Appendix A
Methods for identifying, mapping and analyzing landscape classes

Estuaries, bays, beaches and marine waters are the four broad landscape classes described in this chapter. Further refinement of some of these classes reflects the current wisdom of how various geomorphological and oceanographic processes act on the various salmon life histories. "Pocket estuaries" for example are a subset of the estuary class that seems to have relevance to certain life history stages of salmon. We understand beaches to be largely controlled by sediment transport processes that operate as littoral drift cells. Bays and marine waters were not specifically mapped comprehensively but they serve either as the matrix within which these smaller components reside or in the case of some bays, have unique oceanographic conditions that may affect salmon.

Estuaries

River mouth estuaries were delineated based on the occurrence of the 22 independent populations of Chinook salmon spread across the Puget Sound landscape. The 22 populations emanate from drainages emptying into certain river mouth estuaries, or the 11 main natal deltas we specifically highlight. Thus, 11 natal estuaries are identified on Puget Sound region maps throughout the chapter.

Methods

Delineating the physical boundaries of the 11 natal deltas was the first step in the mapping procedure. The physical boundaries are:

1. Seaward edge
2. Shoreward edge
3. Alongshore end point 1
4. Alongshore end point 2

The Department of Natural Resources' Shorezone data set provided the platform for which to identify and delineate these boundaries. The seaward boundary was delineated by using the –20 meter MLLW line in the nearshore (also the outer seaward definition of the nearshore region), as this region of depth is associated with the limit of the photic zone. The landward boundary was approximated as the landward region of tidal influence. Finally, the alongshore boundaries (upper and lower) were delineated by selecting a Shorezone data point at two locations, each signifying the approximate terminus of the natal delta in each direction (PSAT staff applied best professional judgment for the alongshore boundary locations). At this point it was possible to calculate the area within the newly formed polygon, plot the area on a map, and generate a variety of statistical information. See Figure 2-3 for an example of the 11 natal deltas (dark-colored regions at river mouths).

Bay

Bays are generally semi-enclosed portions of the larger marine waters matrix that are influenced by the land and/or freshwater and sediment sources flowing into them. Most maps contain

numerous named bays, which may or may not have a specific influence on salmon. In many cases, bays are transitional between the delta or pocket estuary where critical salmon functions occur and the larger migratory corridor through Puget Sound and to the Pacific Ocean. Where bays have lowered salinities or shallow depth, they may be extensions of the refuge and physiological transition functions provided by deltas and pocket estuaries.

Methods

Since bays were not specifically mapped for this project, certain bays that have unique characteristics affecting salmon are mentioned by name in the sub-basin analyses. The boundaries of a bay are not well established as a mapping convention and there are few common features of all bays.

Beaches

Puget Sound beaches are described by geologists as receiving their primary sediment source from eroding bluffs and only secondarily from inland sediment sources like rivers or streams. Nonetheless, with 10,000 or so streams and rivers intersecting the marine shoreline, the influence of those sediments and flows in shaping Puget Sound beaches cannot be underestimated.

Methods

Washington Department of Ecology produced several useful data layers and web based products to aid in the identification of and description of Puget Sound beaches. The Digital Coastal Atlas allows viewing of littoral drift cells, oblique aerial photos, armoring approximations by Shorezone and other features in an interactive map. Special GIS products with drift cells, armoring and digital elevation features were compared with aerial oblique photo images to produce sub-basin maps that describe large sections of Puget Sound's beaches.

Marine Waters

As mentioned above, the marine waters of Puget Sound are the larger matrix within which these other landscape classes and components are arranged. There are widely variable oceanographic parameters within each sub-basin of Puget Sound that depend on their distance from the Pacific Ocean, the interactions of those waters with geologic features, human influences and the salmon populations themselves

Methods

Characteristics of marine waters are described within the context of each sub-basin and calculated as an aerial extent subtracting the other "nearshore" features. In this way, the relative area of nearshore Vs. offshore waters can be used to further describe the nature of each sub-basin and the amount of influence the Pacific Ocean or the land and waters of the Puget Sound basin may have on them.

Appendix B
Methods for identifying and evaluating pocket estuaries

Purpose

In this appendix we describe the type of habitat we are seeking to identify, the rationale, the methods and procedures for identifying these habitats, and the methods and procedures for rating or evaluating the function of these habitat types across the 11 sub-basins.

Background

"Pocket estuaries" are one of a number of important habitats for juvenile salmon in Puget Sound's nearshore environment. These features of the landscape generally punctuate otherwise linear shoreline features such as the protected or exposed shorelines, and beaches and bays, that dominate most of Puget Sound. Pocket estuaries are the result of mid to small-scale (as compared to large river deltas) interactions between marine and freshwater influence at low elevations along the shoreline. These processes create and sustain a physical structure that appears similar to large river deltas in that pocket estuaries usually contain emergent marsh, sand or mudflats, a channel structure, uplands and open water in close proximity. These features may or may not contain freshwater input.

We chose to focus on identifying, mapping and evaluating pocket estuaries because the diversity of habitat types within pocket estuaries supports a variety of fish and wildlife species including several life history stages of juvenile salmon. The channels and protected open waters provide refuge from storms and extreme events. The mixing of saltwater and freshwater in some pocket estuaries can support osmoregulation for juvenile salmon. The proximity of uplands with riparian vegetation, mudflats and sand flats supporting rich diatom growth and emergent marshes shedding detritus fuels a diverse prey base for juvenile salmon. Migratory corridor functions for juvenile salmon may be the only function not directly supported by individual pocket estuaries. However, across the landscape, the proximity of one pocket estuary to another can be measured using landscape connectivity and fragmentation metrics. The support of pocket estuaries for the migratory corridor function can only be known after the locations of pocket estuaries are mapped on the nearshore landscape.

Methods and procedures for locating and identifying pocket estuaries

In each of the 11 marine sub-basins several sources of physical landscape representations were used to locate potential pocket estuaries, confirm their existence and rate their current (observed) function (discussed below). The primary tools used to identify pocket estuaries were 1) the Department of Ecology's Digital Coastal Atlas (http://www.ecy.wa.gov/programs/sea/SMA/atlas_home.html) and 2) the DeLorme Washington Atlas and Gazetteer (1995).

General reference and named locations for each pocket estuary was obtained from a DeLorme Washington Atlas and Gazetteer. The Digital Coastal Atlas was used to identify potential targets for pocket estuaries and was the most helpful tool utilized during this exercise. This atlas allows a user to highlight and magnify any section of a Puget Sound shoreline, overlay a number of

physical and biological characteristics on the magnified area, and click on a photo point to reveal a shoreline photo.

