R E S O U R C E S

A N A T U R A L

Aquatic Resources Program Endangered Species Act Compliance Project

Habitat Classification Verification and Activities Effects Report

November 2005

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

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Habitat Classification Verification and Activities Effects Report

Task 1: Habitat Classification Verification.

This task was designed to verify the accuracy of the habitat classification system used in the Washington State Department of Natural Resources (Washington DNR) ESA Compliance Project. This verification was designed to help determine how accurately the geospatial mapping component of the study mapped the distribution of the habitat types. The task compared the actual habitat types with the mapped habitat types.

The goal of this task was to verify the habitat classification for 50 saltwater and freshwater sites throughout the state and to provide trophic state information for 10 lake sites for which no trophic data were listed in the Washington DNR database. A "site" consisted of a distinguishable unit in the landscape that was large enough to be visible on maps produced for the project (e.g., drift cell, delta, stream reach). Two types of data were used to achieve the goal of the habitat classification and verification. The first data type consisted of information about the habitat types that was available from governmental agencies, published documents, and studies conducted by Battelle. All of these studies were documented and, where possible, copies of them were obtained for the project records. The second information source consisted of direct observations of habitats by scientists familiar with the definitions and characteristics of the defined Washington DNR habitat types (Washington DNR 2005). The data from both sources were be entered into a tabular format and are presented as an appendix to this report.

The habitats at 24 saltwater sites (9 offshore, 10 nearshore, 5 estuarine wetlands) and 25 riverine/freshwater wetland sites (15 west side, 10 east side) were verified and the trophic status of 10 unclassified lake sites were determined (Tables 1, 2 and 3). The habitat at one offshore saltwater site, T21R02E (Tacoma Narrows), could not be verified. Sites were selected by considering the number of Washington DNR activities in the area (preference given to higher numbers of activities), the proximity to ongoing studies, the potential for use of existing data sets, and to allow reasonable geographic coverage. Sites selected for verification were defined in terms of the township/range identifiers associated with a summary of Washington DNR leases statewide. The percentage of accuracy based on this limited sample size allowed the accuracy of the whole habitat data set to be evaluated, although the evaluation is approximate because the samples were not chosen randomly.

There was good correspondence between the mapped and actual saltwater habitats. Of the 25 sites evaluated, only 1 was incorrectly classified during the habitat mapping exercise (Tables 1 and 2). These results are summarized by habitat in the text box. Within township/range T30R03W, Port Williams/Sequim Bay, habitat previously listed

as consolidated was found to be predominantly unconsolidated, but did include a few places of consolidated habitat consisting of glacial erratics (Woodruff 2005).

Trophic status information was found for all five lakes included in the survey; Green Lake, West Medical Lake (Spokane County), Lake Union, Lake Washington and Lake Sammamish (Table 3). The first two lakes were found to be eutrophic, whereas the latter three lakes were mesotrophic. It was noted that the eutrophic condition at West Medical Lake was probably a naturally occurring condition. Recently, a eutrophication model was developed for Lake Washington (Arhonditsis and Brett 2005a, b). The model was developed to simulate plankton community dynamics in the lake, but also was designed to be used to evaluate the effects of various management options on the lake's condition. Of the 25 riverine/freshwater wetland sites evaluated, only 2 were incorrectly classified during the habitat mapping exercise (Tables 1 and 3). Within township/range T13R37E (Snake/Palouse Rivers confluence) and township/range T24R04E (Duwamish River) the correct habitat was low-gradient valley, rather than pool-riffle (Table 3). It was also noted that the Snake River substrate here was not identifiable. The misclassification in the habitat database may be at least partly related to the non-discrete boundaries between the habitat classifications. The primary classification metric is channel slope, which is a continuous gradient from steeply sloping cascades (slope >8 percent) to low-gradient valleys (slope <0.1 percent). Thus there is not a clearly marked boundary between adjacent categories.

Table 1 – Comparison of database habitat classifications versus those observed during the verification activities.

Database Classification *(number of sites)* *	**Field Observations (*number of sites*)**		
	Consolidated *(3)*	Unconsolidated *(16)*	Estuarine Wetland *(5)*
Saltwater Sites			
Consolidated *(4)*	3	1	
Unconsolidated *(15)*		15	
Estuarine Wetland *(5)*			5
Freshwater Sites	Pool-riffle *(10)*	Low-gradient valley *(9)*	Freshwater Wetland *(7)*
Pool-riffle *(12)*	10	2	
Low-gradient valley *(7)*		7	
Freshwater Wetland *(7)*			7

* Note: Shaded cells indicate areas of agreement with the original database classification.

Although there was very close concordance between the classifications and the actual field data, the confidence in the classifications could be further increased by having a more detailed field data set on habitat types state-wide. The classifications were necessarily coarse, which improved the probability of concordance. Resolution of other co-dominant or subdominant habitat types would have helped define and evaluate effects further. As done in the report, if a habitat classified as present in a unit area and it was seen or recorded from field observations, the classification was verified as accurate. However, only a small proportion of a unit may have this habitat type. Thus evaluating effects in this unit could be affected by the bias for a subdominant habitat type.

Task 2: Activities Effects Development

Purpose and Objective

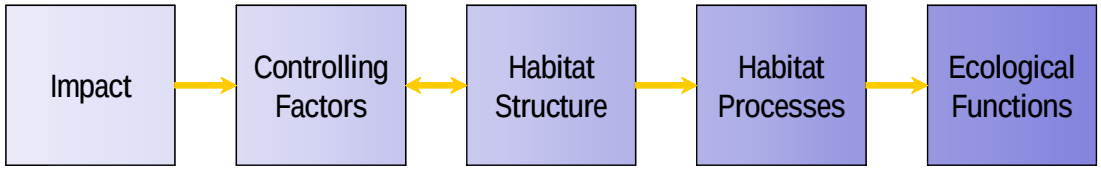
The general objective of this task, complemented with field verification, is to provide supplementary information to help assess impacts from Washington DNR authorized activities. Verification of all Washington DNR activities is beyond the scope of this effort. Here the focus is on a single activity group, overwater structures, for which there are considerable data on impacts (Nightingale and Simenstad 2001; Williams et al. 2001; Haas et al. 2002; Toft et al. 2003; Woodruff et al. 2002; Borde et al. 2002; Southard et al. 2005). The analysis of overwater structures is meant to exemplify the sum of the most evident impacts to the ecosystem. One of the key points from this analysis is that the impacts of a dock generally extend beyond the area shaded. It is likely that if all covered activities were examined in detail, multiple (and cumulative) impacts would be evident.

The currency of impact used in this assessment is the area of bottom (benthic) habitat affected. Dock structures typically are located in shallow water where intertidal and shallow subtidal habitats important to many fish and wildlife species also occur. In Puget Sound and coastal estuaries, the affects of docks on eelgrass habitat have received the most attention. For this analysis, information was derived from published literature, easily available reports and new data collected in 2005 by Battelle. The general approach follows what is termed a "Biologically Directed Approach" as described by Foran and Ferenc (1999), where stressors are linked to a response of a valued ecosystem component.

