal elevations, displacing eelgrass and native marsh plants, and reducing habitat for migratory waterfowl, invertebrates, and possibly fish.

In Washington, four different marine *Spartina* species grow in intertidal regions from high intertidal marshes to within 1 meter of mean lower low water. *Spartina patens* and *S. densiflora* are adapted to grow in upper marshes where they mix with native plants. *Spartina alterniflora* and *S. anglica* tend to invade bare mud in the lower tidal area. *Spartina* species infestations occur throughout Puget Sound, in Willapa Bay, and in Grays Harbor (Washington State Department of Agriculture, 2005).

In all, there are presently 11 counties in western Washington with one or more infestations of marine *Spartina* species: Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Pacific, San Juan, Skagit, Snohomish, and Whatcom counties. *Spartina anglica* was identified for the first time in Whatcom County in 2005. The infestation was found by a shoreline resident in Birch Bay at the northern boundary of Whatcom County (Murphy, 2005).

Aggressive, comprehensive treatment programs continue to be implemented and improved to address the control of *Spartina* species. Post-treatment evaluations indicate that most effective reductions occur in contiguous infested areas; reductions are more difficult to achieve in vegetative transition areas. Cooperative efforts include participation by the Washington State Department of Agriculture, Washington Department of Fish and Wildlife, Washington DNR, other state agencies, universities, U.S. Fish and Wildlife Service, counties, tribes, private organizations, and private landowners (Murphy, 2005).

Japanese eelgrass (*Zostera japonica*) was listed as a Class C noxious weed by the Washington State Noxious Weed Control Board in 2012. Japanese eelgrass was listed as a noxious weed because it is non-native, difficult to control, and negatively impacts the shellfish industry (WA State Noxious Weed Control Board, 2012).

Washington DNR will evaluate *Zostera japonica* presence on a site-by-site evaluation of the state-owned aquatic lands that it leases. Protections will apply if forage fish are utilizing *Zostera japonica* for spawning only.

1.5.4 Land uses and population

Population distribution, growth, trends

Washington's population has almost doubled since 1970, with most of the growth occurring in the urban areas of western Washington. The Washington Office of Financial Management (OFM) has released its first population forecast since the 2010 Federal Census. The state’s population is currently estimated at 6,668,200. Nearly 70 percent of the population is concentrated in the counties surrounding Puget Sound (OFM, 2011). Over the 30-year forecast period, Washington

State's population is expected to grow by just over 2 million, reaching 8,791,000 in 2040 (OFM, 2011).

The state's population is expected to increase almost 40 percent in the next 20 years; the largest growth is projected to occur in Franklin County (southeast Washington), Stevens County (northeast Washington) and the less-developed regions surrounding Puget Sound (OFM, 2011). As the state's population grows, the demand for access to the water for recreation, commerce, and food production will increase. Development pressures will also increase the amount of impervious surface in the state, generating more storm water and non-point source pollution.

Uses and modifications of aquatic lands

Aquatic lands are used for a variety of recreational (for example, private docks, and floats) and commercial purposes (such as marinas and shellfish culture). These activities occur on lands owned by the state as well as those outside state ownership. Human use of aquatic land is also associated with modifications of the aquatic landscape through the introduction of exotic species; alteration of flowing waters for hydropower, flood control, or irrigation; dredging to create and maintain navigational channels; shoreline armoring; filling aquatic land to create terrestrial land; and placement of structures in nearshore and littoral areas. The resulting changes in the landscape include the loss of wetlands and deltas; the channelization of waterways; altered river flows and flow patterns; changes in land cover; interruption of small drainages; increased runoff; altered shoreline structure and function; and disruption or elimination of sediment transport and nutrient processes (Redman *et al.*, 2005; Williams and Thom, 2001).

Lacustrine ecosystem

In addition to changes in light, wave energy, and sediment transport associated with the placement of structures, lacustrine ecosystems are modified through:

- **Cultural eutrophication:** Activities such as wastewater treatment discharges, failing septic tanks, timber harvest, agricultural practices, and residential development may increase the loading of nutrients to a lake. This increased supply of nutrients often causes an increase in productivity and a shift in trophic status.
- **Shoreline modification and fill:** The concentration of shoreline modifications, including shoreline armoring, overwater structures, and road and bridge construction, may alter the structure and function of lake ecosystems. The effects are particularly severe in urbanized areas, with littoral habitats impacted most heavily. In general, these modifications cause alteration of substrate composition, natural water movement processes (for example, wave energy), and water chemistry (such as increased nutrient supply); loss of riparian vegetation; artificial shading of benthic habitat; and reduced productivity.
- **Invasive aquatic vegetation:** While not all species become an ecological threat, in some cases they have significantly altered the structure and function of lake ecosystems. Aquatic weeds such as the Eurasian water milfoil (*Myriophyllum spicatum*), Brazilian elodea, parrot-feather, hydrilla (*Hydrilla verticillata*), and fanwort (*Cabomba caroliniana*) became established in lakes and are outcompeting native plant species (Washington Department of Fish and Wildlife, 1997a).

Riverine ecosystem

As with nearshore ecosystems, modification of riverine systems occur through changes in light, hydrologic processes such as wave and current energy, and sediment transport associated with structures, fill, and dredging. In addition, modifications to riverine systems result from damming, channel alteration, and changes in adjacent land use. Specific modifications include:

- **Dams:** Effects associated with many large dams include migration barriers, isolating species behind the barriers; altered aquatic thermal regimes; encroachment of terrestrial vegetation into channels; and sediment trapping. Hundreds of miles of riverine ecosystems have been converted to lake-like systems rendering them unsuitable for organisms that require flowing water or lengthy migration corridors.
- **Channel alteration:** Simplification of riverine ecosystems results from adjacent land use practices such as levees, bank armoring, channel simplification, dredging, and removal of woody debris. Flood control structures (including levees and tidegates) disconnect floodplain and secondary channels from the stream channel, thereby reducing or eliminating wetland and shallow water refuge habitat for amphibians, fish, and birds. The practice of straightening river channels to increase flood conveyance has reduced habitat complexity and eliminated high flow refuges. Bank armoring to prevent channel migration and bank erosion has altered the dynamic equilibrium of riverine ecosystems and riparian succession. Many of the federally navigable water bodies were historically subjected to systematic removal of large woody debris to promote settlement; this further reduced refuge habitat and altered flow dynamics throughout the state.
- **Agriculture and livestock grazing:** Agriculture and livestock grazing continue to be a significant factor in the degradation of riverine ecosystems. Increased nutrient inputs from agricultural fertilizers and livestock waste stimulate algal and plant growth, resulting in an increase in biological oxygen demand. Irrigation diversions increase summertime water temperatures, and reduce the quantity and quality of instream habitat for aquatic organisms. Livestock grazing and trampling eliminate riparian vegetation, increasing erosion and sedimentation. Loss of riparian vegetation negatively impacts water temperature, reduces wood recruitment potential, and decreases the quality of salmonid spawning habitat (Wissmar *et al.*, 1994).
- **Urban/suburban development:** Impacts associated with urbanization include altered hydrograph and increased likelihood of channel instability; degraded water quality; loss of wetlands; loss of riparian forests; loss of instream habitat; and reduced habitat connectivity (Booth and Jackson, 1997; Gregory and Bisson, 1997).