Hillshade background imagery based on a digital elevation model (DEM) was selected to scan for depressions, canyons or flat spots in the topography adjacent to the shoreline. Small bodies of water and streams intersecting or approaching the shoreline were found by selecting the 1:100,000-hydrography layer also available on the Digital Coastal Atlas. The final feature selected was the 2000-2002 oblique aerial photo layer. Selecting this layer illuminated photo points along the shoreline from which potential pocket estuary targets could be visually verified. All three layers were displayed simultaneously at an appropriate scale to scan the shoreline, identify potential pocket estuaries and verify them.

Once a pocket estuary was identified, an appropriate photo point was chosen to visually represent the feature. This photo point was recorded along with the pocket estuary identifier on the spreadsheet (discussed below) so that others can repeat the methodology, see the variability in types and sizes of pocket estuaries, and re-evaluate the attributes leading to the eventual scoring of each feature for its salmon support function. In the spreadsheet, each pocket estuary was given a two-character identifier and consecutive numbers. For example the 5th pocket estuary located in Whidbey Basin would be called WH5. In most cases, pocket estuaries were also given a name corresponding to the named map location closest to them. Latitude and longitude positions were recorded from the photo point if it was accurately centered onto the feature or from the floating cursor when centered onto a larger pocket estuary covered by several photo points.

Note: We were only capable of identifying and recording those pocket estuaries visible from Digital Coastal Atlas aerial photos. We were unable to determine the presence of any historic pocket estuaries from a photo on a computer monitor, nor was that our intention. It is expected that the locations of historic pocket estuaries cannot be located using this method because modifications to the shoreline were too severe. Potential targets identified using stream intersections often have no pocket estuary associated with them. This could be due to the slope or amount of coarse sediment in the stream preventing effective mixing of freshwater and marine processes necessary to create the pocket estuary structure.

An Excel spreadsheet was constructed to house information obtained from evaluating each pocket estuary. The **spreadsheet fields** include:

1. Existing pocket estuaries in Puget Sound (basin, pocket estuary number and name);
2. Location for mapping point data onto a WA State Plane South NAD27 projection for each pocket estuary (latitude and longitude);
3. Photo point corresponding to Ecology's 2000-2002 oblique aerial photo series;
4. Check boxes for inferred (likely) salmon functions (feeding and growth, osmoregulation, refuge) based on assumptions 1 through 4 below; check boxes for numerous stressors (shoreline development, urbanization, diking and filling, susceptibility to spills and discharges, competition from hatchery releases, aquaculture related substrate alterations, and vulnerability to sea level rise) as listed in assumptions 5 through 11; and a composite function score for each pocket estuary (properly functioning, at risk, or not properly functioning).

Assumptions

We made numerous assumptions when inferring if pocket estuaries provided a) functions for juvenile salmon, and b) presence/absence and effects of stressors. The **assumptions** include:

1. If a pocket estuary has an evident source of fresh water, we will assume it supports osmoregulation and food production,
2. If a pocket estuary has an evident channel structure or is protected by a spit or bar, we will assume it supports refuge,
3. If a pocket estuary has mudflats, intertidal marsh or eelgrass, we will assume it supports food production and refuge,
4. If a pocket estuary lacks any or all of these habitat features due to modification, we will assume the associated functions are impaired,
5. If armoring, clearing or grading and encroachment of manmade structures along the shoreline is evident, we will designate Shoreline Development is a stressor,
6. If significant urban infrastructure is evident surrounding the pocket estuary, we will assume urbanization is a stressor,
7. If diking and filling are evident, we will assume diking and filling is a stressor,
8. If marinas, industrial facilities or wastewater treatment plants are evident, we will assume spills and discharges is a stressor,
9. If pocket estuaries are adjacent to rivers with large hatchery releases, we will assume hatchery interactions are a stressor,
10. If substrate alteration as a result of aquaculture operations is evident, we will assume aquaculture is a stressor, and
11. If intertidal habitats within a pocket estuary are confined from migrating landward by manmade infrastructure, we will assume sea level rise is a stressor.

Methods and procedures for rating and evaluating pocket estuaries

A composite "score," or designation, of *properly functioning*, *at risk*, and *not properly functioning* were given for each pocket estuary, and was based on best professional judgment while viewing an aerial photo. These scores correspond to the inferred Chinook functions, and the number and types of stressors identified for each pocket estuary. For example, a designation of *properly functioning* was given if a pocket estuary possessed all three inferred (likely) Chinook functions, plus one or no visible stressors. A designation of *at risk* was given if three or fewer Chinook functions were evident, plus two or more visible stressors. A designation of *not properly functioning* was given if three or fewer Chinook functions were evident, plus several visible stressors. Often, this last category was attributed to pocket estuaries with no inferred Chinook functions and substantial physical stressors such as shoreline development, urbanization and diking and filling.

The oblique aerial photos also revealed a number of other landscape attributes like shoreline development, adjacent upland urbanization, presence of marinas, roads or industrial facilities that are potential sources of spills and discharges. These are the some of the stressors that are listed in number 4 under the **spreadsheet field** section and further contexted in assumptions 5 through 11. If any of these were observed while reviewing an aerial photo of the pocket estuary and surrounding landscape, then an X was placed in the appropriate field under the appropriate column header.