Components of Effects

There are two spatial components of this impact assessment: the site-specific impacts within the *footprint* of the activity or structure, and the *zone of influence* beyond the footprint. There are temporal components also, but it is assumed for the purposes of this analysis that over the long term temporal impacts are integrated into spatial impacts on habitats. Another simplifying assumption is that habitat structure is correlated with habitat functions, as illustrated in Figure 1. This allows spatial impacts to habitats to be extrapolated to impacts on functions.

Figure 1 - General conceptual model linking impacts to ecological functions (from Williams et al. 2004).



The zone of influence is not only related to the structure itself, but also the attendant activities typically associated with that structure. For example, research at ferry terminals indicates that stressor mechanisms include initial construction impacts, shading, propeller scour, turbidity plumes and altered circulation (Simenstad et al. 1997). The "cumulative impact" of these stressors is to eliminate eelgrass from a much larger area than just the dock surface area. Other effects include an altered benthic infauna species composition,

epibenthic invertebrate populations (i.e., altered epibenthic zooplankton assemblage and enhanced Dungeness crab and sea star populations) and fish (enhanced pile perch populations, decreased eelgrass-associated fish) assemblages. The zone of impact can extend well beyond the boundaries of the terminal. Similarly, as the number of docks increases along a shoreline parcel or within a bay, the zones of influence will be much closer together than the distances between docks, and may overlap. Finally, the types of activities can have variable effects. Typically, there are several types of activities occurring in an area. For example, Eagle Harbor, Bainbridge Island, has shoreline armoring, dock, fill, marinas and mooring buoys. It is expected that each of these activities has a variable effect, but cumulatively they contribute to measurable alteration of habitat.

There are data sets emerging on overwater structures impacts that inform the quantification of cumulative effects. First, shading from overwater structures can be severe enough to cause the loss of eelgrass and algae. The light requirements for eelgrass are also known (Thom et al. in prep.). Additionally, a numerical model that predicts the shadow cast from docks of various sizes, shapes, and heights has been developed by Battelle. These data can be used to predict the zone of shaded bottom around and under the dock (i.e., the zone of influence) and whether or not a dock would predictably affect eelgrass survival. Data gathered on light and fish behavior (focused on juvenile salmon) at various sites over the past two years allow the extension of the shading impacts to fish migration and feeding behavior along shorelines (Nightingale and Simenstad 2001; Williams et al. 2003; Southard et al. in prep). Further, there is a significant correlation between photosynthetically active radiation (PAR, 400 to 700 nanometers) that plants require and luminance (lux), which is the unit used in behavior studies on fish (Southard et al. in prep.). Thus, by knowing the level of PAR or luminance characteristics of the docks, and the extent of shade cast by the docks, the effects on eelgrass and juvenile salmon can be predicted. This understanding can be used to predict how increasing numbers of docks of various sizes and spacing along a shoreline or in an embayment will affect the distribution of eelgrass and the use of nearshore areas by juvenile salmon.

Data Sources

Six sources of information directed at identifying and quantifying the zone of influence and general impacts of overwater structures are summarized below. These sources provide lines of evidence to inform and verify the effects analysis applied to Washington DNR activities in The Potential Effects Technical Paper (Washington DNRa).

Field Study at John Wayne Marina in Sequim Bay

The John Wayne marina is a typical small boat marina. It primarily harbors pleasure craft, but also temporarily harbors larger vessels (e.g., U.S. Navy) near the mouth of the marina. PAR was measured at seven sites within John Wayne marina (Figure 2) around solar noon on 9 September 2005, with the sites located in areas representative of the structures present in the marina. Triplicate sites were sampled within the following strata: (1) open to full sunlight; (2) under the edge of the floating dock (float); and, (3) between a boat and the nearest float to which it was secured. Spacing between the boat and the float ranged about 0.4 to 0.5 meters. PAR measurements were made in air above the surface of the water, and at 0.1 and 1.0-meter depths at the sites. In some cases the in-air measurements were shaded by surrounding structures, so measurements were also made in the closest unshaded area near the site.

PAR at 1.0 meter depth in unshaded areas averaged 36 percent of the measured in-air levels (Table 4). In comparison, PAR under the floats and between the boats and floats averaged 16 percent and 12 percent of unshaded in-air values, respectively. In other words, the floats and a boat reduced light in water 56 to 67 percent compared to unshaded areas. Float widths varied from about 1.5 to 2.5 meters, and most boats in the marina were both wider than the widest float and approximately as long as the floats to which they were attached. The cumulative effect of floats and boats is to significantly shade an area greater than that for the boat and float alone. Throughout much of the marina, boats were secured to each side of one float. Considering the shading effect on water column PAR levels, and the number of boats per float, the approximate ratio of shaded area to float (including boats) was estimated to be about 4:1. As boats are not always tied to the floats, this represents a worst-case estimate of shading effect.

Bainbridge Island Analysis

Williams et al. (2004) showed that the nearshore system of Bainbridge Island ranged from relatively unimpacted to heavily degraded. Recent work by Woodruff et al. (2005) used a variety of remote sensing methods to focus on watershed condition. Among the preliminary findings were that where marinas were developed, sub-watersheds contained the highest level of impervious surface (Figure 3). In rural areas, even where individual docks were dense, there was less associated upland development. Marinas are typically found in areas with higher population density and more commercial development. Impervious surface enhances the potential for runoff of contaminants from the watershed into the body of water at the base of the watershed.

Shade Model Analysis

Shading analysis allows for the shadow of a structure to be cast around the structure throughout a day and over longer time periods (Figure 4). This type of analysis has shown that the shadow excursion from a dock is larger than the dock deck surface area (Thom et al. 2005). The excursion area varies with season and several other factors, but an approximate excursion-to-deck-area ratio is 4:1. Thus, a dock of 200 square meters (meters^2)in area would cast a shadow more than 800 meters^2 in area. Where dock shadows overlap there is potential for cumulative impacts on a point between the two docks. Thus, a point between two docks that are oriented north and south would receive a shadow twice a day rather than once a day as would occur for a single dock.

Nearshore Mapping of Eelgrass

Discontinuities in eelgrass or other submerged vegetation can indicate the zone of influence of overwater structures and identify areas that show any cumulative effects of overlapping shadows. Evidence from many areas where eelgrass was mapped, showed that docks and marinas clearly had wider areas of effect than just those from the footprint of the structures (Woodruff et al. 2001). Figure 5 illustrates the discontinuity in eelgrass cover around the Meadowdale marina, which is typical of what has been observed elsewhere. The causal mechanisms for the discontinuity are not known completely, the discontinuities are also evident in areas where no structures are apparent (Figure 5). Although possible in areas without structures, the abruptness of the discontinuity near this marina is typical of situations where it is suspected that eelgrass would have occurred had no structure been present.

