# East Kitsap County Nearshore Habitat Assessment and Restoration Prioritization Framework

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Port Orchard, Washington 98367

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# Executive Summary

The East Kitsap County Nearshore Habitat Assessment and Restoration Prioritization Framework is an ecological decision-support tool developed for Kitsap County to summarize the state of the nearshore and to identify priority areas for protection, restoration, enhancement, or creation within the nearshore. Funding for the project was provided by the Washington State Salmon Recovery Funding Board. The Kitsap County Department of Community Development completed the field data collection task for the project in the summer of 2007, while Battelle Marine Sciences Laboratory in Sequim, Washington, developed the conceptual model and project results. The Nearshore Assessment builds a scientifically defensible framework for assessing the potential effects of changes to nearshore ecological functions caused by human modifications to nearshore habitats. This document provides an overview of the concepts of the science behind the GIS- based model utilized in the assessment, along with a description of the methods and results.

Kitsap County's nearshore ecosystem is characterized by a wide range of conditions, ranging from fairly unmodified stretches of natural shoreline, to private residences with associated armoring structures, to highly developed industrial areas. This assessment was developed for east Kitsap County Puget Sound shoreline which extends from the south east County line in Colvos Passage north up to Foulweather Bluff (the county shore excluding the Hood Canal region and Bainbridge Island). This portion of the shoreline covers approximately 151 miles, with numerous bays and inlets and other coastal land forms, including spits, bluffs, lagoons, tide flats, stream and tidal deltas, and rocky outcrops.

The project provides Kitsap County with the needed tool to assess the condition of its marine shorelines and develop a strategic method for prioritizing and protecting habitats. The need for the assessment stems from the lack of consolidated information for historic and current nearshore habitat characteristics. Scientific information was also needed in regards to the associated ecological impacts of land-use development and modifications on these habitats.

The nearshore assessment required the fulfillment of information gaps for: nearshore habitat characteristics; current quantity and quality of nearshore habitat; physical processes that drive the nearshore environment; and for human stressors to the nearshore. Based on these information needs, the primary objectives of the East Kitsap County nearshore habitat assessment effort were to:

- Summarize baseline nearshore conditions
- Evaluate the impact of nearshore disturbances on nearshore controlling factors and nearshore physical processes
- Develop a framework for prioritizing management and restoration options for nearshore habitats and for improving ecosystem functions.
- Consolidate this information into a single, GIS-based database that can be used by planners and resource managers.

The assessment approach uses a conceptual model that is based on the best available science for the nearshore ecosystem. This model organizes the verified linkages between human impacts/actions, controlling factors and physical processes, habitat structure, and ecological functions. The approach for this assessment focused on the following components:

- Two ecologically-relevant spatial scales: site and drift cell;
- Geomorphic context based on the dominant physical processes at the site level;
- A scoring system based on the status of nine controlling factor metrics;
- A management action prioritization framework based on a two-tiered approach;
- A validation of the scoring utilizing field data on ecological indicators of functions.

Key findings of the nearshore assessment are as follows:

- East Kitsap County's shoreline represents a microcosm of what is found in Puget Sound, with moderate levels of impacts to nearshore resources, but extreme examples of high and low impacts as well. Most drift cells were considered moderately impacted by human activities.
- Of 97 drift cells on East Kitsap County, 12 were considered highly altered (score = 3.00); these are located in the most populated inlets in the County.
- Of the 516 sites, 96 (19%) were highly altered and 140 (27%) were relatively unaltered.
- The most altered process among the physical processes evaluated was wave erosion in embayments.
- The site scale data provided allows managers to determine which stressor is having the greatest effect on the nearshore ecological condition, which allows decisions as to what would be the most appropriate actions to take to improve conditions.
- Preliminary validation efforts suggest that high disturbance scores are often correlated with reduced habitat structure metrics which indicate ecological function. The validation indicates that improving processes at the site and drift cell scale will improve ecological functions. Closer examination of outliers may assist in refining assessment techniques and selecting a more appropriate suite of parameters for monitoring.
- In general, the assessment appeared to offer the right balance of detail and consistency when used as the first step in a screening process for management options.

A key application of the Nearshore Assessment results is the comparison of landscape level disturbances with site-scale disturbances as the first step in a screening process for restoration management options. In this way, recommendations are provided on the best potential areas for protection, restoration, enhancement, or creation management strategies. As a further evaluation, specific restoration projects in East Kitsap County were compared to the scores for the site and for the landscape (drift-cell) and given a recommended management option of protection, restoration, enhancement, or creation. If damages (or disturbances) are great at both scales, fewer management strategies are likely to be successful. Conversely, if damage is relatively low on both scales, there is a broader array of management options. For example, it would make little sense to restore the ecosystem at a heavily damaged nearshore site if the landscape (drift cell) upon which this site depends is also heavily damaged. A more appropriate strategy would be restoration of selected attributes of the site. The results are provided in the Appendices of the report.

In summary, the Assessment summarizes disturbances to the East Kitsap County shoreline and provided a balanced level of detail and consistency when used as the first step in a screening process for evaluating restoration management options.

# Acronyms

| | |
|---|---|
| BAS | best available science |
| CF | controlling factor |
| DPP | dominant physical process |
| DC | drift cell |
| DCD | Kitsap County Department of Community Development |
| GIS | geographic information system |
| NAU | nearshore assessment unit (also referred to as "site") |
| OHWM | ordinary high-water mark |
| WDFW | Washington Department of Fish & Wildlife |
| WDNR | Washington Department of Natural Resources |
| WDOE | Washington State Department of Ecology |
| WRIA | water resource inventory area |

# Acknowledgements

This report is the product of collaboration, information sharing, and discussion with the Kitsap County Department of Community Development (DCD), Environmental Programs. We are particularly grateful to Susan Donahue, Kitsap County Watershed Project Coordinator who provided valuable support throughout the project and led the extensive shoreline inventory with the help of numerous individuals within the Department. Kathleen Barnhart, Kitsap County Stream Team Coordinator compiled the field data and provided public outreach. David Nash, Kitsap County GIS analyst, performed work in GIS that was critical to the completion of this study and developed the extensive maps provided in the Appendices. We appreciate the efforts of the Puget Sound Nearshore Restoration Partnership (PSNRP), particularly Steve Todd and Curtis Tanner for delivering a preliminary version of the Puget Sound geomorphology database to us. The authors would also like to acknowledge the work of Greg Williams, Peter Best, Nathan Evans, Heida Diefenderfer, Chris May, and Dave Shreffler, who developed aspects of these methods for earlier studies.

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*Updated June 10, 2009

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# Tables and Figures

# 1.0 Introduction

This project was driven by the need for a tool to assess the condition of Kitsap County marine shorelines and to develop a method for prioritizing restoration projects, both as a response to the Shoreline Management Act and for resource management. Until recently, detailed information was lacking on Kitsap County's nearshore habitat characteristics and the associated ecological impacts of land-use development and modifications on these habitats. General information was needed on the following:

- Nearshore habitat characteristics
- Current quantity and quality of nearshore habitat
- Physical processes that drive the nearshore environment
- Human-caused stressors to the nearshore.

In 2007, the Kitsap County Department of Community Development (DCD) conducted a shoreline inventory to provide information on disturbances and other nearshore characteristics. This information provided the foundation for conducting this nearshore assessment and developing the associated framework for management action and restoration prioritization (Kitsap County, DCD, Shoreline inventory methodology provided in Appendix A)

## 1.1 Study Area

Kitsap County is located on the west side of the central Puget Sound Basin. It has a population of approximately 247,000 people and encompasses approximately 400 square miles. This assessment was developed for East Kitsap County (Figure 1), which extends from the southeast County line in Colvos Passage north to Foulweather Bluff (the county shore excluding the Hood Canal region and Bainbridge Island). This portion of the shoreline is approximately 155 miles in length, encompassing numerous bays and inlets and other coastal land forms including spits, bluffs, lagoons, tide flats, stream and tidal deltas, and rocky outcrops.

Kitsap County's nearshore ecosystem is characterized by a wide range of conditions, ranging from relatively unmodified stretches of natural shoreline to private residences with associated armoring structures to highly developed industrial areas. According to the recent shoreline inventory conducted by Kitsap County, approximately 42% of the eastern shoreline has some type of armoring or modification. In addition, Kitsap County's population has grown approximately 2.1% yearly over the past 15 years. In terms of direct stress on the nearshore, over the past four years, the County has received over 3,600 permit requests for shoreline development, the majority for single family dwellings.


**Figure 1. East Kitsap County study area (shoreline is highlighted in gray).**

## 1.2 Project Objectives and Benefits

The goal of this nearshore assessment is to develop a science-based protocol for determining priorities and strategies for improving nearshore ecosystem functions. The primary objectives of the East Kitsap County nearshore habitat assessment effort were the following:

- Conduct a field inventory of shoreline features;
- Delineate assessment units at “site” and “landscape” scales;
- Characterize the ecological features and conditions within those assessment units;
- Provide a baseline assessment of disturbances to nearshore ecological functions using repeatable methods;
- Consolidate this information into a single, GIS-based database for use by planners and resource managers;
- Validate the disturbance results by evaluating habitat structures indicative of ecosystem functions, including juvenile salmonid habitat.
- Develop a framework for prioritizing preservation and restoration of nearshore habitats used by salmonids.

Ultimately, this information will form the scientific basis for future preservation and conservation, as well as appropriate restoration actions[1] and will assist in the revising of the Kitsap County Shoreline Master Program and in supporting future management actions in the nearshore region.

## 1.3 Assessment Approach

This assessment builds upon research conducted over the past decade. Studies include the Best Available Science (BAS) review conducted for the City of Bainbridge Island (Williams et al. 2003), the Bainbridge Island Nearshore Assessment (Williams et al. 2003), the Lower Columbia River Restoration Prioritization Framework (Evans et al. 2006), and the Jefferson County Nearshore Assessment (Diefenderfer et al. 2006; Diefenderfer et al. in press). These studies and associated documents are recommended as a reference for detailed descriptions and background documentation.