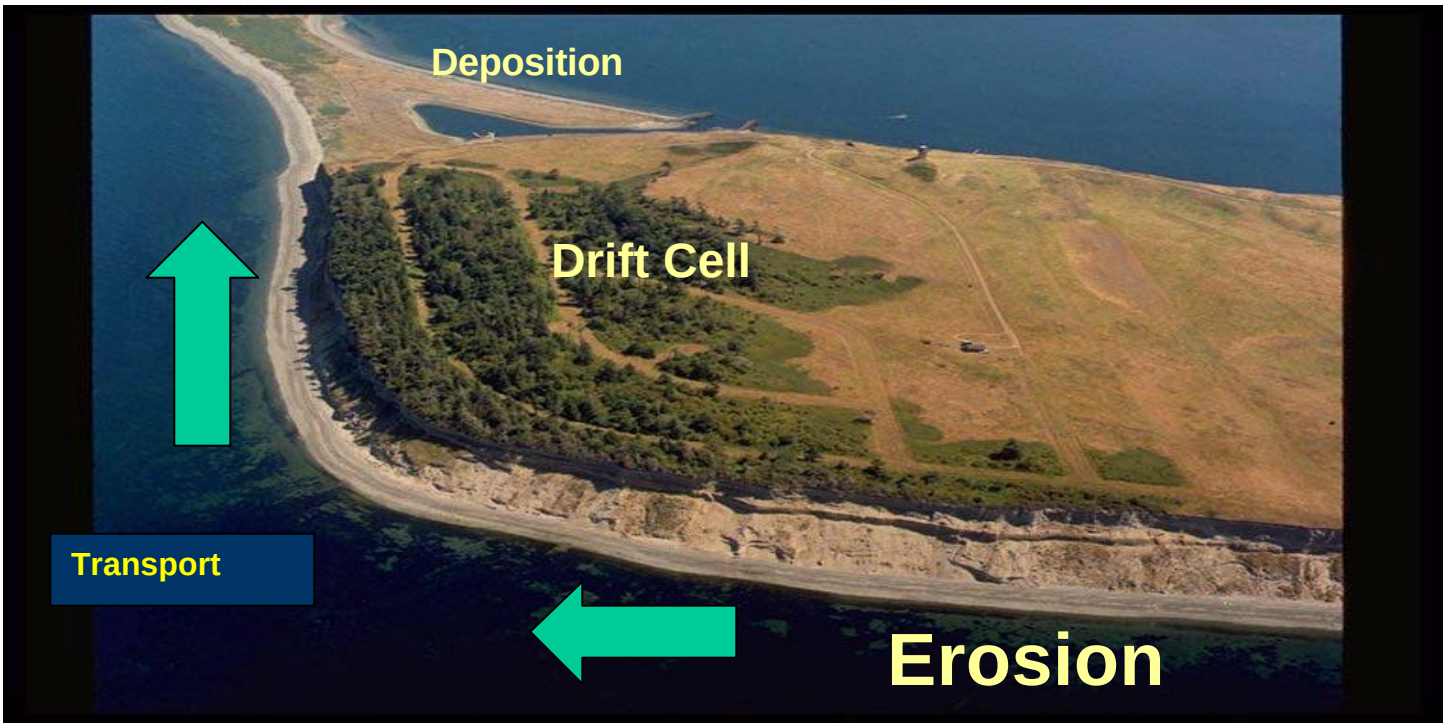
Using this method consistently throughout Puget Sound will likely produce similar results. However, users should be familiar with the variability of Puget Sound's shorelines, have some local knowledge of certain features they see on oblique aerial photos and understand the interactions between water, sediment and the underlying geologic landscape in bringing about features such as pocket estuaries. Functions for salmon, however, may be more subjective, especially since the functions are inferred from opportunities observed from the air and not empirical data on salmon feeding, refuge or osmoregulation.

Appendix C
Methods and mapping procedures for drift cell analysis

Background and assumptions:

Following the salmon conceptual model, smaller life history types of juvenile salmon need shallow, low-gradient shorelines for rearing. These types of shorelines occur within embayments (pocket estuaries) and deltas. Larger life history types need a variety of landscapes including the above plus more open shorelines with stronger wave action. Bull trout have been documented to have a primary association with sand and gravel spits, a depositional feature near the mouths of many pocket estuaries. The complex structure of nearshore environments is an interplay of several important processes.

At the larger scale, it is useful to understand the fundamental processes of sediment delivery and transport. While most people are familiar with the fact that sediments are transported downstream in rivers to form deltas at their mouths, longshore sediment transport is less fully understood. The fundamental unit of longshore sediment transport is known as a "drift cell" where waves and currents cause localized erosion, carry sediments for some distance down the beach in a predictable net direction and deposit them when the wave energy is insufficient to keep the particles suspended. (reference Terich) The picture below describes a "typical" drift cell with erosional, transport and depositional sections.



According to the draft nearshore typology being developed by Hugh Shipman for Puget Sound Nearshore Ecosystem Restoration Project (PSNERP), Puget Sound beaches operating within the sub-basin scale being used in this chapter fall into two basic types: bluff-backed beaches and barrier beaches. Bluff-backed beaches are defined by Shipman to be generally erosional in nature and barrier beaches are generally depositional in nature. Smaller scale beaches are defined elsewhere in Shipman's typology but those are better suited for finer scale analysis.

See **figure 1** for an example of a "typical" bluff-backed erosional beach. The physical appearance of a bluff-backed beach from an aerial photo does not necessarily indicate whether or not it is an erosional feature. Sometimes recent landslides and lack of vegetation indicate active erosion. Rather, its location in the drift cell is more informative. **Figure 2** shows a bluff-backed beach with a low, erosional scarp not typical of a bluff as most people know it.

Likewise, depositional beaches may be in the form of low sand and gravel spits (**Figure 3**) or wide sandy beaches situated in front of a tall bluff that has been stabilized (**Figure 4**). Again, the presence of the bluff is less determinant of type than the location within the drift cell.

This drift cell analysis proceeds from the assumption that, at the grossest scale, drift cells contain both erosional and depositional features. These two types of beaches are logically linked into interconnected units by the littoral drift cell because the material that deposits on barrier beaches is assumed to derive from sediment eroding within the same drift cell. Near large estuarine deltas and pocket estuaries with significant freshwater influence, additional deltaic sediments may be incorporated into the littoral drift system and deposited at the mouths of embayments. This method of mapping is not intended to draw strict boundaries between these two processes but instead to consider where both deltaic and longshore processes might be working in concert to produce a shoreline landform.

Areas of shoreline with rocky substrate are assumed to not be subject to the action of littoral drift cells because longshore drift processes have little affect on beach substrate and structure along rocky shorelines. Secondary stressors like adjacent land use on rocky shorelines may affect salmon but were not evaluated in this analysis.

Methodology and description of map symbols:

Mapped drift cells for Puget Sound (cite Ecology data layer) were linked on GIS with DNR Shorezone coverage of relative shoreline armoring. The two layers were then displayed on a Digital Elevation Model base map of Puget Sound. Drift cells of less than one mile in length were masked so that analysis could occur at the largest scale of drift cell function within the sound.

Drift cells with large amounts of armoring (Shorezone red lines) were considered for their degree of function and ability to be restored. For example, in cases where large amounts of armoring are present, secondary land uses were evaluated by viewing Ecology's digital coastal atlas and oblique aerial photo sets for corresponding geography. In some cases, the armoring was the only stressor and removal of the armoring should be expected to restore many of the historic functions of the shoreline. Some shorelines with large amounts of armoring occur in deltaic shorelines like

the Skagit, and therefore are expected to impair intertidal functions while others are part of the littoral drift system and presumed to impair longshore sediment transport patterns. Differences in impairment for various shoreline segments are discussed in the sub-basin assessments.

In other cases, the high level of armoring is treated as a surrogate for other shoreline stressors like stormwater and sewage discharge, industrial legacy, and proximity to continued urban growth. These shorelines are considered barriers to migration and have no boxes associated with them on the map. Additional landscape metrics such as continuity of natural or disturbed shoreline may need to be employed to ascertain whether barriers to migration represent a stressor to salmon. Drift cells corresponding with small (Shorezone green lines) or moderate (Shorezone yellow lines) amounts of armoring were also explored using Ecology's digital coastal atlas and oblique aerial photo sets.