At the Hood Canal Bridge, eelgrass and algal distributions were mapped using aerial hyperspectral imagery and underwater videography with diver verification (Woodruff et al. 2002). These maps showed that eelgrass distribution was patchy near and under the

bridge with much denser coverage about 100 meters north and south of the bridge. Lobes of intertidal land to the north and south of the bridge also contained dense cover of eelgrass. The authors did not speculate on the mechanisms affecting eelgrass coverage, but indicated that the bridge was the only obvious difference among all the sites mapped. The presumed loss of eelgrass could be from bridge construction, enhanced current velocities, shading, or a combination of these factors. The ratio of the length of shoreline with sparse to no eelgrass coverage in areas with suitable water depth, slope and substrata to the bridge width is greater than 10:1. Although data on impacts from structures on submerged aquatic vegetation in freshwater systems in Washington are scarce, the literature indicates that the general response of impacts to factors holds for both freshwater (e.g., Carrasquero 2001, Toft et al. 2003) and saltwater.

Lidar Imagery

Water-penetrating lidar imagery of the southeastern shoreline of Whidbey Island provides an illustration of the zone of influence of a dock structure on bathymetry (Figure 6). Docks can affect the longshore transport of sediments (Downing 1983, Komar 1999). Typically, sediment accumulates along the shore under and immediately adjacent to the dock and forms a portion of the shoreline with a shallower bathymetry (salient zone). In addition, the vessels using the dock can scour the bottom and deposit sediments adjacent to the scoured area to form a berm. The scour, berm and salient zones are shown in Figure 6. The net effect is that the dock has a wider influence on the bottom than just that contained within the dock footprint. In this case, the area of altered bottom bathymetry encompasses about 10 times the area of the overwater structure deck.

Fish Migration and Predation

There is a growing recent body of evidence that addresses the issue of juvenile salmon passage under docks and whether or not overwater structures affect fish habitat, feeding and predation pressure (Simenstad et al. 1999; Shreffler and Moursund 1999; Haas et al. 2002; Williams et al. 2003). The general results are:

- Very low light can limit juvenile salmon movement and feeding efficiency.
- Vegetation and juvenile salmon prey production is reduced under overwater structures.
- Small docks (about10 meters or less, if the structure is high above the water) do not inhibit juvenile salmon movement and feeding efficiency during the day.
- Larger docks sometimes limit juvenile salmon movement.
- There is no strong evidence of increased predation on juvenile salmon under or near docks.

PAR levels less than 300 micro moles per square meter per second will limit eelgrass growth if those levels are sustained through the spring and summer. Light levels far less than this appear to affect fish movement. Thus, although vegetated habitat may be affected by reduced light, fish behavior and feeding may not be affected.

There are no comparable data sets for fish migration in freshwater relative to overwater structures. However, it is assumed that much of the same principles hold with regard to limitation of migration at time, food limitation and predation. However, this needs further research and testing (Carrasquero 2001, Toft et al. 2003).

Summary

The data compiled from docks, marinas and associated typical activities indicates that the zone of influence is larger than the footprint of the structure. The mechanisms of impact identified in the studies discussed here include passive activities such as shading and shade pattern travel; sediment accumulation from the dock and associated vessels and structures; and active effects such as propeller scour, sediment and bathymetry reworking. Other effects on habitat and fisheries have been well summarized by Nightingale and Simenstad (2001) and Carrasquero (2001). The ratio of structure footprint area to zone of influence area is much greater than 1:1 and based on the studies reviewed here, ranges from about 4:1 to greater than 10:1. Preliminary evidence suggests that the zone of influence relative to the affects of overwater structures on fish behavior coincides best with that for shading cast by the dock structure for wide overwater structures.

Research is required to further verification and quantify impacts, especially cumulative impacts. For cumulative impacts, research on the level of impact versus the response by the ecosystem is required. Two general types of cumulative effects (i.e., single stressor, multiple stressors) should be studied. For the single stressor an example would be “At what point does increasing the number of docks in a bay result in an exclusion of migratory shallow water fish from the bay?” Under a more complex multiple stressor scenario, the cumulative effects of multiple stressors need to be considered. For example, “What is the cumulative effect of a dock in combination with related impacts of riparian habitat loss, prop scour, and contaminant release on migratory shallow water fish?” We surmise from the data presented above that the physical impacts (e.g., scour, light reduction) extend well beyond the footprint of a dock. But it is not possible to predict the effects of the total suite of related stressors. Research could be set up to develop empirical data sets to better assess these two major types of cumulative effect.

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Table 2 - Saltwater Marine ecosystem sites evaluated for habitat verification

Saltwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
Columbia Estuary	T04R01W	Nearshore	Unconsolidated	Habitat classification is correct: Garono, R.J., R. Robinson, and C. Simenstad. 2003. Estuarine and Tidal Freshwater Habitat Cover Types Along the Lower Columbia River Estuary Determined from Landsat 7 ETM+ Imagery. Prepared for Lower Columbia River Estuary Partnership by Earth Design Consultants, Inc. Corvallis, OR. http://www.earthdesign.com/lowercolumbia/CR_TM_Classification_Oct_2003.pdf	Garono et al. 2003 is currently being updated; new report will be released by end of 2005.
	T03R01W	Nearshore	Unconsolidated	Habitat classification is correct: Garono, R.J., R. Robinson, and C. Simenstad. 2003. Estuarine and Tidal Freshwater Habitat Cover Types Along the Lower Columbia River Estuary Determined from Landsat 7 ETM+ Imagery. Prepared for Lower Columbia River Estuary Partnership by Earth Design Consultants, Inc. Corvallis, OR. http://www.earthdesign.com/lowercolumbia/CR_TM_Classification_Oct_2003.pdf	Garono et al. 2003 is currently being updated; new report will be released by end of 2005.
Southwest Outer Coast	T11R10W	Estuarine	NA	Habitat classification is correct: Willapa Watershed Information System. 2005. See maps of Naselle River estuarine habitat at http://www.inforain.org/willapa/catalog/htm/spatial.htm	Accessing maps at this website requires GIS software that can view Arc/Info coverages
	T16R11W	Nearshore	Unconsolidated	Habitat classification is correct: USACE. 2001. Grays Harbor Navigation Project, Final Environmental Assessment. 2001. http://www.nws.usace.army.mil/ers/reposit/Final_EA_GH_OM_FY01-06.pdf.	

Saltwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T16R11W	Estuarine	NA	Habitat classification is correct: Borde, A. B., R. M Thom, S. Rumrill, and L.M. Miller. 2003. Geospatial habitat change analysis in Pacific Northwest coastal estuaries. Estuaries 26 (4B):1104-1116.	
Strait of Juan de Fuca	T30R03W	Nearshore	~~Consolidated~~ Unconsolidated	Habitat classification is incorrect: Woodruff, D.L. 2005 (unpublished). Sequim Bay Hyperspectral Data. Battelle Marine Sciences Laboratory, Sequim, WA.	The predominant habitat type in T30R03W is Nearshore Unconsolidated. A few locations in T30R03W have Nearshore Consolidated habitat, as evidenced by large boulders (glacial erratics).
	T31R07W	Offshore	Unconsolidated	Habitat classification is correct: Woodruff, D.L. 2001 (unpublished). Elwha River Nearshore Underwater Video & Mapping. Battelle Marine Sciences Laboratory, Sequim, WA.	
	T30R02W	Offshore	Unconsolidated	Habitat classification is correct: 1) Nightingale, B. 2000. Summary Report from a Literature Search on the Status of Marine Resources in Jefferson County. http://www.biomes.net/FinalMRCReport2a.htm 2) Point No Point Treaty Council. 2005. Digitized Historical Coast Survey Maps of Hood Canal and Strait of Juan de Fuca: Protection Island- New Dungeness-Grays Marsh http://www.pnptc.org/PNPTC_Web_data/Publications/habitat/Gis_maps/t1169_v092104.zip	Based on changes in cover of canopy forming kelp that require consolidated habitat for holdfast attachment, there may have been more consolidated habitat offshore of Protection Island historically than there is currently (see Fig. 2 in Nightingale 2000). (Nightingale 2000 is HTML only; PNP GIS data, metadata saved)

Saltwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
Northern Puget Sound	T35R03W	Offshore	Consolidated	Habitat classification is correct: San Juan County. 2000. San Juan County Watershed Management Action Plan and Characterization Report. http://www.co.san-juan.wa.us/health/wtrshdpln/index.html	(HTML only)
	T35R02E	Nearshore	Unconsolidated	Habitat classification is correct: Shull, S. 2000. Mapping seagrass meadows of Padilla Bay, Washington using a 1996 compact airborne spectrographic imager (CASI) dataset. Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve: Mount Vernon, Washington. 76 pp. Padilla Bay National Estuarine Research Reserve Reprint Series No. 34.	
	T33R03E	Estuarine	NA	Habitat classification is correct: Beamer et al. 2005. Delta and Nearshore Restoration for the Recovery of Wild Skagit River Chinook Salmon. http://www.skagitcoop.org/Appendix%20D%20Estuary%20final_062705.pdf	
	T33R03E	Nearshore	Unconsolidated	Habitat classification is correct: Beamer et al. 2005. Delta and Nearshore Restoration for the Recovery of Wild Skagit River Chinook Salmon. http://www.skagitcoop.org/Appendix%20D%20Estuary%20final_062705.pdf	
	T28R02E	Offshore	Consolidated	Habitat classification is correct: May, C.W. and G. Peterson. 2003. Kitsap Salmonid Refugia Report. http://www.kitsapgov.com/dcd/nr/refugia/refugia.htm	(13.5 MB file)

Saltwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T30R01E	Offshore	Consolidated	Habitat classification is correct: Jeffries et al. 2000. Atlas of Seal and Sea Lion Haulout Sites in Washington. http://wdfw.wa.gov/wlm/research/papers/seal_haulout/	According to this report, seals and sea lions haul out on rocks along the northeast side of Marrowstone Island
	T28R04E	Offshore	Unconsolidated	Habitat classification is correct: Southard, J.A., G.D. Williams, R.M. Thom, A.B. Borde, S.L. Sargeant, D.L. Woodruff, N.R. Evans, and J.R. Cordell. 2005. Habitat Mitigation Monitoring at the Clinton Ferry Terminal, Whidbey Island. Prepared for Washington State Department of Transportation by Battelle Marine Sciences Laboratory, Sequim, WA.	
	T28R04E	Nearshore	Unconsolidated	Habitat classification is correct: Southard, J.A., G.D. Williams, R.M. Thom, A.B. Borde, S.L. Sargeant, D.L. Woodruff, N.R. Evans, and J.R. Cordell. 2005. Habitat Mitigation Monitoring at the Clinton Ferry Terminal, Whidbey Island. Prepared for Washington State Department of Transportation by Battelle Marine Sciences Laboratory, Sequim, WA.	
Southern Puget Sound	T27R01E	Offshore	Unconsolidated	Habitat classification is correct: Williams, G.D., J.A. Southard, S.L. Blanton, and R.M. Thom. 2001. Findings of Subtidal Dive Resource Surveys: Anchor Cable BN, Hood Canal Bridge. PNWD-3100. Prepared for Washington State Department of Transportation by Battelle Marine Sciences Laboratory, Sequim, WA.	

Saltwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T27R01E	Nearshore	Unconsolidated	Habitat classification is correct: Woodruff, D.L., G.D. Williams, J.A. Southard, S.L. Sargeant, A.B. Borde, N.R. Evans, L. K. O'Rourke, and R.M. Thom. 2004. Hood Canal Bridge Replacement and Retrofit Project: Eelgrass Monitoring and Baseline Assessment. Prepared for Washington State Department of Transportation by Battelle Marine Sciences Laboratory, Sequim, WA.	
	T21R04W	Estuarine	NA	Habitat classification is correct: Barrecca, J. and K. Seiders. 2001. Skokomish River Basin Fecal Coliform Total Daily Maximum (Water Cleanup Report). http://www.ecy.wa.gov/pubs/0110017.pdf	
	T27R03E	Offshore	Unconsolidated	Habitat classification is correct: Woodruff, D.L., P.J. Farley, A.B. Borde, J.S. Southard, and R.M. Thom. 2001. King County Nearshore Habitat Mapping Report: Picnic Point to Shilshole Marina. Prepared for Kind County Department of Natural Resources by Battelle Marine Sciences Laboratory, Sequim, WA.	
	T19R02W	Nearshore	Unconsolidated	Habitat classification is correct: Herrera Environmental Consultants. 2005. Marine Shoreline Sediment Survey and Assessment, Thurston County, Washington. http://www.trpc.org/programs/environment/water/nearshore.htm	(Multiple chapter download; purchase $42)
	T19R01E	Estuarine	NA	Habitat classification is correct: Nisqually National Wildlife Refuge Final Comprehensive Conservation Plan. 2004. http://pacific.fws.gov/planning/draft/docs/WA/finalnisquallyccp.htm	(Multiple chapter download)

Saltwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T21R02E	Offshore	Consolidated	http://www.wsdot.wa.gov/projects/sr16narrowsbridge/ http://www.wsdot.wa.gov/environment/culres/bridges/NarrowsBridge.pdf http://www.co.pierce.wa.us/xml/services/home/environ/water/PS/basinplans/keypen/KGIAnnualReport2001.pdf	The first 2 sites contain detailed information about the current status of the Tacoma Narrows Bridge project and the engineering history, but neither site enables me to confirm the habitat classification of "offshore consolidated." The 3rd site is a nearshore salmon habitat assessment; it does not cover the offshore environment.
	T21R02E	Offshore	Unconsolidated	Habitat classification is correct: Strom and Papanicolaou. 2003. Bed Stability around the East Caisson of the Tacoma Narrows Bridge. http://www.ce.washington.edu/em03/proceedings/papers/770.pdf	
	T24R02E	Nearshore	Unconsolidated	Habitat classification is correct: Williams et al. 2004. Bainbridge Island Nearshore Habitat Characterization & Assessment. http://www.ci.bainbridge-isl.wa.us/nearshore-report	

[1] Columbia Estuary = region from Cape Disappointment eastward to Bonneville Dam.
Southwest Outer Coast = Cape Disappointment to Quinault River
Strait of Juan de Fuca = Cape Flattery to Admiralty Inlet
Northern Puget Sound = Canadian border south to southern tip of Whidbey Island
South Puget Sound = South of southern tip of Whidbey Island; also Hood Canal

[2] Township identifier (keyed to leases map).