The role of this assessment in the overall nearshore habitat management process is that of a screening tool. It can serve as a basis for prioritizing areas for preservation and restoration along the East Kitsap County shoreline and provide a baseline for future comparison and evaluation. This assessment is based on the principle that anthropogenic alterations of shorelines impact nearshore ecological functions and habitats. Geospatial field data recently collected by the Kitsap County Department of Natural Resources were used as the basis for quantifying nearshore habitat modifications and habitat structural attributes (Kitsap County 2007). This dataset provided detailed information (e.g., extent and number of modifications, length of armoring, stormwater outfalls) that assisted in quantifying impacts to controlling factors and physical processes within a particular reach of shoreline. Landscape ecology and geomorphic context were two critical elements for creating the conceptual framework for East Kitsap County shorelines; the assessment was conducted on a "site" scale consisting of distinct geomorphic units and incorporates the drift cell and watershed for the landscape context. Figure 2 provides an overview of the assessment approach, which employs a framework consisting of two tiers as follows:

<u>Tier I – GIS Based Assessment</u>

Development of conceptual model

A conceptual model of ecosystem interactions is developed for the study site. This model outlines the effect of stressors (disturbance) on the factors controlling ecosystem structure, which in turn affects the functions and processes that result from the ecosystem structure.

Representation of elements spatially

After development of a conceptual model, spatial datasets are selected to either measure or approximate these functions and stressors, and the geographic units of analysis are identified. Our analyses and tools include evaluation of ecosystem function and disturbance on multiple spatial units. This permits us to evaluate how a site fits in with landscape scale processes and functions.

Development of weighting and scoring

Among the more difficult decisions in creating a nearshore model is determination of the relative weighting and scoring of the components that are selected when exact quantitative relationships between an ecosystem stressor and its impact are often unknown (NRC 1992). For ecosystem stressors, this is often the case. We summarize datasets based on length, area, and frequency of occurrence within a specific site and use quintiles or equal breaks in the data to rank sites for each factor from low to high (see Judd et al. 2007). This permits sites to be evaluated against one another, but does not permit the exact scoring scheme to be applied in another area.

[1] Restoration actions can include restoration to historic conditions, enhancement of certain attributes, or creation of habitat. Discussed in detail in Section 3.2.2.

Validation of results

Model results are evaluated against known conditions as a qualitative evaluation of model accuracy.

<u>Tier II – Prioritization Framework</u>

Prioritization

In order to prioritize management actions or restoration projects, the results of the disturbance-based GIS analysis can be used to identify the best potential areas for protection, restoration, enhancement, or creation. The tool itself does not identify specific projects for management actions; however, the Tier II analysis can be used to evaluate potential and existing Kitsap County projects using the results of the disturbance-based analysis.

Tier I, the GIS-based assessment should be considered a living management tool, with additional data incorporated as ongoing research clarifies our understanding of nearshore ecological processes and functions and as assessment methods are further refined. We wish to emphasize that this is a screening tool and as such, the assessment provides a framework for guiding future action. This tool will be made the most effective by involving local expertise who are familiar with the East Kitsap County shoreline, its ecological resources, and the relationship between alteration and impact.

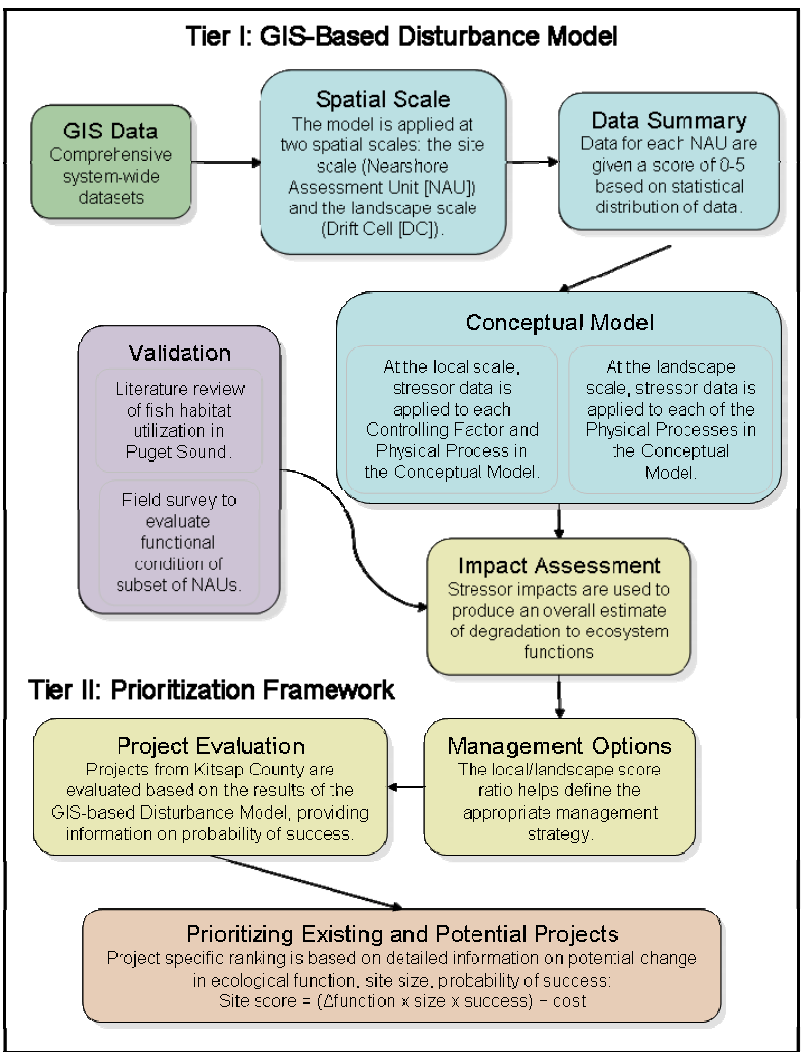


**Figure 2. Diagram of nearshore assessment and prioritization approach.**

## 1.4 Background

The theory behind the nearshore assessment approach has developed over recent decades and is based on the application of several ecological theories. The background of the adaptation of these theories to the current approach is described briefly below.

### 1.4.1 The Nearshore Conceptual Model

Conceptual models are often incorporated into all types of assessments as a device for describing the causal relationship among land use, stressors, valued ecological resources at risk, and their associated endpoints and indicators (Thom and Wellman 1997, Gentile et al. 2001). By understanding the basic scientific foundation regarding which factors control ecosystem structures, processes and functions, scientists and managers have a better idea of what stresses or disturbances may adversely affect them. Several regional assessments include conceptual model as part of their approach. The Kitsap Salmonid Refugia Study (May and Peterson 2003) integrates conceptual models of watershed function and salmon population dynamics to identify those habitats critical to sustaining remaining native salmon populations. The Puget Sound Nearshore Restoration Project also developed a conceptual model to aid in assessing restoration and preservation measures in Puget Sound (Simenstad et al. 2006).

The conceptual model developed for the current study builds upon the best available science for the region. This information is available through a previous study, which summarized the existing scientific literature as it relates to the nearshore environment of Bainbridge Island (Williams et al. 2003). The model is also based on work developed by Williams and Thom (2001), which states that habitat structure, habitat processes, and ecosystem function are driven by the physical processes and controlling factors (Figure 3). Controlling factors are environmental conditions that control local habitat structure and composition (e.g., vegetation, substrate), including where habitat occurs and how much is present. Alterations to these controlling factors can have effects that propagate to the functional level of ecosystems. On this basis, the nearshore assessment approach evaluates stressors to the controlling factors and physical processes as a proxy for ecosystem degradation. This provides a clear and repeatable method for assessing ecosystem impacts using existing data. The metrics of the conceptual model are provided in (Table 1). Stressors were identified in the Kitsap County nearshore inventory in summer 2007 (refer to Appendix A for a summary of the data collection methods). Additional stressor data sets were included in the assessment as available (see Table 3).

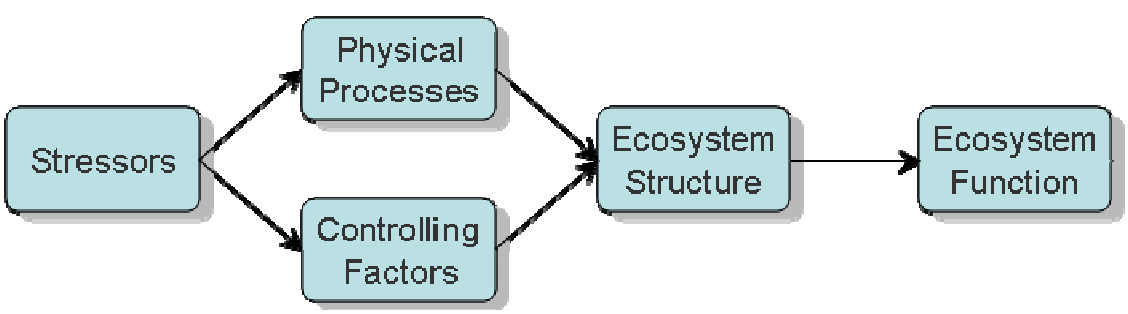


**Figure 3. Simplified conceptual model adapted from Williams and Thom (2001).**

**Table 1. List of major Controlling Factors, Physical Processes, Habitat Structures, Habitat Processes, and Ecological Functions from conceptual model of Puget Sound nearshore ecosystems.**

| Controlling Factors | Physical Processes | Ecosystem Structure | Ecosystem Processes | Ecosystem Functions |
|---|---|---|---|---|
| • Wave Energy<br>• Light<br>• Water Quality<br>• Depth/Slope<br>• Substrate<br>• Physical Disturbance<br>• Hydrology | • Sediment Supply and Transport<br>• Wave Erosion<br>• Tidal Erosion<br>• Wave Deposition<br>• Fluvial Deposition | • Density<br>• Biomass<br>• Length/Size<br>• Diversity<br>• Landscape Position<br>• Patch Shape<br>• Patch Size | • Production<br>• Sediment Flux<br>• Nutrient Flux<br>• Carbon Flux<br>• Landscape Connectivity or Fragmentation | • Prey Production<br>• Reproduction<br>• Refuge<br>• Carbon Sequestration<br>• Biodiversity Maintenance<br>• Disturbance Regulation<br>• Migration Corridors |

### 1.4.2 Nearshore Landscape Ecology

Landscape ecology addresses how the spatial extent, heterogeneity, and geometry of landscape elements (e.g., habitats) affect the flow of energy, biota, and materials through the landscape. Human activities fragment natural landscapes into fewer and smaller pieces at an alarming rate, limiting connectivity and flow of materials between habitat fragments and in some cases causing the local extinction of populations (Weins 1985; Gonzales et al. 1998; Earn et al. 2000). Restoration projects are now utilizing the concepts and principles of landscape ecology to improve the functions and success of restoration projects (Kentula 1997).

Of particular relevance to estuarine and marine nearshore ecosystems are the landscape concepts of habitat size, shape, and accessibility (Simenstad and Thom 1992; Shreffler and Thom 1993; Simenstad and Cordell 2000; Bottom et al. 2005). Knowledge of the behavioral patterns of target species or species groups is essential to refining the site selection and design process for management decisions (e.g., restoration) for a particular habitat. The National Research Council (1992, 2001) recommends that systems should adopt a dynamic perspective that considers current and future conditions at the site and in the surrounding landscape. A dynamic, landscape oriented approach could mean preserving buffers and connectivity to other habitats around a particular site.