Saltwater-nearshore ecosystem

Human alteration of the nearshore ecosystem generally occurs through changes in key controlling factors such as light, wave energy, riparian vegetation, and both sediment transport and delivery (Nightingale and Simenstad, 2001). Specific modifications include:

- **Overwater structures:** Structures can decrease available light, affecting the ability of vegetation to grow, and causing behavioral changes in fish migrating along the shoreline. The structures also change wave energy and currents, which alters sediment transport mechanisms and associated habitat-forming processes.
- **Shoreline armoring:** The installation of bulkheads, breakwaters, and similar structures can greatly change the functional capacity of the nearshore ecosystem by altering wave energy patterns. There are approximately 1,476 kilometers (917 miles) of shoreline

armoring in the nearshore of Washington State, excluding the Columbia River (Washington DNR, 2002).

- **Fill and dikes:** Filling has occurred historically in the urbanized areas of Puget Sound and the Strait of Juan de Fuca because these areas were developed to meet the needs of port facilities and other economic activities on the waterfront. In parts of Puget Sound, over 95 percent of tidal wetlands have been lost or isolated from the adjacent estuaries by dikes (Frenkel and Morlan, 1991; Gregory and Bisson, 1997). In some cases tidal wetlands have been completely or partly filled to accommodate a variety of land uses, including agriculture, recreation, residential development, and industry. These modifications may also affect nearshore flushing rates by altering or eliminating freshwater input (Alberti and Bidwell, 2005; National Ocean Service, 2004).
- **Dredging:** Maintenance dredging of working ports and federal navigation channels is a necessary activity to maintain the usability and economic viability of these resources. In addition, dredging is an important option for the complete removal of contaminated sediments in aquatic cleanup sites. Dredging occurs primarily in the Columbia River navigation channel and in some urban areas where large port facilities are located. There have been several dredging projects greater than 100,000 cubic yards within Puget Sound, including two in Seattle and two in Tacoma. The largest of these is the Blair Inner Reach Cutback and Turning Basin Expansion, which removed 2.6 million cubic yards of material (Science Applications International Corporation, 2005).
- **Aquaculture:** The major aquaculture activities in the nearshore ecosystem target growing shellfish near the sediment surface in ground or line culture. Concerns related to aquaculture activities include the effect of shellfish culture on eelgrass.

1.6 Covered activities

Washington DNR has examined the types of current and logically foreseeable future activities permitted on state-owned aquatic lands to determine what activities will be covered under an incidental take permit. Only those activities listed as “covered” in this HCP will receive protection under an Incidental Take Permit from challenges brought by Section 10 of the federal Endangered Species Act. After examining all uses of state-owned aquatic lands (Washington DNR 2005b, 2007b), Washington DNR has decided to seek coverage for three groups of activities under this HCP (Table 1.9). The selection of covered activities involved a detailed set of analyses:

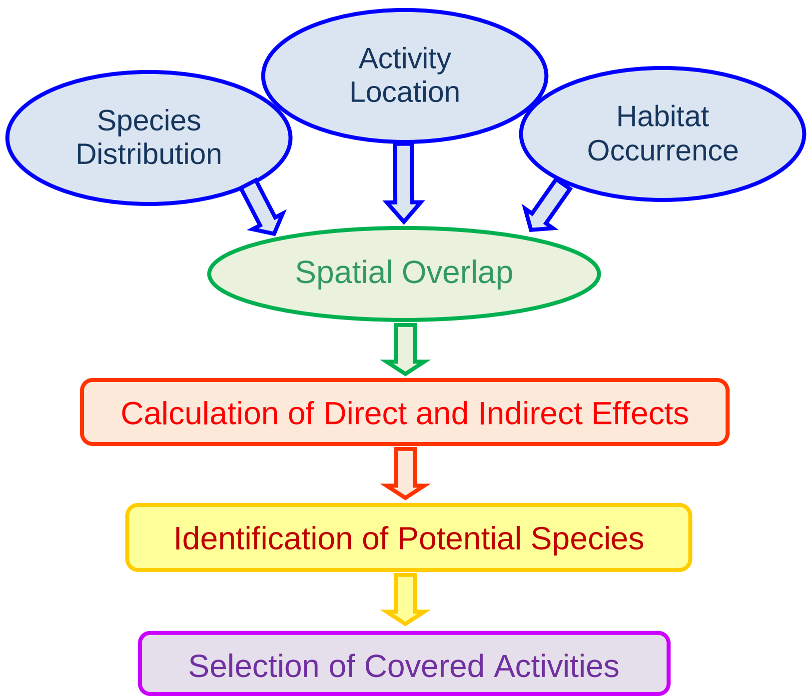
- Categorization of the types of uses authorized on state-owned aquatic land (Washington DNR, 2005b).
- An analysis of the activity categories’ spatial overlap with sensitive species and calculation of the activity categories’ direct and indirect effects on these species (Washington DNR, 2007b).
- An assessment of the agency’s ability to affect change in both the way the activities occur on the landscape, and their effects on sensitive species and their habitats (Figure 1.17).

This section provides a brief summary of the selection process. Detailed descriptions can be found in Washington DNR 2005b, and 2007b. Chapter 3 of this document fully describes how the covered activities occur on state-owned aquatic lands.

Table 1.9. Activities covered by this plan.

Activity Category	Included structures and activities
Aquaculture	Shellfish (mussels, clams, oysters)
Log booming and storage	All in-water structures and operations
Overwater structures	Boat ramps, launches, hoists; docks and wharves; floating homes; rafts; marinas; mooring buoys; nearshore buildings; shipyards and terminals

Figure 1.17. Conceptual illustration of the selection process for covered activities.



1.6.1 Categorization

DNR tracks authorized uses[22] of state-owned aquatic lands in a financial management database (NaturE) that employs 86 unique commodity codes to classify both the use and the revenue stream. Because these codes have no ecological significance, the uses were sorted into 35 classes based on the nature of the structure or activity (such as shellfish culture and stormwater outfalls). These classes were then grouped into eight activity categories based on similarities in attributes and effects (for example, aquaculture and outfalls) for potential inclusion in this HCP. Table 1.10 lists the categories evaluated in the analysis, the definition of each category, and the specific structures/activities included in each category (Washington DNR, 2005b; 2007b).

[22] Authorized uses are those uses specifically granted as a general lease, easement, aquaculture lease, or waterway permit.

Table 1.10. Categorization of authorized uses.

Activity Category	Definition	Included Structures/Activities
Aquaculture	The commercial production or harvest of aquatic plants and animals	Finfish and shellfish culture
Flood, wave, and erosion control	Structures used to control the movement of water and protect human property	Breakwaters; dikes and dams; fill and bank armoring
Miscellaneous nearshore	Dissimilar activities that occur in nearshore/littoral areas with the potential to stress biotic and abiotic factors	Log booming and storage; public access; sediment removal
Mitigation and enhancement	Structures/activities that strive to improve, enhance, stabilize, and monitor aquatic habitats	Artificial habitat; conservation/preservation; remediation of contamination
Outfalls	Structures designed to discharge wastewater into aquatic ecosystems	Combined sewer overflow; desalinization; industrial and municipal; storm water
Overwater structures	Structures built over, or placed in, state-owned aquatic lands at or below ordinary high tide in saltwater ecosystems and ordinary high water in freshwater systems	Multiple element[23]—marinas; shipyards & terminals
		Single element—boat ramps, launches, hoists; docks and wharves; floating homes; rafts; mooring buoys; nearshore buildings
Transportation	Structures that support the movement or transport of motorized vehicles	Bridges; ferries; railroads; highways and roads
Utilities	Linear structures that carry water, electricity, telecommunications, and petroleum products	Oil and gas pipelines; power and cable lines; sewer and waste lines; water pipelines and intakes

[23] Multiple element overwater structures comprise separate and distinct structures that support the use.