Table 3 - Freshwater ecosystem sites evaluated for habitat verification or trophic status determination.

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
Lakes	T25R04E	Lacustrine	Limnetic	Eutrophic: Herrera. 2003. Green Lake Alum Treatment Study. http://www.ci.seattle.wa.us/parks/parkspaces/GreenLakePark/GreenLakeAlumStudy.pdf	Green Lake
	T23R05E	Lacustrine	Limnetic	Mesotrophic: King County. 2005. King County's Lakes Monitoring Program. http://dnr.metrokc.gov/wlr/waterres/lakes/LakeWashFacts.htm	Lake Washington
	T24R04E	Lacustrine	Littoral	Mesotrophic: King County. 2005. King County's Lakes Monitoring Program. http://dnr.metrokc.gov/wlr/waterres/lakes/LakeWashFacts.htm	Lake Washington
	T24R04E	Lacustrine	Limnetic	Mesotrophic: King County. 2005. King County's Lakes Monitoring Program. http://dnr.metrokc.gov/wlr/waterres/lakes/LakeWashFacts.htm	Lake Washington
	T25R03E	Lacustrine	Limnetic	Mesotrophic: King County. 2005. King County's Lakes Monitoring Program. http://dnr.metrokc.gov/wlr/waterres/lakes/LakeUnionFacts.htm	Lake Union
	T25R04E	Lacustrine	Limnetic	Mesotrophic: King County. 2005. King County's Lakes Monitoring Program. http://dnr.metrokc.gov/wlr/waterres/lakes/LakeUnionFacts.htm	Lake Union

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T25R06E	Lacustrine	Limnetic	Mesotrophic: King County. 2005. King County's Lakes Monitoring Program. http://dnr.metrokc.gov/wlr/waterres/lakes/LakeSammFacts.htm	Lake Sammamish
	T24R06E	Lacustrine	Littoral	Mesotrophic: King County. 2005. King County's Lakes Monitoring Program. http://dnr.metrokc.gov/wlr/waterres/lakes/LakeSammFacts.htm	Lake Sammamish
	T24R41E	Lacustrine	Littoral	Eutrophic: http://www.ecy.wa.gov/programs/eap/fw_lakes/spmedsp1.pdf	West Medical (Spokane); Lake receives a waste treatment plant discharge. Because of this, the lake is unusually high in nutrients. Aquatic plants were thick in places; coontail (*Ceratophyllum demersum*) was dominant. The water clarity was surprisingly good considering the sizeable nutrient load within the lake. Hydrogen sulfide odor was observed very deep in the water column (8 meters) and there were many blue-green colonies (probably *Mycrocystis*). West Medical Lake is almost certainly nitrogen limited with TN/TP ratios below 2.
	T24R41E	Lacustrine	Limnetic	Eutrophic: Washington DEC. 1998. Lake Water Quality Monitoring. Lake-specific Studies. Medical West (Spokane). http://www.ecy.wa.gov/programs/eap/fw_lakes/spmedsp2.pdf	West Medical (Spokane); see note above.

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
Riverine/Fresh water Wetlands-Western	T21R04W	Wetlands	NA	Habitat classification is correct: Barrecca, J. and K. Seiders. 2001. Skokomish River Basin Fecal Coliform Total Daily Maximum (Water Cleanup Report). http://www.ecy.wa.gov/pubs/0110017.pdf	
	T11R09W	Wetlands	NA	Habitat classification is correct: Interrain Pacific. 2005. Willapa Watershed Information System. See maps of Naselle River wetland habitat at http://www.inforain.org/willapa/catalog/htm/spatial.htm	Accessing maps at this website requires GIS software that can view Arc/Info coverages
	T04R01W	Wetlands	NA	Habitat classification is correct: Garono, R.J., R. Robinson, and C. Simenstad. 2003. Estuarine and Tidal Freshwater Habitat Cover Types Along the Lower Columbia River Estuary Determined from Landsat 7 ETM+ Imagery. Prepared for Lower Columbia River Estuary Partnership by Earth Design Consultants, Inc. Corvallis, OR. http://www.earthdesign.com/lowercolumbia/CR_TM_Classification_Oct_2003.pdf	Garono et al. 2003 is currently being updated; new report will be released by end of 2005.
	T31R07W	Wetlands	NA	Habitat classification is correct: 1) Bohman, J., Morrill, D., Sheldon, D., Klein, P.O., McCoy, R. 1996. Final Elwha River wetland inventory for the Lower Elwha restoration project: Seattle, Sheldon and Associates, 18 p. 2) also see maps of Elwha River wetland habitat at www.elwha.org/RiverRestoration/Maps.htm	

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T18R01E	Wetlands	NA	Habitat classification is correct: Watershed Professionals Network et al.. 2002. Nisqually River Level 1 Watershed Assessment (WRIA 11). www.ecy.wa.gov/programs/eap/wrias/**assessment**s/wria11/	
	T18R01E	Riverine	Pool-riffle	Habitat classification is correct: Watershed Professionals Network et al.. 2002. Nisqually River Level 1 Watershed Assessment (WRIA 11). www.ecy.wa.gov/programs/eap/wrias/**assessment**s/wria11/	
	T31R04W	Riverine	Pool-riffle	Habitat classification is correct: Bountry, J.A.,T.J. Randle, L.A. Piety, R.A. Link. 2002. Physical processes, human impacts, and restoration issues of the lower Dungeness River, Clallam County, Washington. U.S. Department of Interior, Bureau of Reclamation, Technical Service Center, Denver, CO. http://www.jamestowntribe.org/5-BOR-Dungeness%20River%20Main%20Report.pdf	(88 MB document)
	T23R05E	Riverine	Pool-riffle	Habitat classification is correct: City of Seattle. 2000. Final Cedar River Habitat Conservation Plan (HCP). http://www.ci.seattle.wa.us/util/stellent/groups/public/@spu/@rmb/@resplan/@ltep/documents/spu_informative/habitatco_200401201705386.pdf	(62 MB document; downloaded)

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T31R07W	Riverine	Low-gradient valley	Habitat classification is correct: National Park Service. 2005. Elwha River Ecosystem Restoration Implementation Final Supplement to the Final Environmental Impact Statement. http://www.nps.gov/olym/elwha/docs/Elwha%202005%20Final%20SEIS/PDF/index.htm	
	T05R01E	Riverine	Pool-riffle	Habitat classification is correct: Lower Columbia Fish Recovery Board. 2004. Lower Columbia River Salmon Recovery and Fish & Wildlife Subbasin Plan (Chapter G - NF and EF Lewis). http://www.lcfrb.gen.wa.us/December%20Final%20%20Plans/Approved%20Recovery%20Plan/Subbasin%20Plan/Vol%20II%20G--Lewis.pdf	Lewis River above East Fork
	T26R05E	Riverine	Low-gradient valley	Habitat classification correct: King County. 2005. Chinook Salmon Conservation Plan WRIA 8 - Cedar River, Lake Washington, Sammamish Watershed. http://dnr.metrokc.gov/Wrias/8/chinook-conservation-plan.htm	(Multiple Chapter download)
	T24R04E	Riverine	~~Pool-riffle~~ Low-gradient valley	Habitat classification is incorrect: Collins, B. D., and A. J. Sheikh. 2005. Historical aquatic habitats in the Green and Duwamish river valleys, and the Elliott Bay nearshore, King County, Washington. August 17, 2005. Final project report to King County Department of Natural Resources and Parks, Seattle, Washington. http://riverhistory.ess.washington.edu/project_reports/wria9_final_report_sept_2005.pdf	Predominant habitat type in Duwamish River is low-gradient valley.