In Puget Sound, the marine nearshore landscape encompasses the interface between subtidal marine habitats and the upland watershed (including the riparian zone), which is shaped by alongshore processes that affect sediment transport and aquatic species movement patterns. These shoreline processes must continue to function appropriately across the entire landscape to sustain shoreline habitats and ecological functions in a long-term, resilient condition (Williams and Thom 2001; Best 2003; Thom et al. in review). Further, these processes must be intact for restoration of habitat structure to be successful and self-maintaining (Simenstad et al. 2006).

With this in mind, this assessment was designed to examine impacts to nearshore processes at two spatial scales (Williams et al. 2004; Diefenderfer et al, in press). The larger, landscape scale is defined by drift cells, analogous to upland watersheds, which define sediment transport processes that form the basis for establishing and maintaining habitat structure and function (Figure 3). A drift cell is comprised of multiple sites, which are scaled to current or historic geomorphic conditions. Geomorphology and energy often define or are commonly associated with distinct biological communities (e.g., halophytic plant assemblages in marsh and lagoon settings; Dethier 1990). The smaller site scale is defined as one cohesive ecological unit. The site is our minimum unit for analysis to evaluate the impact of a disturbance or restoration action and is termed the nearshore assessment unit (NAU) in this study. The distribution of biological communities is largely affected by the local environmental conditions that occur at this smaller geographic scale. For example, the local combination of controlling factors, such as slope, elevation/depth, hydrology, and wave energy, define the type of vegetation and substrate (habitat structure) that occurs in that area.

A third spatial scale was incorporated into the assessment to evaluate impacts from watersheds emptying into the nearshore. Kitsap County is located on a relatively flat peninsula and therefore has no large river systems or watersheds; however, inputs from the existing watersheds could influence the nearshore and were assessed to the extent possible with the available information. Watershed characteristics, such as percent impervious surface and agriculture for the larger watersheds in the study area were recorded for the site assessment unit that they fed into, and then aggregated based on the drift cell that they resided in following Diefenderfer et al. (in press).

### 1.4.3 Geomorphology and the Conceptual Model

The shoreline's geomorphic setting provides not only the basis for deriving consistent comparisons between nearshore structure and function, but also a context for comparing existing conditions with historical conditions and setting restoration goals. The nearshore conceptual model (Figure 3) can be refined by a shoreline's geomorphic setting to provide better predictive relationships between the physical processes, the nearshore controlling factors, and ecological function. The refined model focuses on six controlling factors and five physical processes used in the assessment framework (described in Section 2.5).

### 1.4.4 Restoration Ecology

Overall, the model developed here relies on restoration of controlling factors and physical processes as the key to successful and long-term sustainability of the nearshore. High stress at the landscape scale minimizes the ability of the degraded processes in the landscape to form and maintain habitats at sites within the landscape. Conversely, sites within a landscape that are relatively undisturbed probably can be restored to historical conditions. In these cases, sites and landscapes should be protected from further disturbances or measures to conserve the biodiversity within the sites and landscape should be applied.

The potential management options discussed in this assessment are as follows:

**Protect** = exclude disturbances;
**Conserve** = maintain the current level of biodiversity;
**Restore to historical condition** = restore structure and functions of the sites to historical conditions based on available historical records;
**Enhance** = improve the structure and functions of a site or landscape beyond current conditions;
**Create** = develop a habitat or function that did not formally exist at a site or landscape.

# 2.0 Methods

This assessment was developed for East Kitsap County (Figure 1). As described in the Assessment Approach overview (Section 1.3), the methods for this approach focus on translating quantitative data on shoreline disturbances into an assessment of nearshore condition. Described below are the specific data sources and methods used for classifying shorelines into geomorphic classes, defining and scoring assessment metrics within a framework derived from the nearshore conceptual model, and using a field study to evaluate ecosystem function as a means of validating this assessment.

## 2.1 Assessment Framework

The nearshore conceptual model used in this assessment was developed to help predict or understand natural and human-caused effects on Puget Sound nearshore ecological functions (Williams and Thom 2001), as described in the Section 1.3.1. This model illustrates the interactions that occur between stressors, controlling factors (e.g., depth, wave energy, light) and physical processes (e.g., sediment transport), habitat structure, habitat processes, and ultimately, ecological functions in nearshore ecosystems (Figure 3). The model also provides the framework for summarizing the current level of scientific knowledge associated with effects of shoreline modifications to geomorphic classes in the nearshore environment of East Kitsap County. As such, the material presented in this assessment is not only guided by, but also builds upon, several previous studies including the Best Available Science (BAS) report conducted for the City of Bainbridge Island (Williams et al. 2003), the Bainbridge Island Nearshore Assessment (Williams et al. 2003), the Lower Columbia River Restoration Prioritization Framework (Evans et al. 2006), and the Jefferson County Nearshore Assessment (Diefenderfer et al. 2006; Diefenderfer et al. in press). These documents are recommended as a reference for detailed descriptions and background documentation.

Figure 2, provides an overview of the assessment approach and is discussed in detail in the following sections. Briefly, the assessment metrics represent six controlling factors and five dominant physical processes from the conceptual model, which are considered the primary drivers of nearshore ecological function. Each metric is ranked using a four-point scale (0 to 3), which is applied according to the potential effect of a disturbance on the assessment unit. The total unit score is additive, but can be scaled up within the landscape. Scoring criteria are based on the Bainbridge Island Best Available Science Report (Williams et al. 2003), with critical values derived from simple percentile distribution analysis to separate classes of impact.

## 2.2 Spatial Scale

This assessment of nearshore condition was evaluated at two nested spatial scales (Figure 4). The first scale uses *drift cells* to define mutually exclusive ecological units (Figure 5). Drift cells "act as closed or nearly closed systems with respect to transport of beach sediment" (Schwartz et al. 1991) and form the basis for establishing and maintaining habitat structure, ecological processes, and ecological functions. Drift cells may converge (e.g., form points) or terminate into areas considered to lack longshore drift (e.g., back bays), and therefore coalesce to form larger interrelated systems, just as upland watersheds may include aggregations of smaller watersheds or subbasins. Drift cells were originally delineated in Kitsap County through a series of master's theses at Western Washington University and later republished in a series of reports by the Washington State Department of Ecology (WDOE) (Schwartz et al. 1991, Taggart 1984). Kitsap County contracted with Coastal Geologic Services, Inc. (CGS) in 2007 to evaluate and update the drift cell boundaries for the East Kitsap County shoreline (Johannessen and MacLennan 2007). The original maps and descriptions were used in conjunction with recent oblique and vertical aerial photos to verify and correct the WDOE digital files of net shore-drift in the study area. Corrected data products were supplied in ArcMap shapefiles to Kitsap County.

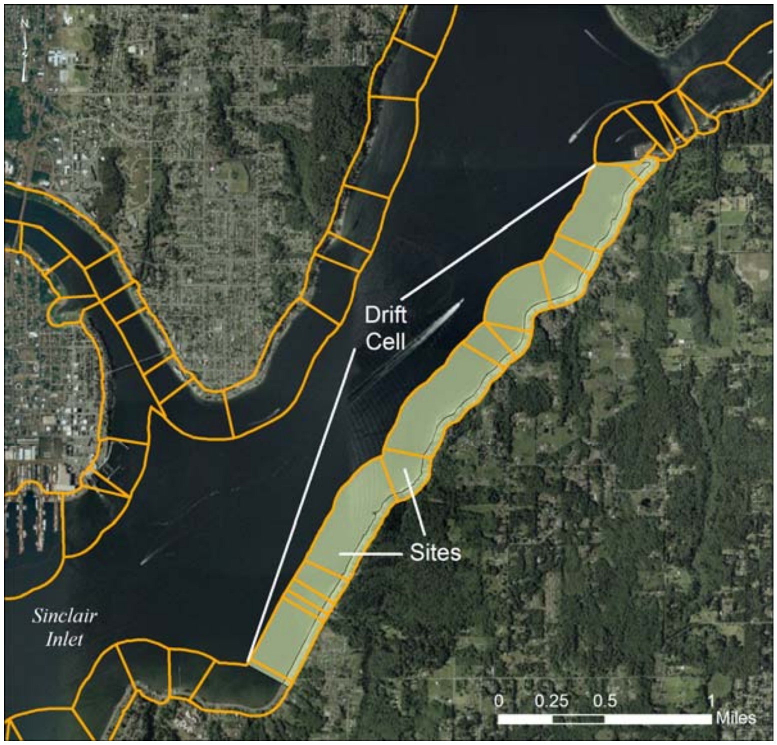


**Figure 4. Example of site scale and drift cell scale assessment units. Sites are symbolized by the smaller polygons with orange boundaries and the drift cell boundary is shown in light green.**

At the second spatial scale, the site scale, nearshore assessment units (NAUs) were created based initially on Washington Department of Natural Resources (WDNR) ShoreZone Inventory (WDNR 2001) and further subdivided and grouped based on an updated geomorphology classification (Figure 6; Todd et al., 2008). A total of 516 nearshore assessment units were delineated in East Kitsap County.

Each NAU extended 200 ft upland and 1000 ft seaward from the shoreline, and boundaries were drawn at a ninety degree angle to the shoreline where possible. In narrow inlets, where a 1000 ft buffer was not possible, units were joined mid-bay. Each NAU contains an identifying code based on the ShoreZone Inventory identification. As some ShoreZone units were further divided based on geomorphology or nearshore drift, an additional attribute was added, identifying whether each is unit 0, 1, 2, or 3 for a specific site. In addition, a unique Unit ID was developed for each NAU. An attribute ‘Length’ was also added which represents the length in feet of the shoreline present in each unit, and ‘Area’ which is the total area in square feet.