1.6.2 Determination of spatial overlap

Washington DNR assessed spatial overlap by determining which of the 35 activity classes were likely to co-occur with each of the 86 species evaluated. The number of activities overlapping with a species' distribution was converted into a rank score of low (1), medium (2), or high (3). Next, the spatial extent of the species' distribution relative to the spatial extent of all authorized uses of state-owned aquatic lands was determined. The calculated percentage of each species' habitat within townships with authorized uses is referred to as *coincident habitat*; the coincident habitat is used as an indicator of the likelihood of interaction between species and activity classes (Washington DNR, 2007c). The results of the analysis were used to refine the list of potential species (see Section 7, Covered Species, within this chapter). Species experts used best professional judgment to arrive at a final recommendation of potential species (Washington DNR, 2007b). Table 1.11 illustrates the ranking criteria and metrics used for the species/life stage and activity overlap, and coincident habitat metrics.

Table 1.11. Ranking criteria for species and activity overlap and coincident habitat metrics.

Species/Life Stage and Activity Overlap		**Coincident Habitat**	
Activity Class Count	Rank	Percent of Townships	Rank
0 – 22	Low (1)	0 – 34	Low (1)
23 – 30	Medium (2)	35 – 66	Medium (2)
31 – 35	High (3)	67–100	High (3)

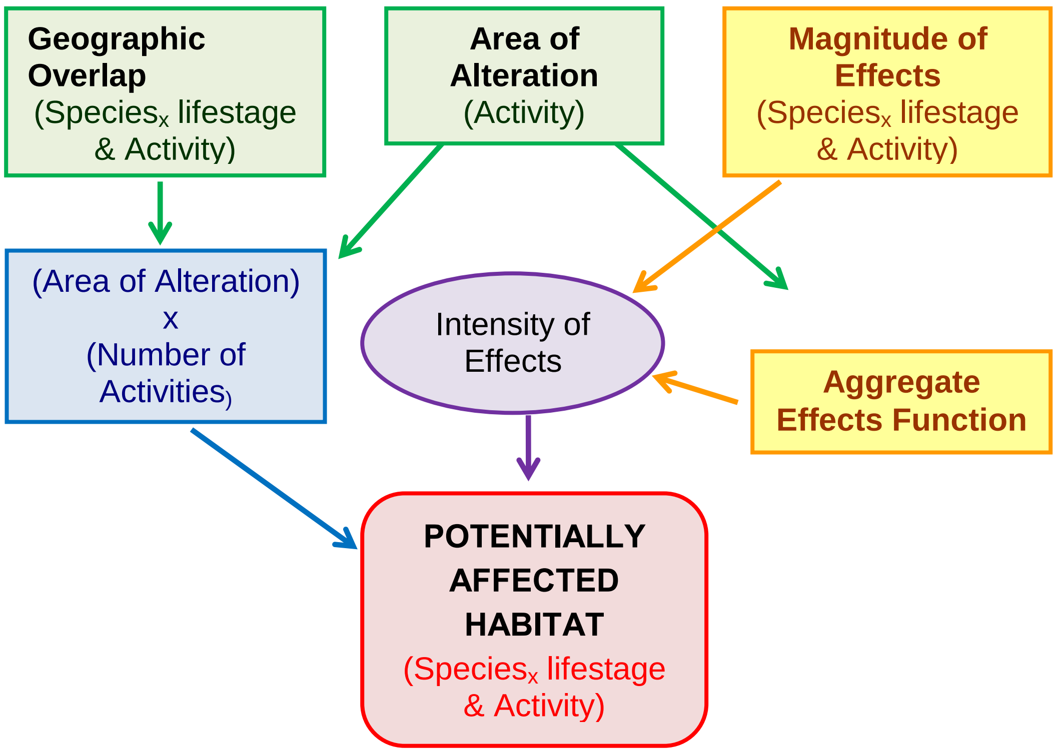
1.6.3 Determination of direct and indirect effects

The determination of direct and indirect effects is based on the impacts associated with currently authorized uses and does not include effects from the construction of new structures, or effects from unauthorized and/or illegal uses of state-owned aquatic lands. The following text provides a brief summary of the process, with a more complete discussion provided in Chapter 4, Section 4.2 (Direct and Indirect Effects of Covered Activities) of this document.

Calculations of direct and indirect effects used a qualitative model that assessed the physical, chemical, and biological impacts associated with existing authorized activities (Washington DNR 2007b). In the first step of the process, species experts determined whether there was a nexus for each activity class between defined risk pathways and individual species life-history stages. Next, rankings for groups of effects (direct—species and habitat; indirect—habitat loss and habitat degradation) were assigned using a scale of no or trace effects (0) to a total loss (1). The ranks were then used to calculate the "Magnitude of Effects" on each species life history stage from each activity.

To quantify the amount of each species habitat affected by an activity class, the total area altered by the activity (Area of Alteration) was estimated using best available science. An "Aggregate Effects Function" was also created and combined with the Magnitude of Effects score to reflect impacts associated with shoreline development (Intensity of Effects). The metrics were then combined to calculate the amount of habitat for each species that is affected by the activity class (Potentially Affected Habitat). Figure 1.18 illustrates the conceptual process for determining effects.

Figure 1.18. Conceptual illustration of the determination of direct and indirect effects.



1.6.4 Ability to affect change

The final step in the process to select covered activities was an evaluation of Washington DNR's ability to affect the factors controlling direct and indirect effects. This step considered the following factors when determining if an activity would be included for coverage in the HCP. Washington DNR was more likely to include an activity under the following circumstances:

- If the effect would not otherwise be addressed as part of a consultation with U.S. Fish and Wildlife Service and NOAA Fisheries required under the Endangered Species Act for "… any action authorized, funded, or carried out by a Federal agency . . ." (16 U.S. Code Section 1536(a)(2)).
- If Washington DNR has a high degree of control over how the activity occurs on the landscape and how the activity affects sensitive species and habitats.

- If the activity has the potential to reach the threshold of incidental take under the Endangered Species Act.

Table 1.12. Decisions made and rationale regarding activities to be covered under the Aquatic HCP.