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T16R11W	Riverine	Low-gradient valley	Habitat classification is correct: Grays Harbor County. 2004. Chehalis Basin Watershed Management Plan. http://www.co.grays-harbor.wa.us/info/pub_svcs/ChehalisBasin/Index.html	Johns River (Multiple Chapter download)
	T17R09W	Riverine	Pool-riffle	Habitat classification is correct: Grays Harbor County. 2004. Chehalis Basin Watershed Management Plan. http://www.co.grays-harbor.wa.us/info/pub_svcs/ChehalisBasin/Index.html	Wynoochee River (Multiple Chapter download)
	T25R02W	Riverine	Pool-riffle	Habitat classification is correct: Golder Associates. 2002. Skokomish-Dosewallips Basin Watershed Planning (WRIA 16). http://www.ecy.wa.gov/pubs/0306014.pdf	Dosewallips River
	T25R02W	Riverine	Pool-riffle	Habitat classification is correct: Golder Associates. 2002. Skokomish-Dosewallips Basin Watershed Planning (WRIA 16). http://www.ecy.wa.gov/pubs/0306014.pdf	Dosewallips River
Riverine/Freshwater Wetlands - Eastern	T09R28E	Wetlands	NA	Field site visit: Easting 0326650 Northing 5124451 (UTM); elevation 309 feet; photos 0310 Upstream; 0311 Downstream; 0312 right bank, West; 0313 left bank, East Habitat Description: Wetland; mud and silt dominant and subdominant	Bridge construction 1/2 mile above GPS point; road construction on highway 240 in wetland near right bank; low boating traffic; GPS point taken in middle of river (from a boat)
	T08R30E	Wetlands	NA	Field site visit: Easting 0349864 Northing 5112559 (UTM); elevation 307 feet; photos 0317 looking West; 0318 looking south, downriver Habitat Description: Wetland; mud and silt dominant and subdominant	Railroad tracks parallel to wetlands, right by GPS point; railroad bridge just up above wetlands, 1/8 mile from GPS; GPS point taken on left bank of river, by tracks

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T09R28E	Riverine	Low-gradient valley	Field site visit: Easting 0325742 Northing 5124602 (UTM); elevation 316 feet; photos 0307 looking across; 0308 downstream; 0309 upstream Habitat Description: Low-gradient valley; medium cobble dominant; small cobble subdominant	Railroad bridge just below GPS point 1/8 mile; highway bridge right by railroad bridge-doing construction on bridge; rock quarry just north of GPS point GPS point taken on left bank of river
	T08R30E	Riverine	Low-gradient valley	Field site visit: Easting 0342678 Northing 5118125 (UTM); elevation 307 feet; photos 0314 across Snake towards wetlands; 0315 downstream on Columbia; 0316 upstream on Snake Habitat Description: Low-gradient valley; medium cobble dominant; small cobble subdominant	Railroad bridge about 1/4 mile up Snake River above GPS point; railroad bridge 1 mile downstream on Columbia below GPS point; State Park right at GPS point; Highway 12 bridge by railroad bridge on Snake; Barge traffic is present sometimes; some boating traffic
	T16R23E	Riverine	Pool-riffle	Field site visit: Easting 0274605 Northing 5193574 (UTM); elevation 528 feet; photos 0301 downstream; 0302 upstream; 0303 across Habitat Description: Pool-Riffle, water is relatively still on top; medium cobble dominant, small cobble subdominant; bar in the middle of the river	Wanapum Dam is half mile above GPS point; train bridge is about a mile downstream of GPS point; Barge Gock below Dam on right bank; GPS taken on left bank side of river
	T23R20E	Riverine	Pool-riffle	Field site visit: Easting 0700757 Northing 5259602 (UTM); elevation 636 feet; photos 0296 looking downstream; 0297 looking upstream Habitat Description: Pool-Riffle; medium cobble is dominant; silt is subdominant	Railroad runs along river; railroad bridge and highway bridge about 1/4 mile away from each other; highway bridge is upstream of railroad bridge; GPS point take on highway bridge; some industries on left side and right side of river; some agriculture, small orchards upstream of bridge; standby wells were right by highway bridge

Freshwater Region [1]	Township [2]	Ecosystem	Habitat	Habitat Classification and Data Source	Notes
	T23R20E	Riverine	Pool-riffle	Field site visit: Easting 0701883 Northing 0701883 (UTM); elevation 546 feet; photos 0292 looking upstream; 0293 across river; 0294 downstream; 0295 looking at confluence Habitat Description: Pool-Riffle; water looks pretty slack on top; medium to small cobble dominant; silt is subdominant	Highway bridge 1/2 mile upstream from GPS point; State Park right at confluence with boat launch; no observed construction going on; GPS point taken on right bank of Columbia River; some orchards on left bank side of river
	T21R22E	Riverine	Low-gradient valley	Field site visit: Easting 0720386 Northing 5246790 (UTM); elevation 708 feet; photos 0298 looking downstream; 0299 looking upstream; 0300 looking across Habitat Description: Low-gradient valley; water a little more swift than pool-riffle; couldn't observe cobble in river because of a fence; tall columns of basalt on left bank side by highway	Dam upstream 1/4 mile from GPS point; railroad tracks on left bank side of river; highway along left bank side of river; 1/2 mile downstream habitat type changes to pool riffle; GPS point taken on left bank side of river by railroad tracks
	T13R19E	Riverine	Low-gradient valley	Field site visit: Easting 0693132Northing 5164465 (UTM); elevation 1066 feet; photos 0304 looking across; 0305 upstream; 0306 downstream Habitat Description: Low-gradient valley; water is kind of swift; medium cobble dominant; small cobble subdominant	Road construction going on 1/4 mile downstream; irrigation inlet above bridge; island upstream of GPS point; bar in middle of river straight out from point; bridge downstream 1/4 mile; GPS point taken on right bank side of river; sportsman state park downstream of GPS point a mile
	T13R37E	Riverine	~~Pool-riffle~~ Low-gradient valley	Field site visit: Easting 0406624 Northing 5159987 (UTM); elevation 603 feet; photos 0319 Palouse confluence; 0320 downriver Snake; 0321 upriver Snake; 0322 zoom Palouse confluence Habitat Description: Original habitat classification incorrect; Low-gradient valley; Snake substrate unidentifiable	Lyon's Ferry State Park @ confluence w/ boat ramp; Highway bridge @ confluence; train bridge upriver on snake; campground & boat ramp nearly straight across from confluence on rr. Photos and GPS point taken right bank snake river directly across from Palouse confluence

Table 4 - Data on light levels at sites in John Wayne Marina, Sequim Bay.