Boxes were drawn to include the entire drift cell or multiple drift cells with net shore drift moving in the same direction. Boxes were also drawn around areas of drift cell divergence to accommodate the erosional and depositional areas of both drift cells. The general color scheme is green for protection, yellow for restoration, rust for upland sediment sources and black for special circumstances such as consideration of beach nourishment.

Green boxes indicate areas of little armoring or other adjacent land use that would be detrimental to shoreline function. Shorelines located within green boxes should therefore be considered for conservation opportunities within shoreline master programs, critical areas ordinances, and stewardship programs.

Yellow boxes denote shorelines with significant current function but depositional features at risk if further armoring and associated land development occurs. These areas are recommended for finer scale analysis. It may be possible to protect important depositional features by restoring erosional and transport processes at a smaller scale.

Rust colored boxes were drawn from the shoreline to several miles inland along the coastal drainage to indicate that upland sediment sources should be protected in addition to longshore sediment transport processes in order to sustain the depositional features within the nearshore. It is evident from viewing oblique aerial photos that the depositional features near the mouths of large river deltas and pocket estuaries with significant freshwater influence contain elements of both deltaic and longshore processes.

Finally, I employed local knowledge of situations in certain large drift cells that result in **"black box"** or special case mapping. For example, the Elwha drift cell from the mouth of the Elwha River to the end of Ediz Hook in Port Angeles is expected to become the beneficiary of new sediment delivery after the Elwha dams are removed. However, the current state of armoring and local proposals to increase that armoring may soon change the structure of this drift cell to the point that it is not capable of receiving the new sediment. In this case, beach nourishment should be considered as an alternative to armoring.

Maps of each sub-basin are contained in **Appendix E** with descriptions accompanying each of the color-coded and numbered drift cell boxes.

Figure 1

Figure 2

Figure 3

Figure 4

Appendix D
Stressor and management tables

Table 1: Activity-stressor relationships: stressors potentially caused by activities, including human actions and natural mechanisms

TABLE 1

ACTIVITIES: (can cause)	HUMAN ACTIONS: Shoreline development and uses								Spills and Discharges									Watershed activities				Biological resource harvest and culture								Marine		NATURAL MECHANISMS									
	Existing shoreline structures--docks, piers, bridges	Existing shoreline structures--bulkheads	Existing shoreline structures--dikes, fills, impoundments	Existing shoreline structures--jetties	Existing shoreline structures--dredged channels	Existing shoreline structures--marina/moorings	Construction or repair of shoreline and in-water structures	Site clearing of marine riparian vegetation	Operation of shoreline & on-water facil (pub. and/or priv.)	Wastewater discharges to marine waters (WWTP, industry)	Wastewater discharges to fresh surface waters	Stormwater discharges to marine waters	Stormwater discharges to fresh waters	Spill/disch. of toxins/oil from vessels & shoreline facilities	Spill/disch. of toxins/oil from upland sites/ flat beach water	Sewage, graywater, & bilge discharges from boats (including cruise ships)	Ballast water discharge	"Failing" on-site sewage treatment	Runoff from agricultural practices	Forest practices	Altering water flow by channeling, dams	Changes in freshwater flows via water removals & diversions	Commercial finfish harvest	Shellfish culture involving working the sediments	Floating aquaculture involving feeding (finfish)	Fish planting and hatchery releases	Introduction of diseases from aquaculture/planting activities	Introduction of new "exotic" species (aquaculture, etc)	Efforts to control invasive plants (e.g., spartina)	Management activities altering marine mammal populations	Channel dredging & disposal, contamin. sed. dredging/capping	Anthropogenic causes of climate change	Tsunamis and volcanism	Storms	Circulation, tidal mixing and turbulence	Natural blooms	Natural hypoxia	Natural landings (within system)	Natural toxicity changes	Natural variation in rainfall	Natural variation in runoff timing	Natural climate variation and ENSO
STRESSORS[1]:																																									
Add toxics	✓		✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓						✓					✓					
Add nutrients						✓			✓	✓	✓	✓	✓			✓		✓	✓	✓				✓	✓											✓		✓			
Alter sediment loadings (increase/decrease)		✓	✓							✓	✓	✓	✓			✓		✓	✓	✓	✓	✓			✓											✓					✓
Alter freshwater input			✓						✓	✓	✓	✓	✓								✓	✓											✓					✓	✓	✓	✓
Reduce organic matter input	✓	✓	✓	✓				✓													✓	✓																✓	✓	✓	✓
Alter runoff timing, increase strength of peak flows			✓										✓						✓	✓	✓	✓											✓					✓	✓	✓	✓
Shading (e.g., subtidal vegetation)	✓	✓	✓	✓		✓	✓		✓																✓										✓						
Create physical disturbance via intrusion							✓	✓	✓											✓			✓	✓	✓				✓	✓	✓				✓						
A change in depth or shoreline slope	✓	✓	✓	✓	✓	✓	✓														✓	✓		✓							✓				✓						✓
Alter sediment type, incl. via water transp.	✓	✓	✓	✓	✓	✓	✓																	✓	✓						✓		✓								✓
Produce noise	✓					✓	✓		✓															✓	✓					✓	✓										
Physically disturb the sediments							✓																✓	✓							✓				✓						
Reduce endemic benthic habitat area	✓	✓	✓	✓	✓	✓	✓																	✓	✓			✓			✓	✓									✓
Sea level change																																✓	✓								
Alter seawater and intertidal temperature regime		✓						✓		✓		✓									✓	✓										✓			✓						✓
Impede water circulation (altered wave energy)	✓	✓	✓	✓																											✓										
Introduction of exotic marine species																	✓								✓			✓													
After local marine species composition (including prey, competition and predation)	✓	✓	✓											✓	✓		✓		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓						✓	✓	✓			
A change in marine organism abundance (including prey, competition and predation)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓

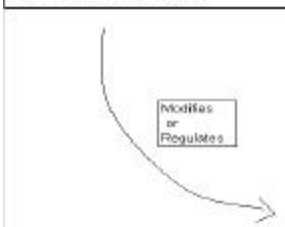
[1]Stressors arranged by: Contamination (1 = Toxics, 2 = Nutrients/Pathogens); Physical Environment Alterations (3 =Input Changes, 4 =Ambient Changes), Biota (5 =Status and Trends).

Adapted from Newton *et al.* (2000). A Conceptual Model for Environmental Monitoring of a Marine System. Puget Sound Ambient Monitoring Program.