Activity Group	Activity Class	Washington DNR's Ability to Affect Change	Decision	Rationale for Decision
Aquaculture	Finfish	Low—siting only	Exclude	Regulatory entities control water and sediment quality, species cultured, and siting (Section 7)
	Shellfish (mussels, clams, oysters)	High—siting and operations	Include	High degree of control if this activity occurs on state lands
Flood, wave, and erosion control	Bank armoring	Low to none	Exclude	Generally occurs on private land
	Breakwaters	Low to none	Exclude	Discourage as a standard
	Dikes and dams	Low to none	Exclude	Permitting controlled by federal entities
	Fill	Low to none	Exclude	Disallow new fill as a standard
Miscellaneous nearshore	Log booming and storage	High—Siting, operations, and maintenance	Include	High degree of control
	Public access	Low	Exclude	Conservation measures associated with structures, not humans
	Dredging	Low	Exclude	Requires federal consultation (Section 7)
	Sand and gravel removal; recreational mining	Low	Exclude	Disallow sand and gravel removal programmatically; Little knowledge about the extent of recreational mining

Activity Group	Activity Class	Washington DNR's Ability to Affect Change	Decision	Rationale for Decision
Mitigation and enhancement	Artificial habitat	High—siting	Exclude	Disallow programmatically
	Remediation of contamination	Low	Exclude	; Regulated by established federal and state programs; Requires federal consultation (Section 7)
	Conservation / preservation	High	Exclude	Minimal risk
Outfalls	Combined sewer overflow; storm water; industrial and municipal	Low—siting only	Exclude	Regulatory entities control water and sediment quality; New construction involves federal consultation (Section 7).
	Desalinization	Low—siting only	Exclude	Extent minimal
Overwater structures	Boat ramps, launches, hoists; docks and wharves; floating homes; rafts; marinas; mooring buoys; nearshore buildings; shipyards and terminals	High—siting, operations and maintenance	Include	High degree of control
Transportation	Bridges; ferries; railroads; roads and highways	Low	Exclude	New construction requires federal consultation (Section 7); Washington State Department of Transportation has standards to manage potential impacts.[24]

[24] Non-state ferry terminals and docks are included in overwater structures.

Activity Group	Activity Class	Washington DNR's Ability to Affect Change	Decision	Rationale for Decision
Utilities	Oil and gas pipelines; power and cable lines; sewer and waste lines; water pipelines and intakes	Low	Exclude	Minimal impact from existing facilities; requires federal consultation for new construction (Section 7); no identifiable conservation measures

1.7 Species covered by this HCP

The Aquatic Lands Habitat Conservation Plan addresses 29 species of fish, birds, amphibians, and reptiles (Table 1.13). While Washington DNR is asking for coverage for all 29 species, the agency recognizes that U.S. Fish and Wildlife Service and NOAA Fisheries may not find that impacts to a given species from covered activities meet the definition of take and may deny coverage for that species. Chapter 4, Section 4 of this document provides information about the life history for each of the 29 species.

Table 1.13. Species Covered by the Aquatic Lands HCP.

Species	Listing Status	Natural Heritage Rank[25]
Amphibians and Reptile		
Columbia spotted frog (*Rana luteiventris)*	State candidate	G4, S4
Northern leopard frog (*Rana pipiens)*	Federal concern; state endangered	G5, S1
Oregon spotted frog *Rana pretiosa)*	Federal candidate; state endangered	G2, S1
Western toad (*Anaxyrus boreas)*	Federal concern; state candidate	G4, S3

[25] *Key to Natural Heritage program ranks:*

G = Global
S = State
B = Breeding populations
N = Non-breeding populations

1 = Critically imperiled
2 = Imperiled
3 = Rare locally or with a restricted range
4 = Apparently secure
5 = Demonstrably secure

GNR = not ranked globally
SNR = not state ranked.

Species	Listing Status	Natural Heritage Rank[25]
Western pond turtle (*Actinemys marmorata)*	Federal concern; state endangered	G3G4, S1
Birds		
Black tern (*Chlidonias niger*)	State monitor	G4, S4B
Common loon (*Gavia immer)*	State sensitive	G5, S2B, S4N
Harlequin duck (*Histrionicus histrionicus*)	Not listed	G4, S2B, S3N
Marbled murrelet (*Brachyramphus marmoratus*)	Federal threatened; state threatened	G3G4, S2
Western snowy plover (*Charadrius alexandrinus nivosus*)	Federal threatened; state endangered	G3, S1
Forage Fish		
Eulachon/ Pacific smelt (*Thaleichthys pacificus)*	Federal threatened; state candidate	G5, S4
Pacific herring (*Clupea pallasi)*	Federal concern; state candidate	GNR, SNR
Pacific sand lance (*Ammodytes hexapterus*)	Not listed	None
Surf smelt (*Hypomesus pretiosus*)	Not listed	G5, SNR
Lamprey		
Pacific lamprey (*Entosphenus tridentatus)*	Federal species of concern; State monitor	G4, S1
Rockfish		
Bocaccio (*Sebastes paucispinis*)	Federal endangered; state candidate	G4, SNR
Canary rockfish (*Sebastes pinniger*)	Federal threatened; state candidate	GNR, SNR
Yelloweye rockfish (*Sebastes ruberrimus)*	Federal threatened; state candidate	GNR, SNR

Species	Listing Status	Natural Heritage Rank[25]
Salmonids		
Bull trout (*Salvelinus confluentus*)	Federal threatened (Columbia River; coastal Puget Sound); state candidate	G4, S3
Chinook salmon (*Oncorhynchus tshawytscha*)	Federal endangered (Upper Columbia—spring Chinook); Federal threatened (Lower Columbia River; Puget Sound; Snake River—spring, summer, and fall Chinook); state candidate	G5, S3S4
Chum salmon (*Oncorhynchus keta*)	Federal threatened (Lower Columbia River; Hood Canal); state candidate	G5, S3
Coastal cutthroat trout (*Oncorhynchus clarki clarki*)	Federal species of concern	G4, SNR
Coho salmon (*Oncorhynchus kisutch*)	Federal threatened (Lower Columbia River); federal species of concern (Puget Sound)	G4, S3
Pink salmon (*Oncorhynchus gorbuscha*)	Not listed	G5, S3
Sockeye/Kokanee salmon (*Oncorhynchus nerka)*	Federal endangered (Snake River), Federal threatened (Lake Ozette), state candidate (sockeye); not listed (kokanee)	G5, S2S3
Steelhead trout (*Oncorhynchus mykiss*)	Federal threatened (Snake River Basin, Upper Columbia, Middle Columbia, and Lower Columbia River); Puget Sound); state candidate	G5, S5
Sturgeon		
Green sturgeon (*Acipenser medirostris*)	Federal threatened (Southern Distinct Population Segment)	G3, S2N
White sturgeon (*Acipenser transmontanus*)	Not listed	G4, S3B, S4N
Marine Mammal		
Southern resident killer whale (orca) (*Orcinus orca* pop. 5*)*	Federal and state endangered	G4G5, SNR

A three-step process was used to evaluate which species would be included in the Aquatic Lands HCP (Washington DNR, 2007c).

In Step 1, project scientists developed a general list of 90 species that were endangered, threatened, of concern, or rare, and that potentially occurred on state-owned aquatic lands. The list of species was refined to 86 based on the following factors:

- The probability that the species would occur on state-owned aquatic lands.
- The degree to which the species, in any life stage, is dependent on aquatic habitat.
- The level of vulnerability of the species, in any life stage, to activities authorized by Washington DNR.

In Step 2, Washington DNR gathered additional information on the historic and current distribution of the species (based on predicted and observed data); habitat use; population trends; threats; and potential effects from activities authorized by Washington DNR. These data, combined with the decision matrix (Table 1.14), support DNR's decision to assign species to the following proposed categories:

Covered species—Species for which sufficient biological information exists, and for which existing conservation measures—or conservation measures that could be easily defined and implemented—support an application for Section 10(a)(1)(B) incidental take permit under the Endangered Species Act. This category includes species that lack adequate information for conservation planning if there is a close habitat association to other covered species, and therefore a benefit sufficient to support application for a Section 10(a)(1)(B) permit. This category also includes those species for which listing appears imminent unless conservation measures are instituted that would likely assure their survival and recovery.