Photosynthetically Active Radiation (PAR) [1]	Mean	Standard Deviation
Attenuation (Kd)	0.55	0.12
PAR [1] at 1 meter depth in open water as a percent of PAR in air	36.3%	5.87
PAR at 1 meter depth between float and boat as a percent of PAR in air	12.0%	3.81
PAR at 1 meter depth under float edge as a percent of PAR in air	15.8%	2.24

[1] Instantaneous photosynthetically active radiation (micro moles per square meter per second)

Figure 2 - Sampling sites in John Wayne Marina, Sequim Bay.

Figure 3 - Marinas and docks in Eagle Harbor on Bainbridge Island. The colors indicate percent cover of impervious surface in the sub watersheds draining into Eagle Harbor. The marina development coincides with heavily paved land surface (Lee Miller and Dana Woodruff, Battelle Marine Sciences Laboratory, September 2005).

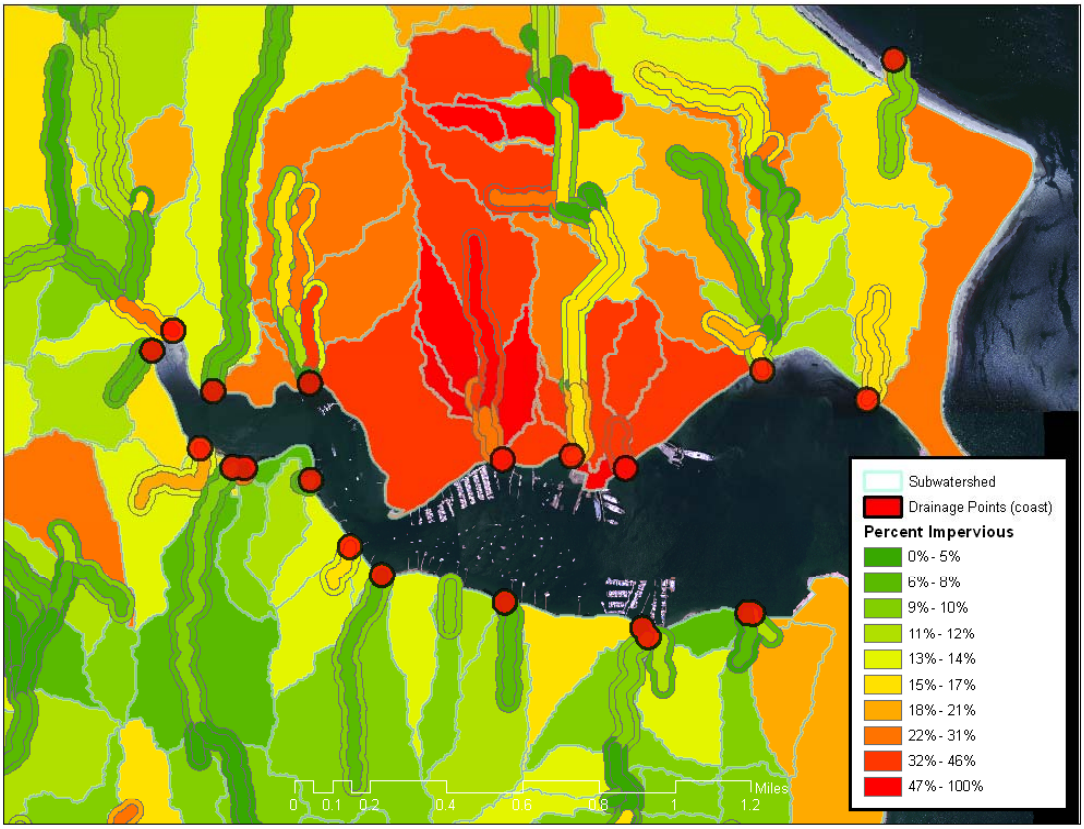

Figure 4 - Shade model rendition of shade around the new Port Townsend Maritime Center dock. Light green = former eelgrass area; dark green = existing eelgrass area. Illustration is from Miller/Hull Partnership Architects (from Thom et al. 2005)

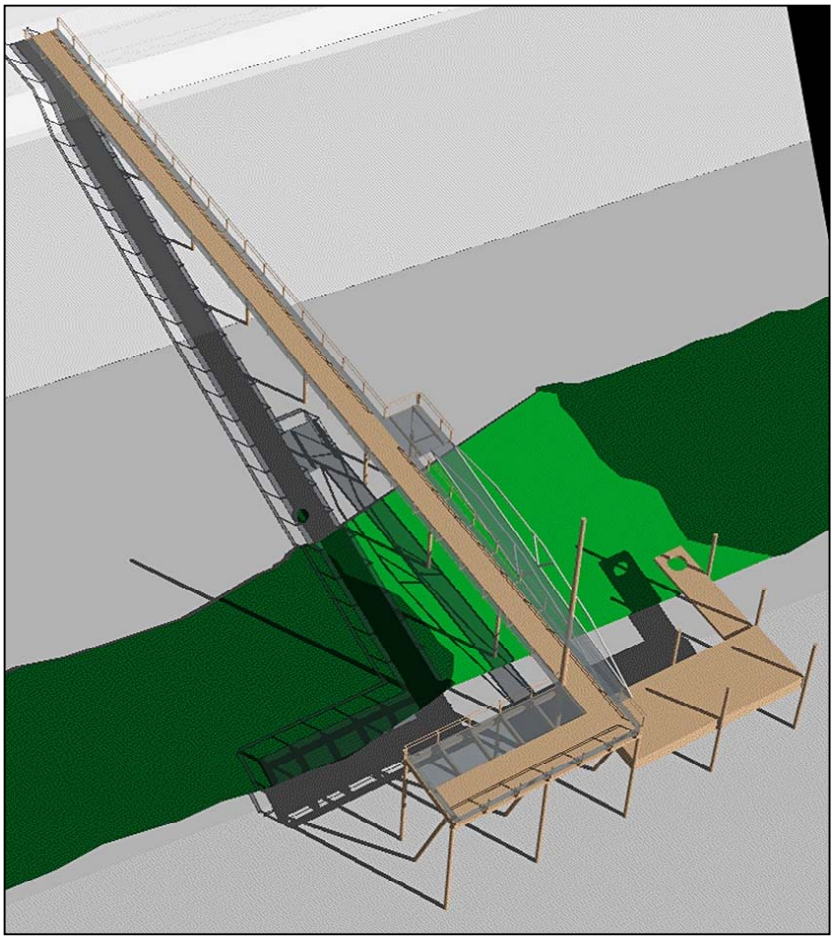

Figure 5 - Map of eelgrass and kelp along the shoreline near Meadowdale Marina (based on data from Woodruff et al. 2001).