Table 2: Activity-management relationships: management approaches to modify or regulate human actions

TABLE 2

MANAGEMENT:	Existing shoreline structures–docks, piers, bulkhe	Existing shoreline structures–bulkheads	Existing shoreline structures–dikes, dikes, impoundments	Existing shoreline structures–jetties	Existing shoreline structures–dredged channels	Existing shoreline structures–marinas/boatlifts	Construction or repair of shoreline and in-water structures	Site clearing or marine riparian vegetation	Operation of shoreline or in-water feed, fish, oil, timber	Wastewater discharges to marine waters (WWTP, industry)	Wastewater discharges to fresh surface waters	Stormwater discharges to marine waters	Stormwater discharges to fresh waters	Spills/slick of materials from vessels & shoreline facilities	Spills/slick of materials from upland sites that reach water	Sewage, graywater, & bilge discharges from boats (including cruise ships)	Ballast water discharge	"Fishing" vessels sewage treatment	Runoff from agricultural practices	Forest practices	Altering water flow by channeling, dams	Changes in freshwater flows via water withdrawal & diversions	Commercial fish harvest	Shellfish culture involving working the sediments	Floating operations involving feeding (finfish)	Fish planting and hatchery releases	Introduction of diseases from aquaculture/planting activities	Introduction of new "exotic" species (aquaculture, etc)	Efforts to control invasive plants (i.e., spartina)	Management activities affecting marine mammal populations	Channel dredging & disposal, contents and dredging/mining	Anthropogenic causes of climate change
Education and outreach	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Corps permit	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓								✓	✓			✓						✓	
DOT transportation construction standards	✓	✓	✓	✓	✓		✓	✓				✓	✓								✓										✓	✓
farm plans								✓					✓		✓				✓													
HPA (Hydraulic Project Approval)	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓							?	✓			✓	✓						✓	
implementation of SMA (Shoreline Mgmt. Act)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓			✓	✓						✓	
local implementation of CMA (Growth Mgmt Act)							✓	✓	✓			✓	✓					✓						✓	✓						✓	✓
Port districts	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓					✓											
shellfish aquaculture voluntary code of practice		?	✓				✓	✓	✓	✓		✓		✓	✓	✓		?						✓			✓	✓			
state and local on-site sewer sys. regs							✓		✓									✓														
state and local stormwater rules	?					✓	✓					✓	✓	✓	✓				✓													
water quality certification	✓		✓	✓	✓	✓	✓															✓			✓						✓	
zoning, building codes	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓		✓										✓	
boater rules and sites						✓			✓					✓		✓												✓				
dredged material management (see FSDMA)			✓				✓																								✓	
navigation rules	✓				✓	✓	✓		✓					✓		✓								✓	✓						✓	
MPDES (Natl. Polut. Disch. Elimin. Sys.)									✓	✓	✓	✓	✓	✓	✓				✓		✓				✓							
spill prevention, preparedness, & response	✓					✓	✓		✓	✓	✓			✓	✓	✓																
state wastewater permit						✓				✓	✓	✓	✓	✓	✓			✓	✓		✓				✓							
park rules								?	✓					✓		✓																
proprietary requirements on state land	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	
reserves								?		✓	✓	✓	✓	✓	✓	✓		✓					✓	✓	✓						✓	
incentives and acquisition to protect functions							✓	✓	✓										✓	✓		✓										
aquaculture disease control regs																											✓	✓				
Endangered Species Act																																
forest practice rules								✓					✓		?					✓												
harvest limits/closures/areas/changes																							✓									
introduction permits																											✓	✓				
Marine Mammal Protection Act									✓																					✓		
state threatened/endang. spp. regs																																
water rights																						✓										
ACTIVITIES:	Shoreline development and uses									Spills/discharges									Watershed activities				Biological resource harvest and culture								Marine	
	HUMAN ACTIONS																															



Appendix F

Historical policies and social, behavioral and cultural factors that have contributed to habitat and ecosystem change

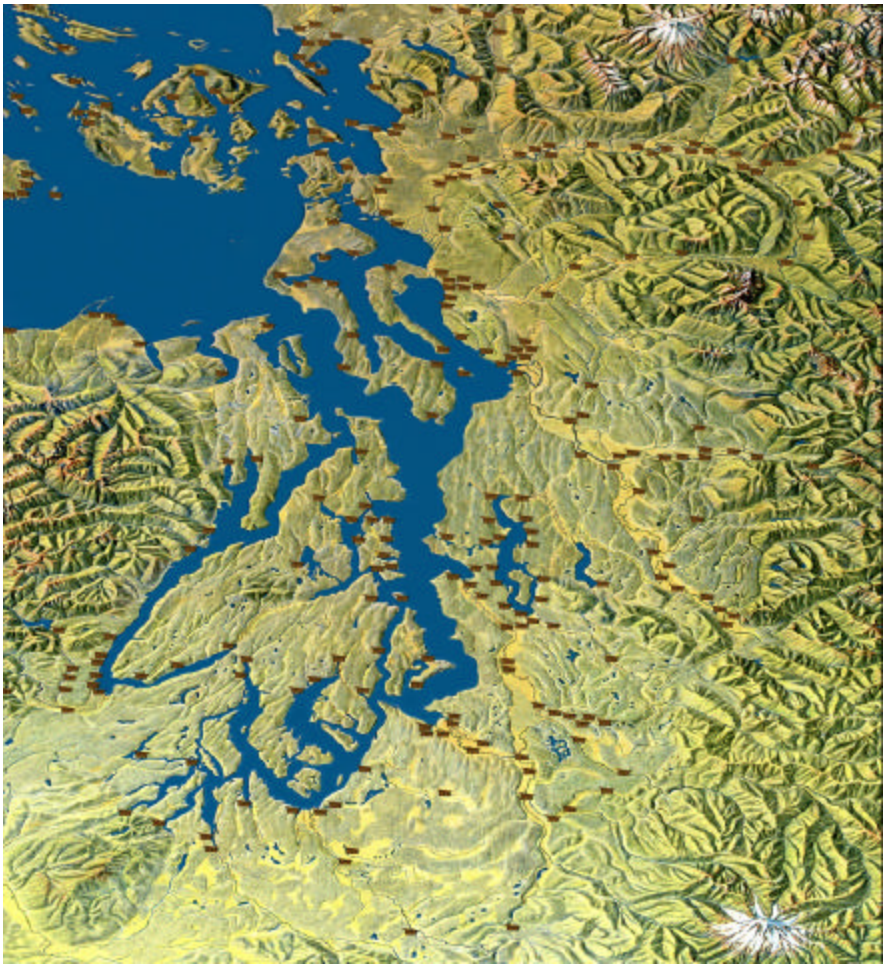
For approximately 10,000 years prior to European settlement of Puget Sound, Coast Salish-speaking native cultures built villages along Puget Sound's shorelines and within its larger estuaries (See map below). Early censuses of Native American communities are inexact, but conservative estimates state that tens of thousands of people lived in the Puget Sound country in ancient times. Even in the mid-1800s, following devastating waves of smallpox, tuberculosis, and other introduced diseases, every river drainage was home to hundreds if not thousands of indigenous people, and every favorable stretch of saltwater coast held a village of one or more extended families (Watson, 1999). Chief Seattle lived in a home, which stretched more than 600 feet along the shore of Agate Passage, across Puget Sound from the city that bears his name. The resources and shorelines of the sound were considered to be a commons shared by all, however, raids between villages occurred from time to time.