Evaluation species—Species that require additional information to provide adequate conservation planning, or those for which conservation measures to support application for a Section 10(a)(1)(B) permit could not be easily defined. Should the listing status of these species change during the term of the Aquatic Lands HCP, or if additional information that supports conservation planning becomes available, Washington DNR will re-evaluate the decision to exclude them from coverage under this HCP and, where warranted, seek amendments to this HCP for inclusion of the species.

Watch list species—Species that are either not considered to be at risk during the term of the incidental take permit, or that lack adequate information regarding habitat, distribution, status, or conservation potential. As with evaluation species, watch list species could be considered for inclusion under the Aquatic Lands HCP if they are deemed to be at risk in the future.

Table 1.14. Decision matrix for preliminary designation of potentially covered species.

Potential to be Affected by Covered Activities	Species Listing Status or Conservation Ranking			
	Currently Federally Listed as Endangered or Threatened	**Federally or State Listed Species of Concern**	**Designated Global or State Conservation Ranking of "Imperiled" (G1 or S1)**	**Not Designated**
High	Covered	Covered	Evaluation	Evaluation
Medium	Evaluation	Evaluation	Evaluation	Watch List
Low	Evaluation	Evaluation	Watch List	Watch List

In Step 3 of this process, species that Washington DNR recommended for the categories of covered or evaluation underwent a screening for spatial and temporal overlap with authorized activities. Potential effects were determined based on review of the available literature, the factors controlling ecosystem function, and quantification of the impacts to species' habitat (Washington DNR, 2007b). In instances where Washington DNR recommended that a species be categorized as an evaluation species and would clearly benefit from an activity-specific or programmatic conservation measure, they have been included as a species of concern.

Appendix B contains a summary of the species considered, their coverage recommendations, and the reasons for their inclusion or exclusion from the Aquatic Lands HCP. Documentation of the methods used in analyzing effects from covered activities on species and habitats, and the results of this analysis, is contained in the Potential Effects and Expected Outcomes Technical Paper (Washington DNR, 2007b).

1.8 Federally listed species not addressed

Although federally listed, it is determined that the species in Table 1.15 have little or no overlap with state-owned aquatic lands or with the activities covered under this plan.

Table 1.15. Federally listed species not addressed by this plan.

		Listing Status		Federal Agency with Jurisdiction	Reason for Exclusion
Common Name	**Scientific Name**	**Federal**	**State**		
Leatherback sea turtle	*Dermochelys coriacea*	Endangered	Endangered	NOAA Fisheries	No covered activities nexus

Blue whale	*Balaenoptera musculus*	Endangered	Endangered	NOAA Fisheries	Presence accidental
Bowhead whale	*Balaena mysticetus*	Endangered	Not Listed	NOAA Fisheries	Presence accidental
Humpback Whale	*Megaptera noveangliae*	Endangered	Endangered	NOAA Fisheries	Presence accidental
North Pacific right whale	*Eubalaena japonica*	Endangered	Not Listed	NOAA Fisheries	Presence accidental
Steller sea lion	*Eumetopias jubatus*	Threatened	Threatened	NOAA Fisheries	Presence accidental
Streaked horned lark	*Eremophila alpestris strigata*	Proposed Threatened	Endangered	U.S. Fish & Wildlife	Section 7 nexus protections

1.9 References

Alberti, M., and M. Bidwell. 2005. Assessing the Impacts of Urbanization on Shellfish Growing Areas in Puget Sound. Urban Ecology Research Lab Final Report. University of Washington. Seattle, WA.

Alvarez, M., and B.L. Peckarsky. 2005. How Do Grazers Affect Periphyton Heterogeneity in Streams? *Oecologia,* 142: 576-587.

Baldwin, J.R., and J.R. Lovvorn. 1994. Habitats and Tidal Accessibility of the Marine Foods of Dabbling Ducks and Brant in Boundary Bay, British Columbia. *Marine Biology,* 120: 627-638.

Bayley, P.B. 1995. Understanding Large River-floodplain Ecosystems. *Bioscience,* 45: 153-158.

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K. Fresh. 2005. Delta and Nearshore Restoration for the Recovery of Wild Skagit River Chinook Salmon: Linking Estuary Restoration to Wild Chinook Populations. Skagit System Cooperative, Research Department. La Connor, WA.

Beechie, T.J., M. Liermann, E.M. Beamer, and R. Henderson. 2005. A Classification of Habitat Types in a Large River and Their Use by Juvenile Salmonids. *Transactions of the American Fisheries Society,* 134: 717-729.

Bell-McKinnon, M. 2002. Water Quality Assessment of Volunteer Monitored Lakes Within Washington State. Washington State Department of Ecology. Publication No. 02-03-019. Olympia, WA. Available at: http://www.ecy.wa.gov/pubs/0203019.pdf.

Benda, L., N.L. Poff, D. Miller, T. Dunne, G. Reeves, G. Pess, and M. Pollock. 2004. The Network Dynamics Hypothesis: How Channel Networks Structure Riverine Habitats. *BioScience,* 54: 413-427.

Birch, P.B., R.S. Barnes, and D.E. Spyridakis. 1980. Recent Sedimentation and its Relationship with Primary Productivity in Four Western Washington Lakes. *Limnology and Oceanography*, 25: 240-247.

Booth, D.B., and C.R. Jackson. 1997. Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detection, and the Limits of Mitigation. *Journal of the American Water Resources Association,* 33: 1077-1090.

Brennan, J.S., and H. Culverwell. 2004. Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems. Washington Sea Grant Program. University of Washington Board of Regents. Seattle, WA.

Burns, R. 1985. The Shape and Form of Puget Sound. Washington Sea Grant. Seattle, WA.

Canning, D. J., and M. Stevens. 1989. Wetlands of Washington: A Resource Characterization. Washington State Department of Ecology. Olympia, WA.

Carlson, R.E. 1977. A Trophic State Index for Lakes. *Limnology and Oceanography,* 22: 361-369.

Collins, B.D., D.R. Montgomery, and A.J. Sheikh. 2003. Reconstructing the Historical Riverine Landscape of the Puget Lowland. In: *Restoration of Puget Sound Rivers.* D. R. Montgomery, S. M. Bolton, D. B. Booth, and L. Wall, (eds.). University of Washington Press, Seattle, WA.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. United States Fish and Wildlife Service. FWS/OBS-79/31.

Dethier, M.N. 1990. A Marine and Estuarine Habitat Classification System for Washington State. Natural Heritage Program, Washington State Department of Natural Resources. Olympia, WA.

Dillon, P.J. 1975. The Phosphorous Budget of Cameron Lake, Ontario: The Importance of Flushing Rate to the Degree of Eutrophy of Lakes. *Limnology and Oceanography*, 20: 28-39.