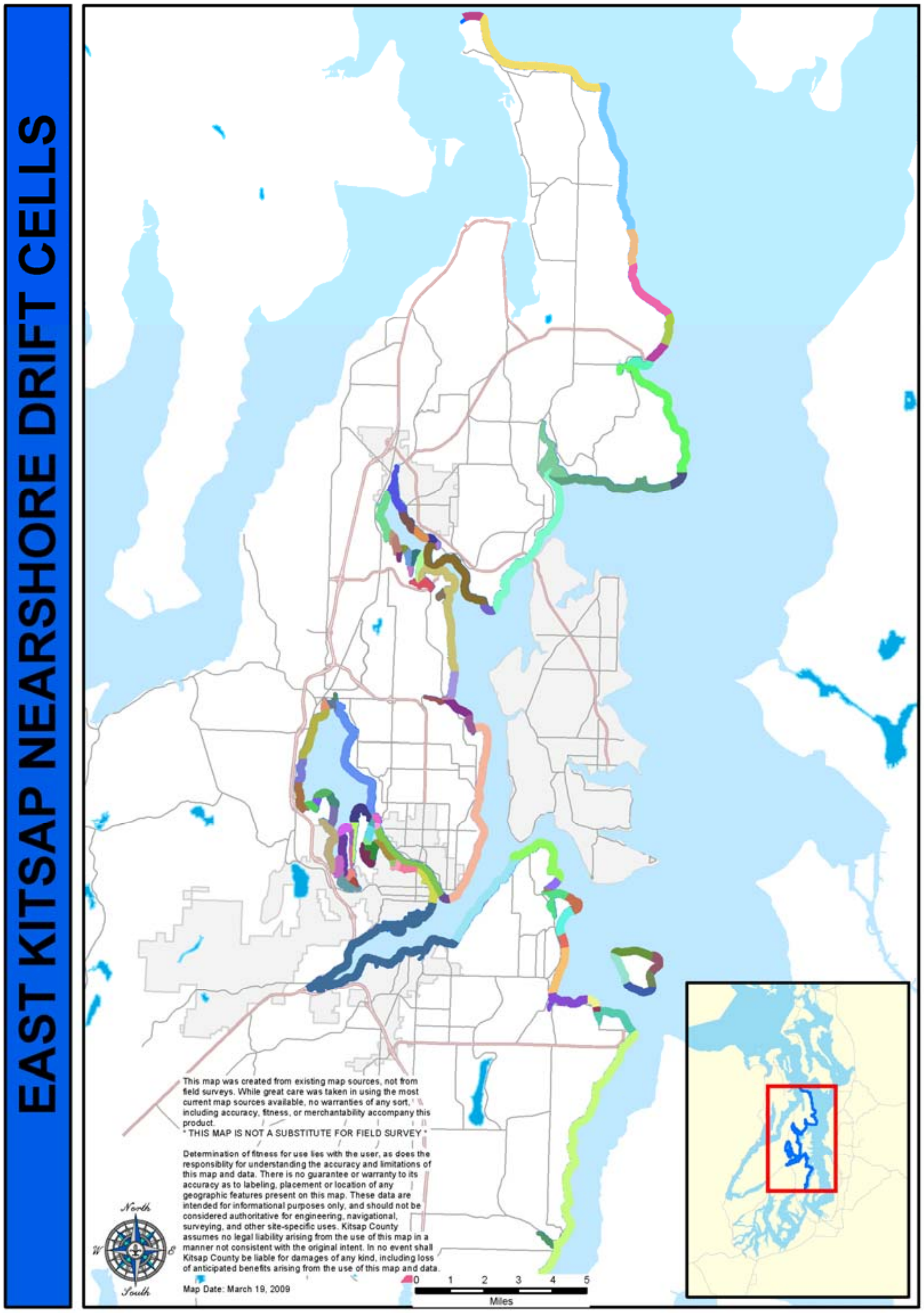


**Figure 5. East Kitsap County drift cells (based on delineation by Johannessen and MacLennan 2007). Drift cells are colored to show boundaries. Maps provided by Kitsap County Department of Community Development.**

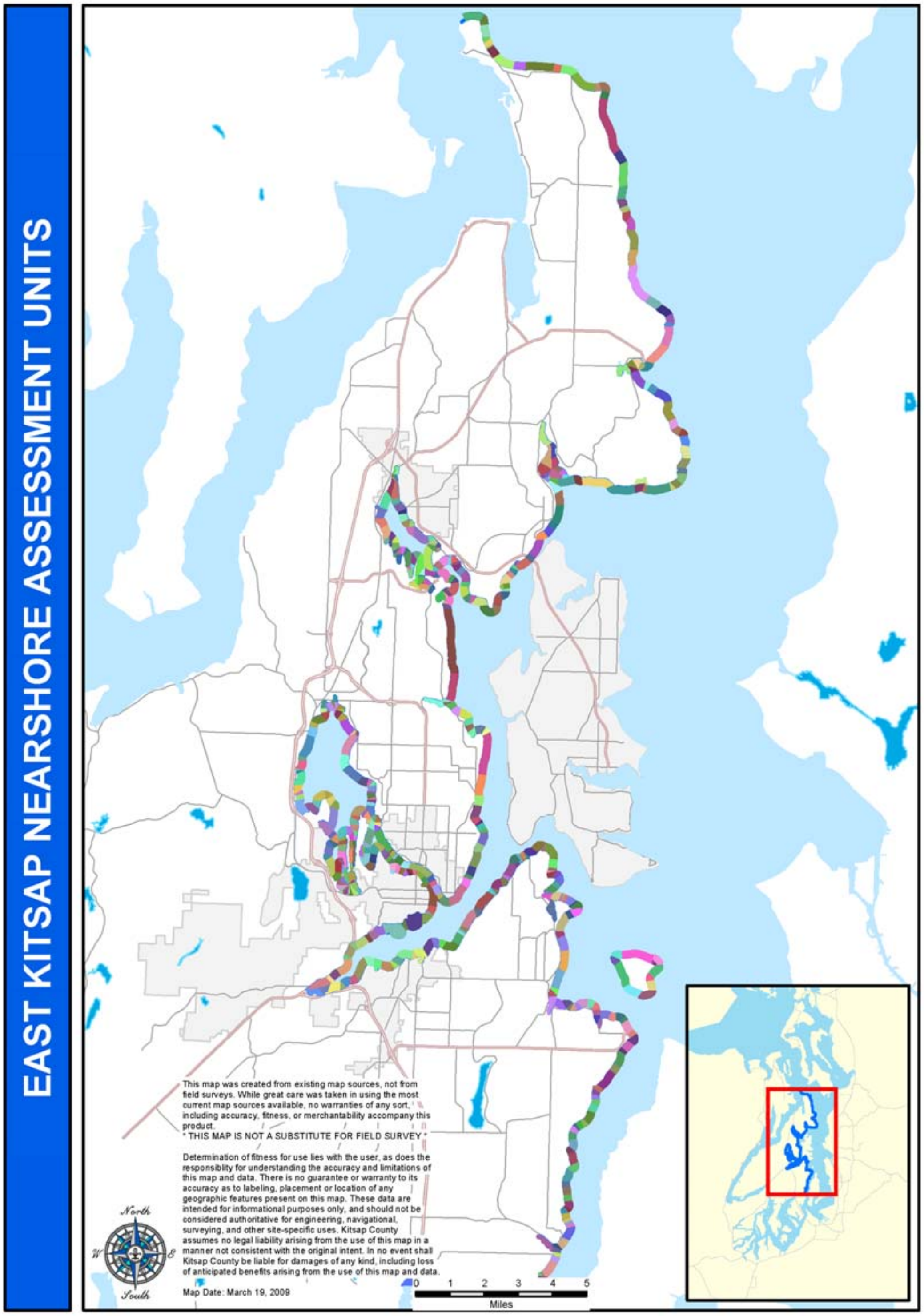


**Figure 6. East Kitsap County nearshore assessment units (NAUs), based on WDNR ShoreZone classification (NAUs are also termed "sites" in text). NAUs are colored to show boundaries. Maps provided by Kitsap County Department of Community Development.**

Watersheds were assessed to the extent that they would affect the nearshore (Figure 7). Watershed characteristics, such as percent impervious surface and agriculture for larger rivers and stream watersheds were recorded for the NAU that they fed into, and then aggregated based on the drift cell that they resided in, following Diefenderfer et al. (in press). Watershed statistics were gathered from the 2001 National Land Cover Dataset and watershed boundaries were based on Kitsap County Salmonid Refugia Study (May and Peterson 2003).


**Figure 7. Example of watershed assessment units shown outlined in yellow and the nearshore drift cell assessment units outlined in pink.**

## 2.3 Defining Dominant Physical Processes

The Kitsap County shoreline contains a diversity of shoreline features and dominant physical processes. A stressor would likely impact different geomorphic shoreline classes differently and therefore they must be assessed separately. The Puget Sound Nearshore Partnership has developed a geomorphic classification and typology for the nearshore of Puget Sound (Shipman 2008). This typology has provided a guide for the development of a GIS database of geomorphic units and contributing dominant processes for the Puget Sound shoreline by a multi-organization group for the Puget Sound Nearshore Partnership (Todd et al. 2008). Currently, the database is still in development; however, a draft version for the region of East Kitsap County was made available for use in this assessment. Through this prior study, dominant physical processes were defined for specific geomorphic systems (Table 2). The landforms that evolve from the geomorphic processes are provided in Table 2; however, they were not used in this assessment. In this analysis, we characterized how stressors would impact each dominant process through a 'Stressor-Process' score for each NAU, based on the defined geomorphic class.

**Table 2. Geomorphic classification used in the East Kitsap County Assessment.**

| System | Dominant Process(es) | Landform |
|---|---|---|
| Embayments | Tidal erosion | Tidal Channel Marsh |
| | Tidal erosion and wave deposition | Tidal Channel Lagoon |
| | Tidal erosion and fluvial deposition | Drowned Channel |
| | Tidal erosion, wave deposition, and fluvial deposition | Drowned Channel Lagoon |
| | Tidal erosion and fluvial deposition | Tidal Delta |
| | Wave deposition, tidal erosion, and fluvial deposition | Tidal Delta Lagoon |
| | Fluvial deposition | Delta |
| | Fluvial and wave deposition | Delta Lagoon |
| | Onshore wave erosion (no adjacent sediment source) and/or fluvial deposition and/or tidal erosion | Pocket Beach Lagoon |
| | Onshore wave erosion (no adjacent sediment source) | Pocket Beach |
| | Wave deposition and tidal erosion | Longshore Lagoon |
| Open | Fluvial deposition (minor variation along a wave dominated shoreline) | Beach Seep |
| | Wave deposition | Depositional Beach |
| | Wave erosion, no net sediment gain or loss<br>Sediment transport | Sediment Source & Transport Beach |
| | Wave deposition | Barrier Beach |
| Rocky | Onshore wave erosion (no adjacent sediment source) and/or fluvial deposition and/or tidal erosion | Pocket Beach |
| | Little or no evidence of coastal or tidal erosion, no fluvial processes. no beach development | Rocky Beach |
| | Wave deposition<br>Sediment transport | Veneered Rock Platform |

Source: Adapted from Shipman (2008) and *Aundrea McBride*[2] *and Steve Todd*[3] *(personal communication).*

[2] Aundrea McBride, Research Ecologist/Geologist, Skagit River System Cooperative, LaConner, WA.
[3] Steve Todd, Habitat Biologist, Point-No-Point Treaty Council, Kingston, WA.