In these coastal villages, extended family groups of 30-40 individuals would harvest and prepare fish and shellfish for consumption, collect large woody debris to build longhouses for shelter and ceremony, construct canoes and discard everyday waste. This level of activity likely put little strain on nearshore natural processes but it is conceivable that localized resource depletion may have resulted in tribal bands moving from one area to another with more abundant seasonal resources.

English explorers entered Puget Sound in 1792 (Harmon, 2004) largely looking to exploit the abundant fur resources of the region. In spring 1833, the Hudson's Bay Company (HBC) established a stockade and trading post on the Nisqually Delta, which becomes the first permanent European settlement on Puget Sound (Crowley, 1999). Gradually, Fort Nisqually grew from a remote outpost to a major international trading establishment. A subsidiary, the Puget Sound's Agricultural Company, was formed to establish new sources of revenue for the HBC. Soon Fort Nisqually was producing crops and livestock for local consumption and export to Russian America, Hawaii, Spanish California, Europe and Asia (Fort Nisqually Historical Site, 1999). The long domination of the Northwest by the fur companies decimated the region's wildlife, especially its populations of otter and beaver (Oregon City Link, 2004). Beavers co-evolved with salmon, so flooding cycles, run timing and stream structure that would have affected the nearshore environment would have changed as a result of the decimation of beaver populations. It is also likely that the Puget Sound Agricultural Company served as a model for settlers who moved into other river deltas, drained and filled the wetlands for agriculture and established new waterfront market centers for distribution. During this time, settlers also considered resources to be held in common within a region largely considered wilderness. Trade was a matter of necessity. Some saw the abundance of those resources as an unfulfilled commercial opportunity.

The United States assumed sovereignty north of the Columbia River in 1846 greatly increasing immigration through land grants ceded by Indian tribes being consolidated into reservations and treaties for establishing hunting and fishing rights (Harmon, 2004). A fundamental difference in

the views of land ownership between native tribes and European settlers led to great hostility. Obviously, the European settlers views won out in the end changing the face of Puget Sound from that time forward. Industrial logging of Puget Sound lowland valleys commenced in the 1870's aided by consolidation of homestead claims into large industrial forestland holdings. William Renton notes in 1883 that the "timber contiguous to the Sound is nearly exhausted" (WA State Historical Society, 2000).



(Source: "Puget Sound Region, Washington" copyright by Dee Molenaar, 1987, with permission and digitally revised by Tom Dailey, 2002)
Known permanent village sites of the Coast Salish peoples, circa 1800.

Throughout this time period, transportation infrastructure increased dramatically as well. All commerce and transportation in the mid 1800's was by water or horse. Steamboats plied Puget Sound waters carrying logs from newly cleared areas, most of which were close to rivers or the sound. By 1883, the Pacific Northwest coast was connected to the eastern states by railroad. Portland became a conduit for agricultural produce from inland and quickly became one of the world's largest wheat-shipment ports (Oregon City Link, 2004). The rail line along most of Puget Sound's eastern shoreline was completed early in the 20th century. Ferries were increasingly important for moving people around the sound. The Tacoma Narrows bridge (1950) and the Hood Canal Bridge (1961) became important links to the Olympic Peninsula. Not only were

there significant direct structural damages and disruption of natural processes from the construction and continued existence of this infrastructure, but upland development patterns followed. Finally, the modern state highway and Interstate 5 reduce travel times around Puget Sound from days to hours.

Robust fishing and logging industries established shorefront processing facilities and mills that further degraded nearshore habitats throughout the 20th century. Immigrant farmers from lowland European countries brought their knowledge of wetland "reclamation" and drained huge swaths of intertidal marsh for agriculture before 1940. This "engineering approach" was not confined to agriculture. The city of Seattle desperately needed more flat land and so they sluiced an entire hill (the Denny Regrade) into Puget Sound (Crowley, 1999). The advent of world wars meant Puget Sound's strategic importance was realized giving rise to a boom in military installations. The military also heavily invested in an airplane company, Boeing, who introduced Seattle and the Puget Sound area to the world at the 1962 World's Fair. The region also received massive government grants for infrastructure projects in the 20th century, including a series of dams on the Columbia River, which provided cheap electricity and fueled additional industrial growth in Puget Sound. Together these incentives swelled immigration to the area and increased the demand for residential land. Improved standard of living spurred waterfront development and newly formed cities enjoyed the high land values and tax revenues waterfront property brings. Local governments responded by platting many small lots along the waterfront and the real estate industry marketed Puget Sound views for premium prices. Some of the same European views about land ownership that resulted in removing native cultures from the region, also dictated the aesthetic of lawns, protection from erosion and restriction of public access along Puget Sound's shoreline. As people moved into Puget Sound from even more environmentally damaged areas, they began to realize the values of beauty and natural function that persist in the region.

Negative feedbacks from rapid development and resource extraction prompted environmental legislation in the early 1970's corresponding to a similar awakening nationwide. Human actions have led to protection of nearshore areas through regulation. Our more recent commitment to restoration of nearshore processes signals additional changes to the social, cultural and economic values that are currently held by many Puget Sound residents.

Appendix G
Climate variability detail

Much of the variability of the coastal waters and biota of British Columbia since 1970 can be related to changes in prevailing winds in winter. The years of 1970 to 2002 experienced significant, persistent, decadal regimes separated by surprisingly strong regime shifts. The strongest shifts appear to have been in 1976/77 and 1998/99, with another, perhaps weaker shift in 1989. Many of the oceanic and biological changes during one regime remained in place well into the following one. For example the cool subsurface waters formed at 120 meters depth during the 1999 to 2002 cool regime remained in place until early 2004. Some changes occurred with no apparent lag. An example of this are coho salmon indicators in the Strait of Georgia, which have oscillated in phase with temperature regimes. All wild and hatchery indicators [of coho] in the Georgia Basin have followed the same trend: minimum survivals in about 1998 after a relatively steady decadal decline followed by a slight improvement until 2001 and a decrease since. In general, warmer regimes are associated with stronger winds from the south along the coast, lower surface nutrient levels, stronger coastal flow to the north, increasing numbers and percentage of southern species of plankton, and of fish such as sardines and hake, and lower marine survival for Pacific salmon at the southern limit of their range. Cooler winds reverse these trends. (Pacific Region 2003 State of the Ocean, Department of Fisheries and Oceans Canada, 2004).