Dowty, P., B. Reeves, H. Berry, S. Wyllie-Echeverria, T. Mumford, A. Sewell, P. Milos and R. Wright. 2005. Puget Sound Submerged Vegetation Monitoring Project: 2003-2004 Monitoring Report. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

Emmett, R., R. Llanso, J. Newton, R. Thom, M. Hornberger, C. Morgan, C. Levings, A. Copping, and P. Fishman. 2000. Geographic Signatures of North American West Coast Estuaries. *Estuaries*, 23: 765-792.

Findlay, S.E.G., W.C. Nieder, E.A. Blair, and D.T. Fischer. 2006. Multi-scale Controls on Water Quality Effects of Submerged Aquatic Vegetation in the Tidal Freshwater Hudson River. *Ecosystems*, 9: 84-96.

Fonseca, M.S., and J.A. Cahalan. 1992. A Preliminary Evaluation of Wave Attenuation by Four Seagrass. *Estuarine, Coastal and Shelf Science*, 35: 565-576.

Frenkel, R.E., and J.C. Morlan. 1991. Can We Restore Our Salt Marshes? Lessons from the Salmon River, Oregon. *Northwest Environmental Journal*, 7: 119-135.

Gabrielson, P.W., T.B. Widdowson, S.C. Lindstrom, M.W. Hawkes, and R.F. Scagel. 2000. Keys to the Benthic Marine Algae and Seagrasses of British Columbia, Southeast Alaska, Washington, and Oregon. Phycological Contribution #5, University of British Columbia, Department of Botany. Vancouver, B.C.

Gaeckle, J., P. Dowty, H. Berry, and L. Ferrier. 2009. Puget Sound Submerged Vegetation Monitoring Project 2008 Monitoring Report. Nearshore Habitat Program, Aquatic Resources Division, Washington State Department of Natural Resources. Olympia, WA.

Geist, D.R., and D.D. Dauble. 1998. Redd Site Selection and Spawning Habitat Use by Fall Chinook Salmon: The Importance of Geomorphic Features in Large Rivers. *Environmental Management,* 22: 655-669.

Gregory, S.V., and P.B. Bisson. 1997. Degradation and Loss of Anadromous Salmonid Habitat in the Pacific Northwest. In: *Pacific Salmon and their Ecosystems: Status and Future Options.* D.J. Stouder, P.B. Bisson, and R.J. Naiman, (eds.). Chapman and Hall, New York, NY.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An Ecosystem Perspective of Riparian Zones: Focus on Links Between Land and Water. *Bioscience*, 41: 540-551.

Hallock, D. 2006. Washington State Water Quality Conditions in 2005 Based on Data from the Freshwater Monitoring Unit. Washington State Department of Ecology, Environmental Assessment Program. Olympia, WA. Available at: http://www.ecy.wa.gov/pubs/0603030.pdf.

Hallock, D. 2009. River and Stream Water Quality Monitoring Report: Water Year 2008. Washington State Department of Ecology, Environmental Assessment Program. Olympia, WA. Available at: http://www.ecy.wa.gov/biblio/0903041.html.

Hallock, D., and J. Parsons. 2006. Washington State Water Quality Condition in 2005, Based on Data from the Freshwater Monitoring Unit. Technical Appendix. Washington State Department of Ecology, Environmental Assessment Program. Olympia, WA. Available at: http://www.ecy.wa.gov/pubs/0603031.pdf.

Harris, G.P. 1986. *Phytoplankton Ecology, Structure, Function, and Fluctuation.* Chapman and Hall, London, UK.

Hemminga, M.A., and C.M. Duarte. 2000. *Seagrass Ecology*. Cambridge University Press, Cambridge, U.K.

Herdendorf, C.E., L. Hakanson, D.J. Jude, and P.G. Sly. 1992. A Review of the Physical and Chemical Components of the Great Lakes: A Basis for Classification and Inventory of Aquatic Habitats. In: *The Development of an Aquatic Habitat Classification System for Lakes.* W.D.N. Busch, and P.G. Sly, (eds.). CRC Press, Ann Arbor, MI.

Hickey, B.M., and N.S. Banas. 2003. Oceanography of the U.S. Pacific Northwest Coastal Ocean and Estuaries with Application to Coastal Ecology. *Estuaries*, 26: 1010-1031.

Hietala, J., K. Vakkilainen, and T. Kairesalo. 2004. Community Resistance and Change to Nutrient Enrichment and Fish Manipulation in a Vegetated Lake Littoral. *Freshwater Biology*, 49: 1525-1537.

Hilt, S. 2006. Recovery of *Potamegeton pectinatus* L. Stands in a Shallow Eutrophic Lake under Extreme Grazing Pressure. *Hydrobiologia*, 570: 95-99.

Holsman, K.K., D.A. Armstrong, D.A. Beauchamp, and J.L. Ruesink. 2003. The Necessity for Intertidal Foraging by Estuarine Populations of Subadult Dungeness Crab, Cancer magister. Evidence from a Bioenergetics Model. *Estuaries*, 26: 1155-1173.

Horne, A.J., and C.R. Goldman. 1994. *Limnology*, 2nd Edition. McGraw-Hill. New York, NY.

Ivey, S. 2004. Aquatic Land Boundaries in Washington State. Proceedings of a Workshop Presented to Washington DNR staff. May 12, 2004. Washington State Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Johnson, D.M., R.R. Petersen, D.R. Lycan, J.W. Sweet, and M.E. Neuhaus. 1985. *Atlas of Oregon Lakes.* Oregon State University Press. Corvallis, OR.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The Flood Pulse Concept in River-floodplain Systems. In: Proceedings of the International Large River Symposium. D.P. Dodge, (ed.). *Canadian Special Publication of Fisheries and Aquatics,* 106: 110-127.

Kendall, AW., Jr., and A.J. Mearns. 1996. Egg and Larval Development in Relation to Systematics of *Novumbra hubbsi*, the Olympic Mudminnow. *Copeia*, 1996: 684-695.

Knutson, K.L., and V.L. Naef. 1997. Management Recommendations for Washington's Priority Habitats: Riparian. Washington State Department of Fish and Wildlife. Olympia, WA.

Komar, P.D. 1997. *The Pacific Northwest Coast: Living with the Shores of Oregon and Washington.* Duke University Press. Durham and London.

Lanzer, E.L. 1999. Aquatic Land Area Estimation. Public Land Report to the Legislature. Washington State Department of Natural Resources, Aquatic Resources Division. Olympia, WA.

Laskov, C., O. Horn, and M. Hupfer. 2006. Environmental Factors Regulating the Radial Oxygen Loss from Roots of *Myriophyllum spicatum* and *Potamogeton crispus*. *Aquatic Botany,* 84: 333-340.

Leopold, L.B., and T. Maddock, Jr. 1953. The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. United States Department of the Interior Geological Survey Professional Paper 252. United States Government Printing Office, Washington D.C.

Levy, D.A., R.L. Johnson, and J.M. Hume. 1991. Shifts in Fish Vertical Distribution in Response to an Internal Seiche in a Stratified Lake. *Limnology and Oceanography,* 36: 187-192.

Long, E.R., (ed.). 1982. A Synthesis of Biological Data from the Strait of Juan de Fuca and Northern Puget Sound. EPA 600/7-82-004. Office of Engineering and Technology, Office of Research and Development, United States Environmental Protection Agency. Washington D.C.

Long, E.R., M. Dutch, S. Aasen and K. Welch. 2004. Sediment Quality Triad Index in Puget Sound. Washington State Department of Ecology, Publication No. 04-03-008. Olympia, WA.