*Pre-processing*
The geomorphic database described above was reviewed and simplified for use in this project. Within the original classification, a given ShoreZone Unit may have had more than one geomorphic classification. Each unit was reviewed and either classified as one geomorphic unit for the purposes of this analysis, or split into more than one analysis unit (NAU; Figure 8). For each NAU, four geomorphic attributes were added characterizing the following:

1. Dominant Process
2. Secondary Process
3. Presence of beach seeps
4. Larger geomorphic context (Embayment, Open shoreline, or Rocky Shoreline) of the unit.

**Figure 8. Example of a case in which a ShoreZone Unit was split into two NAUs based on the geomorphology. The lower unit was classified as a delta and the upper as a drowned channel.**

## 2.4 Data Compilation and Processing

Spatial datasets used for all aspects of the assessment are summarized in Table 3 and include data from the East Kitsap County Inventory and ancillary data sources. To create a final, comprehensive geodatabase, these elements were summarized as attributes within one shapefile. Most features were recorded both in quantity and in a standardized format of that quantity. For example, the number of stairs is recorded per assessment unit, but in addition, that number is standardized based on the length of shoreline present in the unit, and standardized count per 1000 ft is recorded. For linear, polygon and raster features, percent of shoreline and percent of total area is recorded. For land based calculations, such as impervious surface, percent excluded water classes. Processing was carried out in ArcGIS with a PYTHON-based script.

**Table 3. Data Sources for the East Kitsap County Assessment.**

| Feature | Data Source | Data Type | Element Recorded |
|---|---|---|---|
| **Stairs** | Kitsap Nearshore Inventory | Point | Standardized count |
| **Paths** | Kitsap Nearshore Inventory | Point | Standardized count |
| **Public Use** | Kitsap Nearshore Inventory | Line | Shoreline (ft) where use included 'Public' |
| **Shoreline Armoring** | Kitsap Nearshore Inventory | Line | Percent of shoreline armored |
| **Boat Launches** | Kitsap Nearshore Inventory | Point | Standardized count |
| **Buoys** | Kitsap Nearshore Inventory | Point | Standardized count |
| **Outfalls on beach** | Kitsap Nearshore Inventory | Point | Standardized count; includes both pipes and culverts, only elements above 12" or multiples of 9-12." |
| **Culverts** | Kitsap Nearshore Inventory | Point | Standardized count |
| **Overhanging Structures** | Kitsap Nearshore Inventory | Point | Standardized count |
| **Piers & Docks** | Kitsap Nearshore Inventory | Point | Standardized count; divided into those with floats and those with without |
| **Marinas & Docks** | Kitsap County | Polygon | Percent of unit covered by Marinas |
| **Pilings** | Kitsap Nearshore Inventory | Point | Standardized count; estimated number of pilings per unit |
| **Groins** | Kitsap Nearshore Inventory | Point | Standardized count |
| **Geomorphology** | PSNRP | Line | Dominant physical process for unit |
| **Heavily modified** | Geomorphology Dataset, PSNRP | Line | Presence of more than 200 ft within unit. Percent of shoreline with urban waterfront. Zones not reached by inventory. |
| **Water Quality** | Kitsap County | Point | Presence of station exceeding WQ standards within 500ft of unit |
| **Fish Pens** | NOAA, Electronic Navigation Charts, Aerial Imagery | Polygon | Presence |
| **Navigation Channels** | NOAA, Electronic Navigation Charts | Polygon | Presence |
| **Impervious Surface** | National Land Cover Dataset 2001 | Raster, 30m | Percent imperviousness in watershed; Percent imperviousness within 200ft zone |
| **Agriculture** | National Land Cover Dataset 2001 | Raster, 30m | Percent agriculture in watershed and within 200 ft buffer in upland |
| **Areas of Lost Historical Streams & Marshes** | Historic T-sheets, UW PRISM, National Wetland Inventory | Line & polygon | Presence of Historic Stream or Wetland which is no longer present |
| **Areas of Intertidal Fill** | Historic T-sheets | Polygon | Percent of Drift Cell |
| **Watershed Boundaries** | Salmonid Refugia (May and Peterson 2003) | Polygon | None |

## 2.5 Assessment Scoring

Three models were developed, representing the following:

- Level of **direct disturbance on the controlling factors** for nearshore assessment units;
- Level of **local disturbance to processes** for nearshore assessment units;
- Level of **landscape disturbance on processes** for drift cell units.

The controlling factors in East Kitsap County assessment are listed below:

- Substrate Type
- Wave Energy (Embayment)
- Wave Energy (Open Shoreline)
- Wave Energy (Rocky Shoreline)
- Depth/ Slope
- Light
- Frequency of Disturbance
- Water Quality

In addition to the controlling factors listed above, dominant physical processes act to shape the geomorphology of the shoreline. The processes used in this study were determined by a multi-agency study funded by the Puget Sound Nearshore Restoration Partnership as follows:

- Sediment Transport
- Wave Erosion (Embayment)
- Wave Erosion (Open shoreline)
- Fluvial Deposition
- Tidal Erosion
- Wave Deposition

### 2.5.1 Scoring

The amount of disturbance (stress) at each site was standardized by either length or area of assessment unit. Sites were then scored based on quintile[4] breaks in the stressor dataset. Sites (NAUs) that fell within the first quintile received a score of 1 for the stressor in question, the second quintile, 2 and so on. Sites without the stressor present were given a score of 0. The exceptions to this scoring method were net pens, navigation channels, and water quality. For each of those stressors, sites received a score of zero if absent and five if the stressor was present. In addition, for water quality, all sites within 500 ft of a monitoring station that did not meet water quality standards, were also assessed as having poor water quality, and given a score of 5. Heavily modified areas were assessed using percent of shoreline classified as modified in the site scoring and presence/absence of modified areas in the drift cell scoring.

[4] Quantiles are regular divisions of the cumulative distribution (percentile) of a variable, in this case stressors. We used five groups, or quintiles to group the data. To accomplish this, standardized values for each stressor were calculated for each assessment unit. Each site was then ranked based on the amount of stressor present in relation to other sites and a percentile was calculated. The first quintile contains stressor percentiles 1 to 20%, the second 21 to 40%, and so forth for the five groups.

### 2.5.2 Weighting

A three-point scale was used to assign the relative impact or weight of disruption to *applicable* shoreline controlling factor and physical process metrics within each assessment unit (0 = no issue, 1 = low impact (L), 2 = moderate impact (M), 3 = high impact (H)). The weighting applied to the controlling factors and the physical processes are summarized in Table 4 and 5. Only the physical processes identified in the geomorphic database as being the dominant process for each NAU were scored. The potential score for each disturbance (P) is determined by multiplying weighting by the highest possible score (5):

$$P = 5*\text{weighting}$$

The total potential score is the sum of P for each controlling factor and process. The scores were normalized based on the total potential score.

The overall controlling factor score for each site was calculated by averaging the scores for all the controlling factors. The overall physical process scores were calculated by averaging only the scores for the processes that were identified as dominant in the NAU.

**Table 4. Categorization of the effects of direct disturbances on the controlling factors. Each category is weighted as L=1, M=2, and H=3.**

| Direct Disturbances | Substrate Type | Wave Energy[5] (E) | Wave Energy (O) | Wave Energy (R) | Depth /Slope | Light | Frequency of Disturbance | Water Quality |
|---|---|---|---|---|---|---|---|---|
| Stairs to beach | | | | | | | L | |
| Paths | | | | | | | L | |
| Access areas | | | | | | | L | |
| Armoring | L | L | H | L | | | | |
| Boat launches | L | | L | | | | | |
| Buoys | L | | | | | | L | |
| Outfalls on beach | L | | | | L | L | | L[6] |
| Culvert | | | | | | | | L |
| Floats & docks w/ floats | | | | | | M | | |
| Piers & docks (platform only ) | | | | | | L | | |
| Pilings (includes piers with pilings) | | L | M | M | | | M | |
| Marinas | | L | H | H | M | H | H | M |
| Overhanging structures | | | L | L | | M | M | |
| Groins | | | L | M | | | | |
| Heavily modified areas | | H | M | H | M | M | H | H |
| Net pens | L | | L | M | | | | M |
| Water quality | | | | | | | | H |
| Impervious surface 200ft | | | | | | | | L |
| Navigation channel | H | H | M | L | M | | | |
| **Total Potential Score** | **40** | **45** | **80** | **75** | **35** | **55** | **70** | **65** |

[5] Wave Energy is scored based on the following geomorphic systems: E = Embayment, O = Open, R = Rocky.
[6] Only considered outfalls which were not culverts.

A category of "modified unreachable" was applied to 8 sites where all or part of the sites could not be reached during the shoreline inventory field effort. These sites were located in the vicinity of the Naval Ship Yard in Bremerton. Because these sites were known to be highly modified, the category was given a High weighting (3) to calculate the process scores. If disturbances were measured as part of the inventory or included from other GIS layers (e.g. marinas) at the 8 sites then those were included in the process score calculation also. The total score was standardized by the total potential score listed in Table 5 as explained above.

**Table 5. Categorization of the effects of direct disturbances on the physical processes. Each category is weighted as L=1, M=2, and H=3.**

| Direct Disturbances | Sediment Transport | Wave Erosion[7] (E) | Wave Erosion (O) | Fluvial Deposition | Tidal Erosion | Wave Deposition |
|---|---|---|---|---|---|---|
| **Stairs to Beach** | | L | L | | L | L |
| **Armoring** | H | H | H | M | M | H |
| **Boat Launches** | M | L | L | L | L | L |
| **Culverts** | M | | | | L | |
| **Floats and Docks with Floats** | | | H | | M | |
| **Pilings (includes Piers with Pilings)** | H | M | H | M | M | H |
| **Marinas** | M | M | H | M | M | M |
| **Groins** | H | M | H | H | M | H |
| **Total Potential Score** | **75** | **55** | **85** | **50** | **65** | **65** |

The criteria for scoring the drift cells are summarized in Table 6. Each tercile group (Low, Medium, and High) was given a score respectively of 1, 2, or 3. The overall drift cell score was an average of the three drift cell process scores (Sediment Transport, Fluvial Deposition, Tidal and Wave Processes).

### 2.5.3 Quality Control

An independent quality control (QC) exercise was conducted by calculating the site scores and the drift cell scores using formulas in a spreadsheet. At least twenty percent of the sites and drift cells were checked for consistency between methods.

[7] Wave Erosion is scored based on the following geomorphic systems: E = Embayment, O = Open.