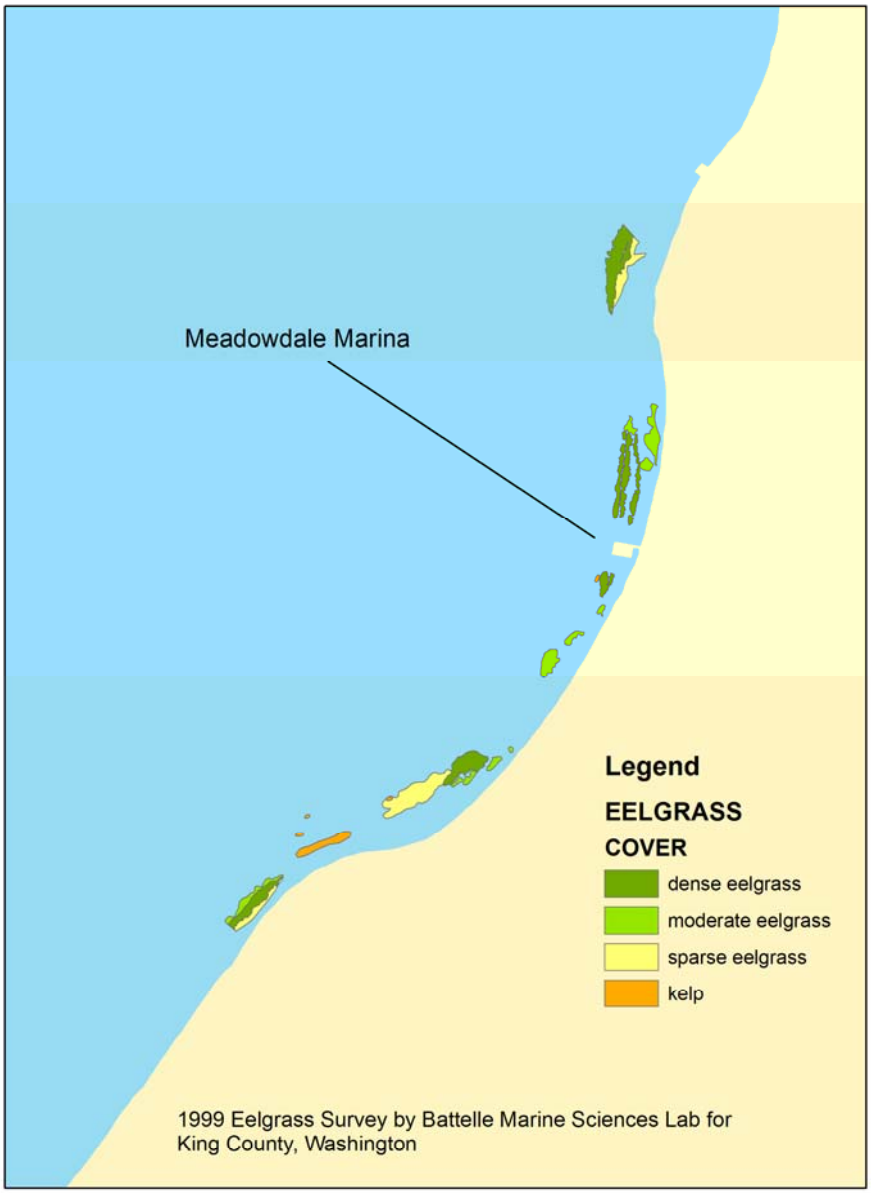

Figure 6 - Typical patterns of disturbance at commercial and non-commercial overwater structures. Lidar is from the Puget Sound Lidar sortium (pugetsoundlidar.org)

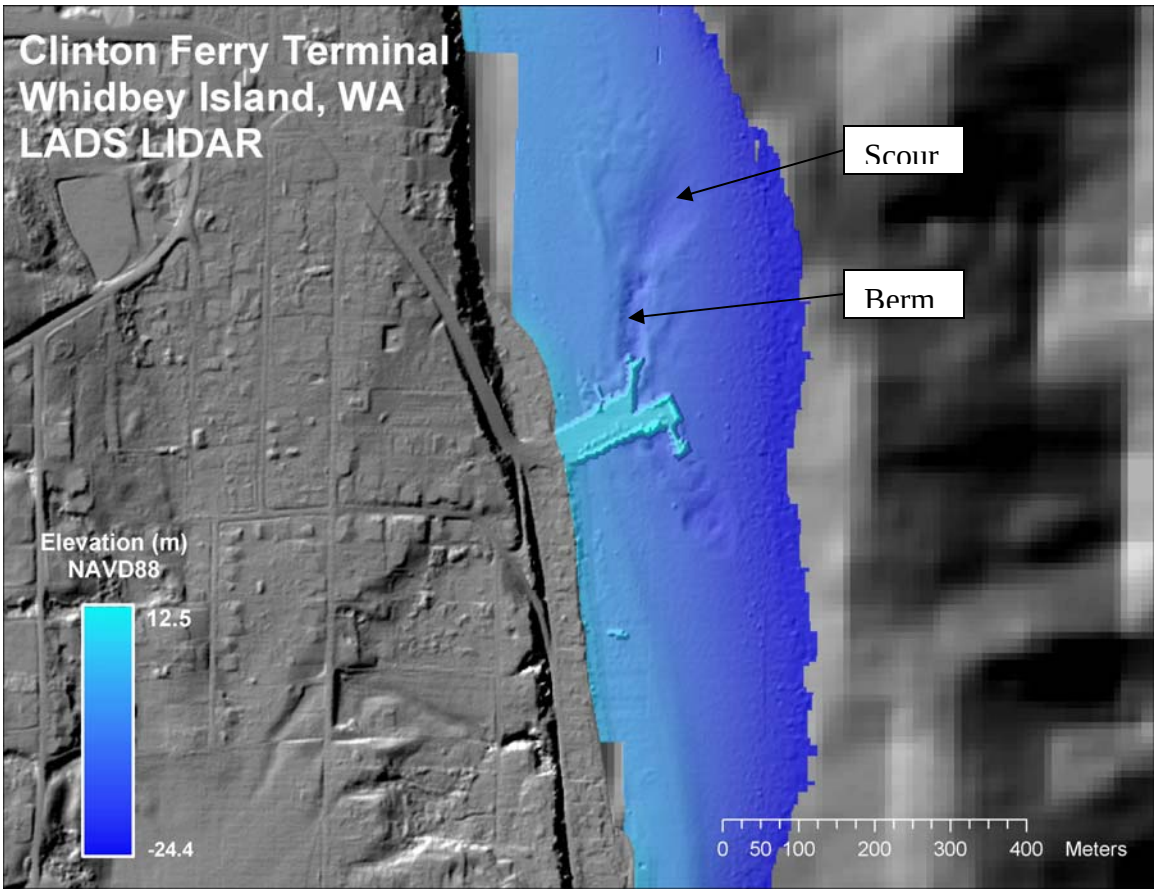

Figure 7 - Columbia River upstream from the Wenatchee.

Figure 8 - Wenatchee River near the confluence with the Columbia.

Figure 9 - Columbia River at Grant and Kittitas County lines.

Figure 10 - Columbia River near Wanapum Dam.

Figure 11 - Yakima River in the City of Yakima.

Figure 12 - Yakima River near the confluence with the Columbia.

Figure 13 - Columbia River at the confluence with the Snake.

Figure 14 - Snake River at the confluence with the Palouse.