Many oceanic features and biological species responded in 2003 to these past changes in winter winds and surface ocean temperatures in the Canadian waters. Specific examples of responding features and species are listed below. The descriptions below are taken verbatim from the DFO report itself, referenced in the Section 8.

"Coastal water levels were well above normal in the warm 1990s, lower than normal in 1999 to 2002, and a bit higher again in 2003.

The **North Pacific Current** flowed more toward the north in late 2002 and early 2003, coinciding with the weak El Niño. It normally flows eastward along 40°N toward North America. By early 2003, perhaps when El Niño-like winds abated in the Gulf of Alaska, it returned to a more normal course.

Coastal temperatures sampled at light stations were above normal during the 2002-2003 winter along the west coast of Vancouver Island, and normal during the rest of 2003. Strait of Georgia and northern BC temperatures were warmer in 2003 than during the previous 4 cool years.

Ocean surface waters of the Canadian Exclusive Economic Zone (200-mile limit) were also warmer in 2003 than in previous three to four years. However, subsurface waters from 100 to 200 metres depth carried cooler temperatures from the 1999 to 2002 cold regime because the ocean surface heating requires more than one year to penetrate below 100 metres.

Alongshore current in 2003 on the Vancouver Island continental shelf saw a return to near 1990-96 average northward flow since a gradual but dramatic shift to a more equator-ward component that began in 2000. Both shifts are likely due to winter wind patterns noted above.

Phytoplankton growth in spring of 2003 along the southwest coast of Vancouver Island was lower than observed by satellite in the preceding four cool years, and closer to the low growth observed in the spring of 1998, the previous warm year.

Deep-sea zooplankton biomass during spring (May-June) was lower in 2003 than in the previous two colder years by about a factor of 2, based on preliminary analysis of a few samples. (When surface waters are cool, nutrient levels are often higher.) For June to August 2003 it appears that subtropical species extended further north *and* boreal species were still doing well throughout the region.

West Coast Vancouver Island zooplankton showed effects of the 2002/2003 El Niño. Southern species increased in biomass, following an increase in northern species during the 1999-2002 years of cool coastal waters. For most species, the strongest anomalies were in spring and early summer of 2003, and had returned to near-zero by early autumn.

Barkley Sound euphausiid (*T. spinifera*) larvae and adults biomasses in 2003 were the lowest in the time series; adult biomass was at least 10 times lower than in most other years and 100 times less than in 2000.

Pacific hake were also found farther north in 2003, due perhaps to warmer waters in the continental shelf than 1999 to 2002, and perhaps to the continued, normal, northward spread of an individual year-class of hake. Hake biomass increased in 2003 due to the growth of individuals in the 1999 year-class that dominates the population along the West Coast.

California tonguefish (*Symphurus atricauda*) were observed in May 2003 in Barkley Sound, the most northerly occurrence ever reported for this species. This is consistent with warmer waters and weak El Niño in 2002-2003.

West Coast Vancouver Island eulachon index increased during the 1999-2002 cool years, but declined slightly in warmer 2003.

Herring year classes of the cool years of 2000 and 2001 are large on the west coast of Vancouver Island, and should result in improved recruitment to the stock in the year 2003 and 2004. The warmer waters of 2003 might impact herring stocks by bringing in more predatory hake.

Sardines were scarce in the 2003 trawl survey off Vancouver Island except in the south and some concentrations at the mouth of the inlets. Their numbers had increased during warm years of the late 1990s, but decreased during the 1999-2002 cool period. The 2003 warming was likely too short duration and too recent to abate this decline.

Juvenile Coho growth conditions off south-western British Columbia were lower in 2002 to 2003 than in 2001 to 2002, but similar to conditions seen during the three preceding cool years. Generally, coho juveniles in this region are healthier in colder years, and their poorer conditions following the warmer 2002-2003 winter support this hypothesis.

Pink salmon returned in record high numbers to the Fraser River in 2001 and estimated high numbers in 2003. (They entered the ocean in 2000 and 2002.)

Sockeye salmon returns to the Fraser River were slightly above average in 2002 and near average in 2003. Survival was slightly below average in both years.

Pacific herring had the largest biomass in 2003 in the Strait of Georgia since 1955. These three adult stocks likely responded well to the cool regime that began in 1999. The warm winter of 2002-2003 was too recent to impact present adult stocks.

Cassin's auklets fledgling production in 2003 was higher in 2003 than during the warm years in the 1990s on Triangle Island off northern Vancouver Island, but lower than during the cool years of 1999- 2002. This production likely varies as the supply of prey, mainly **Pacific sandlance**, which itself varies in biomass with changes in local temperatures, nutrients and plankton biomass."

Other Aspects of Climate change

Working Hypothesis

Regional expressions of global climate change may affect juvenile Chinook and chum salmon as a result of sea level rise, warmer water temperatures and changes in precipitation.

Effects on Ecosystem Processes and Habitat Characteristics

Researchers affiliated with Pacific Northwest Coastal Ecosystem Regional Study (PNCERS) suggests that a likely possible trend in climate change is for the Pacific Decadal Oscillation to have more El Nino-dominated years and fewer La Nina-dominated years as global sea surface temperatures rise. One such affect of these changes on Puget Sound's nearshore is relative sea level rise. Many nearshore habitats are arranged on the landscape according to their elevation relative to mean sea level. The amount of inundation, dessication, wave scour, substrate type and light penetration and other abiotic factors often determine the distribution patterns of plants from high intertidal fresh and saltmarsh grasses and shrubs to subtidal marine macroalgae. It is likely that some of the loss of certain plant species from an area or shifting of the location of certain species is as a result of relative sea level rise attributed to global climate change and land subsidence. The localized effects of this shift are variable. South Puget Sound, because it is subsiding will likely experience more severe relative sea level rise throughout the next 100 years than other areas.

If relative sea level rise occurs slowly and there are no barriers to plant migration on the upland edge of the continuum, nearshore habitats will likely be able to keep pace. However, sea level rise is accelerating compared to last century and the armoring of the upland portions of many of Puget Sound's shorelines may prevent this migration. The Intergovernmental Panel on Climate Change estimates that overall sea level rise will be at a rate of 2.0 to 8.6 mm/yr over the next century as compared to 1.0 to 2.5 mm observed over the previous decade (UW Climate Impacts Group). The future effects of other climate change parameters such as rainfall and wind field changes on nearshore habitats and salmon are not well understood at this time.

River Deltas

Because deltaic wetlands and lowlands were created by the deposition of river sediments, these lands are generally within a few meters of sea level and hence vulnerable to inundation, erosion, and flooding. Under natural conditions the sediment washing down the river could enable at least a significant fraction of the typical delta to keep pace with sea level rise. Human activities in many deltas, however, have disabled the natural ability of deltas to create land. Over the last 150 years, people have erected dikes and river levees to prevent flooding from storm and river surges. As a result, the annual floods no longer overflow the riverbanks, and as sea level rises, it has left the adjacent land below sea water level, necessitating more coastal defense to prevent the land from being inundated (Titus 1990).