**Table 6. Drift cell score criteria, based on disturbances to physical processes.**

| Longshore Sediment Transport | | |
|---|---|---|
| **Low** | **Medium** | **High** |
| ▪ Heavily modified category is absent[8]<br>▪ Armoring on sediment source or transport NAUs is 0-10%<br>▪ Number of groins in all NAUs within drift cell is 0 or is in the lowest tercile | ▪ Heavily modified is absent<br>▪ Armoring on sediment source or transport beaches is 10-50%<br>▪ Number of groins in all drift cell NAUs is 0 or is in the lowest tercile<br>OR<br>▪ Heavily modified is absent<br>▪ Armoring on sediment source or transport beaches is 0-10%<br>▪ Number of groins in all NAUs within drift cell is the mid or highest tercile | ▪ Heavily modified is present<br>OR<br>▪ Armoring on sediment source or transport beaches is >50% within the drift cell<br>OR<br>▪ Heavily modified is absent<br>▪ Armoring on sediment source or transport beaches is 10-50%<br>▪ Number of groins in all NAUs within drift cell is the mid or highest tercile |
| **Fluvial Deposition** | | |
| **Low** | **Medium** | **High** |
| ▪ Heavily modified is absent<br>▪ Watershed impervious surface is 0-6%<br>▪ NAUs with beach seeps are 0-6% percent impervious in the 200 ft zone<br>▪ NAUs with the dominant process Fluvial Deposition have no groins present | ▪ Heavily modified is absent<br>▪ Watershed impervious surface is 0-6%<br>▪ NAUs with the dominant process Fluvial Deposition also have groins present<br>OR<br>▪ Heavily modified is absent<br>▪ Watershed impervious surface is 6-29%<br>▪ NAUs with beach seeps are 6-29% percent impervious in the 200 ft zone | ▪ Heavily modified is present<br>OR<br>▪ Heavily modified is absent<br>▪ Watershed impervious surface is >29%.<br>OR<br>▪ Heavily modified is absent<br>▪ Watershed impervious surface is 6-29%<br>▪ NAUs with the dominant process Fluvial Deposition also have groins present<br>OR<br>▪ Heavily modified is absent<br>▪ Watershed impervious surface is 6-29%<br>▪ NAUs with beach seeps are >29% percent impervious in the 200 ft zone |

[8] Presence or absence of "heavily modified" classification based on whether a length of shoreline greater than 200 ft occurred in the drift cell.

**Table 6. (continued)**

| Tidal Erosion, Wave Erosion, and Wave Deposition | | |
|---|---|---|
| **Low** | **Medium** | **High** |
| ▪ Heavily modified is absent<br>▪ Number of groins in all NAUs within drift cell is 0 or is in the lowest tercile | ▪ Heavily modified is absent<br>▪ Number of groins in all NAUs within drift cell is in the mid tercile<br>OR<br>▪ Heavily modified is absent<br>▪ Nearshore fill is > 0 and <2% in NAUs with a dominant process of Tidal Erosion, Wave Erosion, or Wave Deposition | ▪ Heavily modified is present.<br>OR<br>▪ Heavily modified is absent<br>▪ Number of groins in all NAUs within drift cell is in the highest tercile<br>OR<br>▪ Heavily modified is absent<br>▪ Nearshore fill is >2% in NAUs with a dominant process of Tidal Erosion, Wave Erosion, or Wave Deposition |

## 2.6 Validating Assessment Scores

Nearshore assessment units were evaluated by conducting a field assessment to validate the GIS stressor-based scoring approach. The field assessment was designed to evaluate habitat structures as a proxy for ecosystem function (Figure 9). In order to connect the structure-based field effort with function for juvenile salmon, we conducted a literature review of salmon and habitat associations in the Pacific Northwest.

### 2.6.1 Literature Review

Literature on salmon and habitat associations was gathered for the years 2002-2008 to provide a means of evaluating ecosystem function. While habitat structures provide numerous ecosystem benefits, one of importance to the region is the provision of juvenile salmonid habitat. Other studies have evaluated the effect of shoreline disturbances on fish communities (Bilovik and Roggero 2008). However, the ability to conduct an intensive field survey for evaluation of fish use of nearshore habitats was beyond the scope of this study. Further, it was deemed unlikely to provide any conclusive results due to the extensive range in habitat types in Kitsap County as well as the high temporal and spatial variability of salmonids in nearshore ecosystems. The information from the review provides the first steps at linking intact habitat structures observed in the field with salmonid habitat function. The results of the review are summarized in Section 3.4.1 and in an annotated bibliography (Appendix E).

### 2.6.2 Field Validation Approach

*Site Selection*

The nearshore assessment units (NAUs) examined for the field validation were selected to represent different geomorphic types. The types were chosen based on preliminary geomorphic classification categories developed as part of a GIS-based classification for Puget Sound for the Puget Sound Nearshore Restoration Program (personal communication Steve Todd[9], May 2008). Because the classification was not completed at the time of the field validation, sites were chosen on our best estimate of their

[9] Habitat Biologist, Point-No-Point Treaty Council, Kingston, WA

geomorphic type. The sites were selected independent of the GIS-based assessment to avoid any bias in selection.

*Metric Selection*

We wanted to evaluate the functional attributes of the NAU's in comparison to the disturbances from the GIS-based assessment, therefore we chose very different metrics than those evaluated as part of the GIS assessment. Structural metrics (such as eelgrass beds and overhanging vegetation) were chosen to be representative of natural, undisturbed features expected to be present at each geomorphic type of shoreline. The chosen metrics are also known to be functional indicators within nearshore ecosystems (Adamus 2005). Information regarding the types of natural structures expected to be present and the quality of undisturbed habitats was gleaned from various literature sources (Williams et al. 2003; Higgins et al. 2005).

*Field Survey*

Structural metrics representative of functional indicators within nearshore ecosystems were systematically evaluated at each of the NAUs during June 2008. However, because the NAUs represent different geomorphic types, the specific metrics used for evaluation differed between units in some cases (Table 7).

Fourteen NAUs were evaluated during low tidal conditions (MLLW ≤ 0 ft) by a team of two experienced marine biologists. After walking the length of the unit, several predetermined structural metrics (e.g., LWD, eelgrass, wrack, vegetation, etc.) were evaluated. Within each of the structural metrics, several functional indicators were qualitatively assessed and scored. For example, within the 'Driftwood' metric, indicators including percent coverage, average width, composition, and quantity of Driftwood were assessed. To minimize observer subjectivity, scores were independently derived by the two individuals performing the assessment. If the scores were incongruent between the observers, an average of the two scores was calculated. Further information pertaining to the structural metrics and functional indicators is displayed in Appendix F.

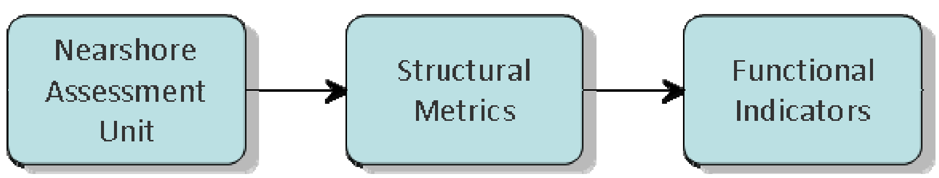


**Figure 9. Schematic approach for the field validation technique.**

**Table 7. The structural ecological metrics examined within each of the geomorphic types during the June 2008 field validation effort. The X denotes the structural metric was evaluated.**

| Structural Metric | Geomorphic Type | | | | | |
|---|---|---|---|---|---|---|
| | Rocky Shore | Tidal Delta | Pocket Estuary | Pocket Beach | Drowned Channel | Depositional/Source Transport Beach |
| Flats | NA[10] | x | x | x | x | x |
| Driftwood | NA | x | x | x | x | x |
| Vegetation | x | x | x | x | x | x |
| Eelgrass | NA | x | x | x | x | x |
| Wrack | NA | x | x | x | x | x |
| Substrate | x | NE[11] | NE | NE | NE | NE |
| Organisms | x | NE | NE | NE | NE | NE |
| Barrier | NA | NA | x | NA | NA | NA |
| Marsh | NA | x | x | NA | NA | NA |
| Tidal Inundation | NA | x | x | NA | NA | NA |
| Shade (of all marsh) | NA | x | x | NA | NA | NA |
| Shade (of low marsh) | NA | x | x | NA | NA | NA |
| Bare | NA | x | x | NA | NA | NA |
| Pannes | NA | x | x | NA | NA | NA |
| Freshwater sources | NA | x | x | NA | NA | NA |
| Marsh vegetation structure | NA | x | x | NA | NA | NA |

### 2.6.3 Field Validation Analysis

The aim of the field validation analysis was to obtain a final assessment score for each NAU evaluated and compare it with the GIS stressor score. The structural metrics (e.g., eelgrass) contained a series of functional indicators (e.g., percent cover), as well as replicate scores within each indicator. To derive a single value for each of the functional indicators, we calculated the mean of each replicate and summed the means. The final score for each of the NAUs was determined by obtaining the sum for the collective functional indicator scores (Figure 10).

[10] NA = Not Applicable
[11] NE = Not Evaluated due to constraints in evaluation methods.

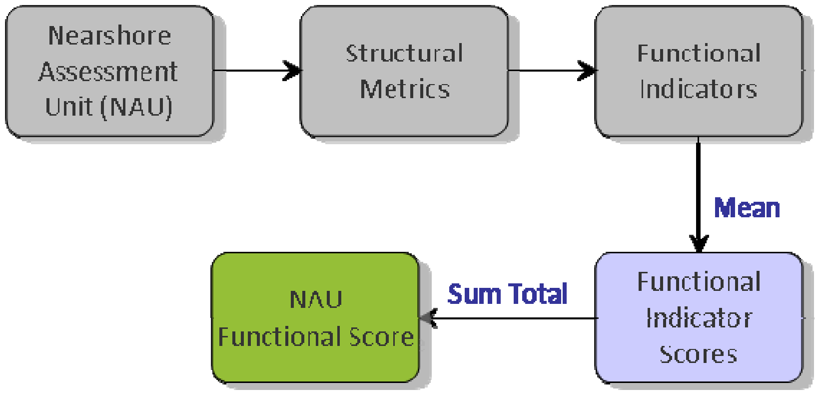


**Figure 10. Functional validation scoring schematic.**

To evaluate the scores within a specific geomorphic context, we determined the range of possible scores. Because the assessment of functional attributes was related to individual geomorphic types, the maximum possible score was not equal across geomorphic categories. To normalize the data, field validation scores were converted to represent a proportion of the total possible score for each geomorphic type. The scores were segregated into categories representing low, moderate, and high, with the breaks based on the highest possible score for each category. For example, for tidal delta the highest possible score is 80 (5 for each of 16 metrics). The highest possible moderate score is 48, which equates to a proportion of 0.60. Likewise, the highest possible low score is 16 or 0.20. Therefore, if the field validation analysis yielded a tidal delta score equal to 29 percent of the total possible score, the NAU is deemed a moderately functioning unit. These categorical characteristics reflect the existing ecosystem condition within each of the geomorphic types. The functional attribute ranges within each of the categories are a proportion of the total possible score for each geomorphic type as follows:

| | |
|---|---|
| Low | 0.00 – 0.20 |
| Moderate | 0.21 – 0.60 |
| High | 0.61 – 1.00 |

### 2.6.4 Field Validation comparison with GIS stressor scores.

The functional assessment scores (represented as a proportion to the total possible score for a given geomorphic classification) were used to evaluate the representativeness of the GIS-based stressor scores within a given NAU. Data were plotted for the visual interpretation of differences between the actual and predicted ecosystem conditions. Results are presented in Section 3.4.