MacCoy, D.E., and R.W. Black. 1998. Organic Compounds and Trace Elements in Freshwater Streambed Sediment and Fish from the Puget Sound Basin. United States Geological Survey, National Water Quality Assessment Program. Accessed December 21, 2007: http://wa.water.usgs.gov/pubs/fs/fs.105-98/

McIntyre, J.W., and J.F. Barr. 1997. Common Loon. In: *The Birds of North America,* No. 313. A. Poole, and F. Gill, (eds.). The Birds of North America, Inc., Philadelphia, PA.

McMillan, R.O., D.A. Armstrong, and P.A. Dinnel. 1995. Comparison of Intertidal Habitat Use and Growth Rates of Two Northern Puget Sound Cohorts of 0+ Age Dungeness Crab, *Cancer magister. Estuaries,* 18: 390-398.

Mitsch, W.J., and J.G. Gosselink. 1999. *Wetlands,* 2nd Edition. John Wiley & Sons, Inc. New York, NY.

Montgomery, D.R. 1999. Process Domains and the River Continuum. *Journal of the American Water Resources Association,* 35: 397-410.

Montgomery, D.R., and J.M. Buffington. 2001. Channel Processes, Classification, and Response. In: *River Ecology and Management.* R.J. Naiman, and R.E. Bilby, (eds.). Springer.

Moore, J.E., M.A. Colwell, R.L. Mathis, and J.M. Black. 2004. Staging of Pacific Flyway Brant in Relation to Eelgrass Abundance and Site Isolation, with Special Consideration of Humboldt Bay, California. *Biological Conservation,* 115: 475-486.

Munger, J.C., M. Gerber, K. Madrid, M-A. Carroll, W. Petersen, and L. Heberger. 1998 U.S. National Wetland Inventory Classifications as Predictors of the Occurrence of Columbia Spotted Frogs (*Rana luteiventris*) and Pacific Tree Frogs (*Hyla regilla). Conservation Biology,* 12: 320-330.

Murphy, K.C. 2005. Report to the Legislature. Progress of the 2005 *Spartina* Eradication Program. Washington State Department of Agriculture. Agriculture Publication 850-151 (N/1/06). Olympia, WA.

Naiman, R.J., H. Decamps, and M. Pollock. 1993. The Role of Riparian Corridors in Maintaining Regional Biodiversity. *Ecological Applications,* 3: 209-212.

National Ocean Service. 2004. Addressing Elevation and Inundation Issues in Habitat Restoration Planning and Implementation. A Guidance Document. National Oceanic and Atmospheric Administration. Washington D.C.

Newton, J.A., S.L. Albertson, K. Van Voorhis, C. Maloy, and E. Siegel. 2002. Washington State Marine Water Quality, 1998 through 2000. Washington State Department of Ecology, Environmental Assessment Program. Publication No. 02-03-056. Olympia, WA. Available at: http://www.ecy.wa.gov/pubs/0203056.pdf.

Nightingale, B., and C. Simenstad. 2001. Overwater Structures: Marine Issues. Submitted to Washington State Department of Fish and Wildlife, Washington State Department of Ecology, Washington State Department of Transportation. Olympia, WA.

Nowak, G.M., and T.P. Quinn. 2002. Diel and Seasonal Patterns of Horizontal and Vertical Movements of Telemetered Cutthroat Trout in Lake Washington, Washington. *Transactions of the American Fisheries Society*, 131: 452-462.

Partridge, V., K. Welch, S. Aasen, and M. Dutch. 2005. Temporal Monitoring of Puget Sound Sediments: Results of the Puget Sound Ambient Monitoring Program, 1989-2000. Washington State Department of Ecology Environmental Assessment Program Publication No. 05-03-016. Olympia, WA.

Phillips, R.C. 1984. The Ecology of Eelgrass Meadows in the Pacific Northwest: A Community Profile. FWS/OBS-84/24. United States Fish and Wildlife Service.

Poff, N.L., and J.D. Allan. 1995. Functional Organization of Stream Fish Assemblages in Relation to Hydrological Variability. *Ecology,* 76: 606-627.

Puget Sound Action Team. 2007. State of the Sound 2007. Puget Sound Partnership. Olympia, WA. Available at: www.psp.wa.gov/publications/puget_sound/sos/07sos/2007_stateofthesound_fulldoc.pdf

Redman, S., D. Myers, and D. Averill. 2005. Regional Nearshore and Marine Aspects of Salmon Recovery in Puget Sound. Puget Sound Action Team. Submitted for inclusion in the Shared Strategy for Puget Sound Regional Salmon Recovery Plan.

Reeves, G.H., L.E. Benda, K.M. Burnett, P.B. Bisson, and J.R. Sedell. 1995. A Disturbance-based Ecosystem Approach to Maintaining and Restoring Freshwater Habitats of Evolutionarily Significant Units of Anadromous Salmonids in the Pacific Northwest. American Fisheries Society Symposium, 17: 334-349.

Reub, G.S. 1987. The Influence of Groundwater Upwelling in the Selection of Spawning Locations by Chum Salmon (*Oncorhynchus keta*) in the Susitna River, Alaska. Masters Thesis. San Francisco State University. San Francisco, CA.

Rice, C. A. 2006. Effects of Shoreline Modification on a Northern Puget Sound Beach: Microclimate and Embryo Mortality in Surf Smelt (*Hypomesus pretiosus*). *Estuaries and Coasts* 29:63-71.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A Method for Assessing Hydrologic Alteration within Ecosystems. *Conservation Biology,* 10: 1163-1174.

Science Applications International Corporation 2005. US Army Corps of Engineers Sediment Management Annual Review Meeting May 5, 2005 Meeting Minutes.

Shaffer, A. 2004. Preferential Use of Nearshore Kelp Habitats by Juvenile Salmon and Forage Fish. 2003 Georgia Basin/Puget Sound Research Conference Proceedings. February 2004.

Simenstad, C.A., and R.C. Wissmar. 1985. δ13C Evidence of the Origin and Fates of Organic Carbon in Estuarine and Nearshore Food Webs. *Marine Ecology Progress Series,* 22: 141-152.

Smith, K., D. Hallock, and S. O'Neal. 2000. Water Quality Assessment of Selected Lakes Within Washington State. Washington State Department of Ecology. Publication No. 00-03-039. Olympia, WA. Available at: http://www.ecy.wa.gov/pubs/0003039.pdf.

Sobocinski, K. L. 2003. The Impact of Shoreline Armoring on Supratidal Beach Fauna of Central Puget Sound. University of Washington, Seattle, WA.

Stanford, J.A., and J.V. Ward. 1993. An Ecosystem Perspective of Alluvial Rivers: Connectivity and the Hyporheic Corridor. *Journal of the North American Benthological Society,* 12: 48-60.

Strickland, R.M. 1983. *The Fertile Fjord: Plankton in Puget Sound*. Washington Sea Grant. Seattle, WA.

Sumioka, S.S., and N.P. Dion. 1985. Trophic Classification of Washington Lakes Using Reconnaissance Data. Washington State Department of Ecology Water Supply Bulletin, 57. Olympia, WA.

Swanston, D.N. 1991. Natural Processes. In: Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. W.R. Meehan, (ed.). American Fisheries Society Special Publication 19.