Tidal marshes

The standard method for evaluating whether sea level rise is threatening tidal marshes is through comparison of the accretion rate of marshes with the relative rise rate of the sea. Using Cs137 as a marker, Thom *et al*. (2001) found that most marshes are presently keeping pace with sea level rise in the Pacific Northwest. Perhaps the most vulnerable marshes are those in central and lower Puget Sound where relative sea level rise exceeds the global rate. The marshes depend on a steady supply of sediments and nutrients to support accretion. If these were cut off through shoreline armoring and watershed development, the marshes in southern Puget Sound would predictably succumb to rising sea level (Thom *et al*. 2001). Many marshes in the Puget Sound region have been diked, drained, and converted to farmland during the last century. Sea level rise could gradually inundate the remaining tidal flats. Over half of these could be lost under a 1-3 foot rise in sea level (EPA 1997).

Eelgrass

There is little doubt that all of the estuarine and marine plants respond in a similar manner physiologically to temperature. Submerged plants such as eelgrass and kelp (*Nereocystis luetkeana*), may be the most susceptible to warmer conditions. Our experiments with eelgrass (*Zostera marina*) indicate that Pacific Northwest estuarine system processes are vulnerable to temperature variations (Thom *et al.* 2001).

Under a warmer climate, water temperatures may be higher on average, which may cause greater warming in summer and further stress on the plants. Eelgrass ranges into warmer regions south of the Pacific Northwest. However, the genetics and phenology of these warm water populations probably differs substantially from those in the Northwest. We do not expect elimination of eelgrass from the Pacific Northwest with a warming climate unless the warming occurs so rapidly as to not allow for northward expansion of these southern populations or adaptation of local populations (Thom *et al.* 2001).

Water quality

Newton *et al* (2003) demonstrate that changes in river inflows to Puget Sound affect the circulation of water into and out of the region. When river flows into Puget Sound are reduced, the density structure of the water column is reduced, as is the exchange of waters with the Pacific Ocean (Newton *et al.* 2003).

Puget Sound streams with headwaters at high elevations, especially in the Cascades and Olympics, are affected by winter snow and spring snowmelt, but lower elevation streams are dominated by winter rainfall. The seasonal pattern of flow in most streams would be highly susceptible to warmer temperatures. Runoff peaks would occur earlier in the year. The reduced summer and fall flows that would accompany a warmer climate almost certainly would result in degraded water quality. In addition, increased snowmelt could increase winter flooding for some streams (EPA 1997). The effect of these runoff changes will also affect salinity in the shallow water corridors used by juvenile salmon for migration.

Effects on Salmon

Climate is an important process control. While salmon are highly adaptable to changing conditions, the end result of some climate-related large-scale disturbances may alter the nearshore ecosystem in ways that will not recover (K. Fresh, NOAA-Fisheries, personal communication). For example, sea level rise coupled with upland infrastructure prevents the landward migration of salt marshes (Titus 1990).

Beamish (1995) found significant correlations between climate changes and fish populations for many fish species, including salmonids, Pacific herring, Pacific cod, walleye pollock, and species of zooplankton upon which many fish depend for food. As models of these variations improve to the point of becoming predictive, hatchery and harvest managers may need to make adjustments to their management plans. The regime shifts are also often accompanied by changes in the geographic distribution of marine species.

Because of the strength of ocean conditions on salmon viability throughout its life cycle, it is difficult to predict the ultimate response salmon will have to improvements or degradation of habitat features.

Appendix H
Glossary of Technical Terms

Nearshore
The river mouth estuaries, shoreline reaches and their adjacent upland areas (e.g., to the top of the bluff) and shallow waters (e.g., to the depth of light penetration sufficient for plant or macroalgae growth).

Marine
Deeper waters of Puget Sound and the North Pacific Ocean

Working Hypotheses
A collection of component hypotheses – a set of key assumptions that are based on assessment of data and analysis

Conceptual model
An arrangement of assumptions and hypotheses that allow organization of how systems work and how relationships are formed between processes and outcomes

Life History Strategy
The behavioral attribute of randomly selecting a number of different pathways to utilize habitats across the landscape throughout life

Life History Trajectory
The likely progression from one location to another along the landscape for any particular pathway

Life History Stage
An arbitrary classification relevant to the age or size of a salmon

Life History Diversity
The number of life history stages occupying the landscape at any given time.

Drift Cell
A distinct unit of shoreline responding to localized sediment transport processes. A drift cell generally has erosional, transport and depositional sectors.

Ramp
A shoreline modification structure used to launch boats across the intertidal zone

Overwater structure
Category of shoreline modification generally including piers, docks, wharves, dolphins, etc

Restoration
Taking actions consistent with a conceptual model to restore structure, processes or functions of the landscape

Regional
Puget Sound-wide including all 11 sub-basins

Local
Watershed or sub-basin wide

Ecosystem processes
The delivery and routing of water, sediment, wood, heat, nutrients and toxicants that along with the biological inhabitants, creates and sustains aquatic ecosystem structure and function at any particular time.

Typology
A classification of geomorphic features on the landscape expressed as manifestations of ecosystem processes

Functions
Physical, chemical and biological conditions necessary for sustaining the lives of species using the ecosystem.

Structural Features
The arrangement of water, sediment, wood, heat, nutrients and toxicants and biological organisms delivered by ecosystem processes to a particular location.

Habitat Attributes
Specific structural features relevant for any particular species

Estuary
A semi-enclosed body of water where saltwater and freshwater mix

Pocket estuaries
Small scale estuaries located at the mouths of streams and small rivers and other semi-enclosed embayments within Puget Sound that have a tidal channel structure, intertidal marsh and/or mudflats, eelgrass beds and other features typical of larger estuaries.

Delta
The feature associated with the mouths of large rivers into Puget Sound. Deltas normally have multiple river distributary channels, blind tidal channels, marshes and mudflats that cover large areas of the landscape. For this chapter deltas are defined as associated with rivers that have natal populations of Chinook salmon.

Shoreline
The linear feature generally associated with the mean higher high water mark and adjacent features such as beaches, backshores and bluffs

Quantitative
Having some measurable component such as miles of shoreline, acres of mudflats or numbers of fish.

Qualitative
Having a relationship with a conceptual model or hypothesis that is predictive in direction but not magnitude or can be explained in narrative form

Stressors
Anthropogenic activity that interrupts ecosystem processes

Primary Productivity
Production by plants that result in organic compounds that supply energy for the food web

Secondary Productivity
Growth of consumers of organic compounds produced by primary