# 3.0 Results and Discussion

## 3.1 Disturbance Scoring

A summary of the East Kitsap County shoreline disturbances is provided in Table 8 and Table 9, with a brief discussion of the factors that most significantly influenced scoring. Original data, controlling factor scores, dominant process scores, and drift cell scores for each site are provided in Appendix B and maps of the scoring results can be found in Appendix C.

Number of Sites = 516
Number of Drift Cells = 97

**Table 8. Stressor data quintile breakdown.**

| Stressor | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| **Stairs** | >0 - 1.09 | 1.09 - 2.64 | 2.64 - 4.05 | 4.05 - 6.36 | 6.36 - 14.3 |
| **Access Paths** | >0 - 0.54 | 0.54 - 0.78 | 0.78 - 1.18 | 1.18 - 1.92 | 1.92 - 4.93 |
| **Shoreline with Access**[12] | >0 – 569 | 570 - 847 | 848 - 1207 | 1208 - 1997 | 1998 - 7110 |
| **Armoring** | >0 - 0.23 | 0.23 - 0.53 | 0.53 - 0.74 | 0.74 - 0.94 | 0.94 - 2.25 |
| **Boat Launches** | >0 - 0.72 | 0.72 - 1.06 | 1.06 - 1.69 | 1.69 - 2.45 | 2.45 - 9.45 |
| **Buoys** | >0 - 0.97 | 0.97 – 2.00 | 2.00 - 3.15 | 3.15 - 4.61 | 4.61 - 25.8 |
| **Outfalls** | >0 - 0.67 | 0.67 - 0.96 | 0.96 - 1.41 | 1.41 - 2.28 | 2.28 - 8.83 |
| **Non-Culvert Outfalls** | >0 - 0.66 | 0.66 - 0.96 | 0.96 - 1.36 | 1.36 - 2.22 | 2.22 - 5.48 |
| **Culverts** | >0 - 0.48 | 0.48 - 0.71 | 0.71 - 1.11 | 1.11 - 1.53 | 1.53 - 6.62 |
| **Overhanging Structures** | >0 - 0.60 | 0.60 - 0.97 | 0.97 - 1.36 | 1.36 - 2.11 | 2.11 - 6.54 |
| **Heavily Modified Areas** | >0 - 0.45 | 0.45 - 0.89 | 0.89 - 0.97 | 0.97 – 1.00 | 1.00 - 2.31 |
| **Marinas** | >0 – 0.00 | 0.00 - 0.01 | 0.01 - 0.05 | 0.05 - 0.11 | 0.11 - 0.35 |
| **Piers (Decking Only)** | >0 - 0.33 | 0.33 - 0.64 | 0.64 - 0.90 | 0.90 - 1.46 | 1.46 - 4.05 |
| **Floats & Docks w/ Floats** | >0 - 0.67 | 0.67 - 0.99 | 0.99 - 1.75 | 1.75 - 2.98 | 2.98 - 7.88 |
| **Pilings** | >0 - 4.04 | 4.04 - 6.91 | 6.91 - 14.5 | 14.5 - 32.3 | 32.3 - 180 |
| **Groins** | >0 - 0.56 | 0.56 - 0.79 | 0.79 - 1.44 | 1.44 - 2.43 | 2.43 - 13.4 |
| **Groins, Drift Intercept** | >0 - 0.54 | 0.54 - 0.78 | 0.78 - 1.24 | 1.24 - 2.24 | 2.24 - 13.4 |
| **Impervious Surface** | >0 - 4.40 | 4.40 - 7.62 | 7.62 - 11.5 | 11.5 - 20.0 | 20.0 - 88.8 |
| **Agricultural Land** | >0 - 0.01 | 0.01 - 0.01 | 0.01 - 0.02 | 0.02 - 0.02 | 0.02 - 0.05 |
| **Loss of Historical Marsh** | >0 - 0.01 | 0.01 - 0.02 | 0.02 - 0.05 | 0.05 - 0.08 | 0.08 - 0.15 |
| **Loss of Historical Channels** | >0 - 0.06 | 0.06 - 0.10 | 0.10 - 0.14 | 0.14 - 0.28 | 0.28 - 0.93 |

[12] Length of shoreline in feet, where public or private access observed in shoreline inventory.

**Table 9. Summary of average standardized disturbance scores for controlling factors and dominant processes, and overall scores at the site and drift cell scales.**

| | Average Standardized Score | Range |
|---|---|---|
| Controlling Factor Scores | | |
| Substrate | 0.212 | 0 - .75 |
| Wave Energy | 0.201 | 0 - .91 |
| Slope | 0.108 | 0 - .86 |
| Frequency of Disturbance | 0.158 | 0 - .60 |
| Water Quality | 0.087 | 0 - .54 |
| Light | 0.124 | 0 - .62 |
| | | |
| Dominant Process Scores | | |
| Sediment Transport | 0.26 | 0 - 0.73 |
| Wave Erosion-Estuary | 0.37 | 0 - 0.69 |
| Wave Erosion-Open | 0.248 | 0 - 0.56 |
| Tidal Erosion | 0.226 | 0 - 0.62 |
| Fluvial Deposition | 0.267 | 0 - 0.66 |
| Wave Deposition | 0.292 | 0 - 0.75 |
| | | |
| Overall Scores | | |
| Controlling Factor Site Score | 0.148 | 0 – 0.61 |
| Dominant Process Site Score | 0.263 | 0 – 0.75 |

### 3.1.1 Nearshore Assessment Summary

The East Kitsap County shoreline used in this assessment measures 795,502 linear ft (150.7 miles). A total of 98 drift cells were evaluated, comprised of 516 individual nearshore assessment units. The shoreline is made up of numerous types of geomorphic landforms (Table 10) formed by the physical processes shown in Table 11. The smallest drift cell in East Kitsap County is located at the mouth of Dyes Inlet (DC-135; 1 NAU, 514 linear ft), and the longest encompasses the upper portion of Sinclair Inlet (DC-34; 37 NAUs, 89,043 linear ft).

Within the study area's 200-ft riparian zone (5.2 sq. miles), forested surfaces (coniferous and deciduous trees) compose 27% of land cover and agriculture 8.5%. Additionally, 12% of the area is impervious (e.g., roads, roofs). Approximately 43% of East Kitsap County's shoreline is modified by armoring; primarily rip rap and vertical structures. Of this total armoring, 84% has a portion that encroaches into the intertidal zone. A total of 11,793 point modifications were recorded along East Kitsap County shorelines (unpublished data, Kitsap County 2007), at an average density of 15.5 structures per 1000 ft. The complete data from the Kitsap County shoreline inventory is available at http://www.kitsapgov.com/dcd/nr/nearshore/default.htm).

**Table 10. Nearshore landforms present in the East Kitsap County study area. Data from PSNRP Geomorphic GIS database, Units = Shorezone Units.**

| Landforms | Number of Units |
|---|---|
| Barrier Beach | 56 |
| Beach Seep | 5 |
| Delta | 46 |
| Delta Lagoon | 8 |
| Depositional Beach | 39 |
| Drowned Channel | 16 |
| Drowned Channel Lagoon | 22 |
| Longshore Lagoon | 4 |
| Modified | 30 |
| Pocket Beach | 2 |
| Pocket Beach Lagoon | 4 |
| Rocky Beach | 23 |
| Sediment Source/Transport Beach | 204 |
| Tidal Channel Lagoon | 1 |
| Tidal Channel Marsh | 18 |
| Tidal Delta | 13 |
| Tidal Delta Lagoon | 2 |
| Veneered Rock Platform | 16 |

**Table 11. Dominant physical processes in the East Kitsap County study area. Data from PSNRP Geomorphic GIS database, Units = Nearshore Assessment Units[13].**

| Dominant Process | Number of Units |
|---|---|
| Fluvial Deposition | 47 |
| Fluvial Deposition, Wave Deposition | 10 |
| Fluvial Deposition, Wave Erosion | 6 |
| Sediment Source/Transport | 196 |
| Tidal Erosion | 15 |
| Tidal Erosion, Fluvial Deposition | 28 |
| Tidal Erosion, Wave Deposition | 23 |
| Transport | 23 |
| Modified | 30 |
| Wave & Fluvial Deposition, Tidal Erosion | 3 |
| Wave Deposition | 104 |
| Wave Deposition & Transport | 16 |
| Wave Deposition & Tidal Erosion | 3 |
| Wave Erosion | 5 |
| Wave Erosion, Fluvial Deposition | 1 |
| Wave & Tidal Erosion, Fluvial Deposition | 6 |

[13] Seven ShoreZone Units were further divided based on site specific reviews, resulting in 516 Nearshore Assessment Units compared to 509 ShoreZone Units.

### 3.1.2 Disturbance Characterization

East Kitsap County's diverse shoreline conditions range from urban waterfronts (Bremerton and the Puget Sound Naval Shipyard) and moderate-density residential development to undisturbed stretches of shoreline with intact riparian habitats. East Kitsap County may be viewed as a microcosm of Puget Sound, with moderate levels of impact to nearshore resources on average but extreme examples of high and low impacts as well. However, because this analysis involved only data from East Kitsap County and the scores are relative to the ranges found within the County, it is currently inappropriate to make comparisons relative to all of Puget Sound (Diefenderfer et al. in press).