Thom, R.M. 1980. Seasonality in Low Intertidal Benthic Marine Algal Communities in Central Puget Sound, Washington USA. *Botanica Marina,* 23: 7-11.

Thom, R.M., and R.G. Albright. 1990. Dynamics of Benthic Vegetation Standing Stock, Irradiance, and Water Properties in Central Puget Sound. *Marine Biology,* 104: 129-141.

Thom, R.M., J.W. Armstrong, C.P. Staude, K.K. Chew, and R.E. Norris. 1976. A Survey of the Attached Marine Flora at Five Beaches in the Seattle Washington Area. *Syesis,* 9: 267-275.

Thom, R.M., C.A. Simenstad, and J.R. Cord. 1989. Fish and their Epibenthic Prey in a Marine and Adjacent Mudflats and Eelgrass Meadow in a Small Estuarine Bay. Fisheries Research Institute, University of Washington School of Fisheries, Seattle, WA.

Thom, R.M., L.D. Antrim, A.B. Borde, W.W. Gardiner, D.K. Shreffler, P.G. Farley, J.G. Norris, S. Wyllie-Echeverria and T.P. McKenzie. 1998. Puget Sound's Eelgrass Meadows: Factors Contributing to Depth Distribution and Spatial Patchiness. Battelle Marine Sciences Laboratory.

Thom, R. M., A. B. Borde, S. Rumrill, D. L. Woodruff, G. D. Williams, J. A. Southard, and S. L. Sargeant. 2003. Factors Influencing Spatial and Annual Variability in Eelgrass (*Zostera marina L.*) Meadows in Willapa Bay, Washington, and Coos Bay, Oregon, Estuaries. *Estuaries* 26:1117-1129.

Thomson, R.E. 1994. Physical Oceanography of the Strait of Georgia-Puget Sound-Strait of Juan de Fuca System. In: Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait: Proceedings of the B.C./Washington Symposium on the Marine Environment, January 13 and 14, 1994. R.C.H. Wilson, R.J. Beamish, F. Aitkens, and J. Bell, (eds.). C*anadian Technical Report of Fisheries and Aquatic Sciences*, 1948.

Tonnes, D. M. 2008. Ecological Functions of Marine Riparian Areas and Driftwood Along North Puget Sound Shorelines. University of Washington, Seattle, WA.

Torgersen, C.E., R.N. Faux, B.A. McIntosh, N.J. Poage, and D.J. Norton. 2001. Airborne Thermal Remote Sensing for Water Temperature Assessment in Rivers and Streams. *Remote Sensing of Environment*, 76: 386-398.

Townsend, C.R. 1996. Concepts in River Ecology: Pattern and Process in the Catchment Hierarchy. *Archive of Hydrobiology Supplement*, 113: 3-21.

United States Geological Survey. 2005. Glacial Lake Missoula and the Missoula Floods. Accessed March 15, 2005. http://vulcan.wr.usgs.gov/Glossary/Glaciers/IceSheets/description_lake_missoula.html

Valiela, I. 1984. *Marine Ecological Processes*. Springer-Verlag. New York, NY.

Van den Berg, M.S., M. Scheffer, and H. Coops. 1998. The Role of Characean Algae in the Management of Eutrophic Shallow Lakes. *Journal of Phycology*, 34: 750-756.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences*, 37: 130-137.

Washington Department of Fish and Wildlife. 1997a. Aquatic Plants and Fish. Publication # APF-11-97. Washington State Department of Fish and Wildlife. Olympia, WA.

Washington State Department of Agriculture. 2005. Statewide Spartina Integrated Weed Management Plan. Washington State Department of Agriculture. Olympia, WA.

Washington State Department of Ecology. 2007. PBDE and Dioxins/Furans in Spokane Stormwater: A supplemental report. February 2009. Publication No. 09-03-010. Washington State Department of Ecology, Environmental Asseessment Program, Olympia, WA. Available at: http://www.ecy.wa.gov/pubs/0903010.pdf

Washington State Department of Ecology. May 2012. Marine Water Condition Index Washington State Department of Ecology. Publication No. 12-03-013. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA. Available at: www.ecy.wa.gov/biblio/1203013.html

Washington State Department of Natural Resources. 2002. ShoreZone Inventory Database. Accessed April 20, 2002. http://www2.wadnr.gov/nearshore/research/index.asp?sp=y&id=9

Washington State Department of Natural Resources. 2005a. Aquatic Resources Program Endangered Species Act Compliance Project, Covered Habitat Technical Paper. Washington State Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Washington State Department of Natural Resources. 2005b. Aquatic Resources Program Endangered Species Act Compliance Project, Potential Covered Activities Technical Paper. Washington State Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Washington State Department of Natural Resources. 2007a. State of Washington Natural Heritage Plan. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2007b. Aquatic Resources Program Endangered Species Act Compliance Potential Effects and Expected Outcomes Technical Paper. Washington State Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Washington State Department of Natural Resources. 2007c. Aquatic Resources Program Endangered Species Act Compliance Project Covered Species White Paper. Washington State Department of Natural Resources, Aquatic Resources Program. Olympia, WA.

Washington State Noxious Weed Control Board 2012. Noxious Weed List: http://www.nwcb.wa.gov/siteFiles/2013%20State%20Weed%20List%20Common%20Name.pdf Washington State Noxious Weed Control Board, Olympia, WA.Washington State Office of Financial Management. 20011. 20011 Population Trends. Washington State Office of Financial Management. Olympia, WA.

Webb, D.G. 1991. Effect of Predation by Juvenile Pacific Salmon on Marine Harpacticoid Copepods. I. Comparisons of Patterns of Copepod Mortality with Patterns of Salmon Consumption. *Marine Ecology Progress Series,* 72: 25-36.

Welch, E. B., J.M. Jacoby, and C.W. May. 1998. Stream Quality. In: River Ecology and Management. R.J. Naiman, and R.E. Bilby, (eds.). Springer Verlag. New York, NY.

Wetzel, R.G. 2001. Limnology – Lake and River Ecosystems. Academic Press. London, UK.

Williams, G.D., and R.M. Thom. 2001. Marine and Estuarine Shoreline Modification Issues. Submitted to Washington State Department of Fish and Wildlife, Washington State Department of Ecology, and Washington State Department of Transportation. Olympia, WA.

Williams, G.D., R.M. Thom, J.E. Sratkes, J.S. Brennan, J.P. Houghton, D. Woodruff, P.L. Striplin, M. Miller, M. Pedersen, A. Skillman, R. Kropp, A. Borde, C. Freeland, K. McArthur, V. Fagerness, S. Blanton, and I. Blackmore. 2001. Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 & 9). J.S. Brennan, (ed.). Report Prepared for King County Department of Natural Resources. Seattle, WA.

Wilson, U.W., and J.B. Atkinson. 1995. Black Brant Winter and Spring-staging Use at Two Washington Coastal Areas in Relation to Eelgrass Abundance. *The Condor,* 97 :91-98.

Wissmar, R.J., J.E. Smith, B.A. McIntosh, H.W. Li, G.H. Reeves, and J.R. Sedell. 1994. A History of Resource Use and Disturbance in Riverine Basins of Eastern Oregon and Washington (Early 1800s-1990s). *Northwest Science,* 68: 1-35.