*Drift Cell Process Disturbance Scores*
The average of all drift cell process disturbance scores was 2.11 on a scale of 1.00 to 3.00 (median: 2.00, range: 0.00 to 3.00). These values represent baseline disturbance scores over all of East Kitsap County for relative comparison with individual drift cells and nearshore assessment units. The twelve most highly impacted drift cells (score = 3.00) in East Kitsap County, which include some of the most highly disturbed NAU's in the study area, are in the following six areas (DC Identification code in parentheses):

Liberty Bay (DC-96)
Keyport (DC-113, 117)
Sinclair Inlet (DC-34, 35, 149)
Dyes Inlet (DC-137, 152, 154, 155)
NE corner Blake Island (DC-104)
Yukon Harbor (DC-29)

The least-impacted drift cells (Score = 1.00) are located in the following areas:

Just North of Kingston (DC-76)
Liberty Bay (DC-63, 68, 118)
Keyport (pocket estuary) (DC-114)[14]
Dyes Inlet (DC-40, 89,135)
Oyster Bay (DC-48, 49)
Clam Bay – EPA Lab (DC-133)
Orchard Point (DC-31)
Olalla Bay (DC-128)
Blake Island (DC-103, 105, 106, 126)

Maps in Appendix C provide a graphical display of these results. Prioritization methods for best determining management options based on these results are discussed in Section 3.3.

*Controlling Factor Disturbance Scores*
The average, standardized controlling factor disturbance score (CF score) of all NAUs was 0.15 on a scale of 0.00 to 1.00 (median: 0.13, range: 0.00 to 0.61). By looking at the individual controlling factor scores, we can evaluate the specific metrics that contribute to this overall score. For example, substrate type had the highest average disturbance score (0.21) and represented the most disrupted controlling factor in the study area. Scoring of this metric was influenced most by proximity to navigation channels, but also was affected by armoring, boat launches, buoys, outfalls, and net pens. The next highest score was wave energy (0.20). This score was primarily affected by the amount of armoring, marinas, and urban

[14] Some pocket estuaries scored low on disturbance, when in fact they are disconnected from tidal hydrology. This is because we did not include disturbance to hydrologic connectivity as a stressor. We recommend that this disturbance be included in future assessment work.

waterfront. The high percentage of armored shoreline (43%) in East Kitsap County contributed to the change in substrate type and the natural wave energies.

In contrast, slope (0.11) and water quality (0.09) metrics scored lowest and represented the least-disrupted controlling factors over all East Kitsap County sites. Depth/slope was primarily affected by activities that involved dredging, such as marinas, urban waterfront, navigation channels. The water quality metric was highly influenced by the presence of urban waterfront and proximity to known sources of degraded water condition. The relatively lower scores in these factors indicate that dredging and urban development have been localized to a few areas of the County (e.g., Sinclair and Dyes Inlet) and based on the limited data available, water quality is generally not a problem over most of the County.

*Dominant Physical Process Scores*

The dominant process scores for the study area are represented by a mean score of 0.26 for all NAUs on a scale of 0.0 to 1.0 (median range 0.24; 0.0 to 0.75). As with the CF scores, we can evaluate the disturbance scores for the physical processes by looking at the individual stressors that contribute to the scores. The highest average process score was for wave erosion in embayments (0.37), representing the most disrupted process in the study area. This process is most affected by armoring and heavily modified areas and is likely the highest score because embayments are generally the areas of greatest disturbance. Several other stressors also affect wave erosion, including pilings, marinas, groins, boat launches, and stairs. Wave deposition was the second highest score (0.29), which was affected by the same disturbances as wave erosion, but included the sites outside of embayments. The lowest process score was tidal erosion (0.23), which is the dominant process for the back-bay areas where pockets of undisturbed estuarine habitats are present.

### 3.1.3 Quality Control Results

Twenty percent of the site and drift cell scores were calculated using an Excel spreadsheet then compared to the GIS scores. When score differences were discovered in the 20% data comparison then the entire dataset was checked for similar differences. This quality control exercise resulted in a set of four conditions as follows:

1) complete correspondence between different calculation methods
2) differences in calculated values due to errors in the description of the calculation criteria (from this report) used to conduct the spreadsheet calculations
3) differences in calculated values due to identified errors in GIS calculations
4) unresolved differences between the two calculation methods.

The majority of the quality control analysis resulted in the first condition, where the values for the calculated scores were the same between the GIS method and the spreadsheet method. In cases where the second condition occurred, corrections were made to the criteria description in the report and necessary corrections were made to the spreadsheet calculations. The resulting scores from the spreadsheet were then compared again to the GIS scores to ensure the problem was resolved. A small number of errors were discovered in the GIS calculations, which were corrected. A percentage of the calculated differences remained unresolved; these could potentially be due to errors in the criteria description, spreadsheet calculations, or GIS calculations. Table 12 provides a summary of the proportion of sites and drift cells that were the same between the calculation methods. The resulting number of differences between the GIS calculated site rank and the spreadsheet calculated rank was 5 out of 516 (1%) of the sites. The resulting number of differences between the GIS calculated drift cell rank and the spreadsheet calculated rank was 6 out of 97 (6%) of the drift cells. The difference in the ranks could potentially effect the recommended management actions for 27 (out of 516) sites. Resolving these differences should be conducted as part of any follow-on work.

**Table 12. Proportion of sites and drift cells from GIS analysis that correspond to scores calculated with spreadsheet in independent quality control review.**

| | Substrate | Wave Erosion | Slope | Freq. of Disturbance | Water Quality | Light | Overall Site CF Score | CF Rank |
|---|---|---|---|---|---|---|---|---|
| Controlling Factor Scores | 0.93 | 0.93 | 1.00 | 1.00 | 1.00 | 1.00 | 0.93 | 0.99 |
| | | | | | | | | |
| | Sediment Transport | Wave Erosion (E) | Wave Erosion (0) | Fluvial Deposition | Tidal Erosion | Wave Deposition | Overall Site DP Score | DP Rank |
| Dominant Process Scores | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | | | | | | | |
| | Sediment Transport | Fluvial Deposition | Tidal and Wave Processes | | | | Overall DC Score | DC Rank |
| Drift Cell Scores | 0.91 | 0.87 | 0.97 | | | | 0.77 | 0.94 |

## 3.2 Management Option Recommendations

One goal of this nearshore assessment is to develop a science-based protocol for determining priorities and strategies for improving nearshore ecosystem functions. The process developed here relies to the extent possible on principles from the fields of restoration ecology, landscape ecology, and conservation biology coupled with the best available scientific understanding of the nearshore ecosystems of Puget Sound (Williams et al., 2001; Williams et al. 2003; Dethier 2006; Fresh 2006; Brennan 2007; Johannessen and MacLennan 2007; Mumford 2007; Pentilla 2007; Shipman 2008) and the best information available on the biophyscial conditions of the nearshore in East Kitsap County (Kitsap County 2007). Specifically, the process developed here relies on restoration of controlling factors and physical processes as the key to successful and long-term sustainability.

### 3.2.1 Influence of Disturbance on Management Options

The prioritization process considers the level of disturbance affecting the nearshore systems of East Kitsap County. The success of any strategy varies in part depending on the level of disturbance of the site and the landscape within which the site resides (NRC 1992). Using the findings of the National Research Council (NRC) and a review of the literature on estuarine habitat restoration, Shreffler and Thom (1993) concluded that the strategies of restoration, enhancement, and creation should be applied depending on the degree of disturbance of the site and the landscape (Figure 11). This theory assumes that historical conditions represent the optimal habitat conditions for a particular site. In general, restoration to historical conditions is best accomplished where the sites and the landscape are not heavily altered (Shreffler and

Thom 1993; NRC 1992). Creation of new habitat (i.e., habitat not historically present) at a site may be the best alternative when the site and the landscape are heavily damaged.

Because the nearshore and adjacent uplands of most of East Kitsap County have not been heavily urbanized, the goal of restoring the nearshore habitats to historical conditions is viable over a portion of the study area. However, in some areas, other alternative actions are more appropriate (see Section 3.2.2). For example, sites with a high degree of disturbance on the landscape and site scales, in general, have a low probability for successful restoration, and creation of a new habitat or ecosystem or perhaps enhancement of selected attributes would be the only viable strategies to apply in these situations (Figure 11). In contrast, where the site and landscape are essentially intact, restoration to historical (i.e., humans present, but insignificant disturbance) or pre-disturbance (i.e., before man) conditions would be viable options and the probability of success would be high.

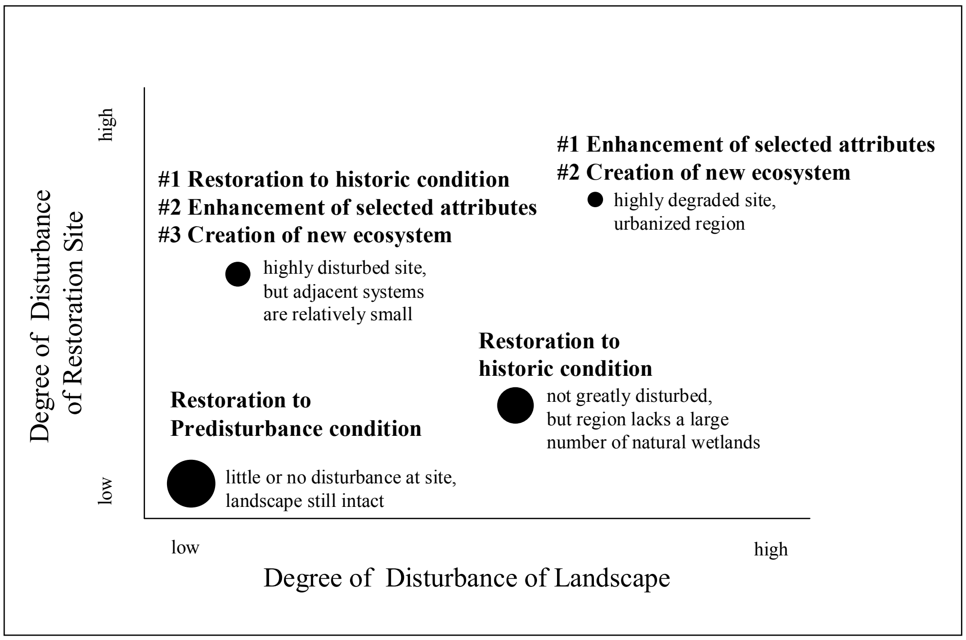


**Figure 11. Restoration strategies for nearshore systems relative to disturbance levels on the site and in the landscape (from Shreffler and Thom 1993). The relative probability of success increases with the size of the dot.**

Protection and conservation are additional management actions that can be employed to sustainably manage the ecosystem. Effectively achieving the goal of a sustainable ecosystem may require that several strategies be employed at a site and in the landscape. For example, preservation of landscape features, enhancement of selected nearshore attributes, and conservation in the nearshore may be highly effective in restoring the controlling factors and physical processes that affect historical structure and functions of the system.

### 3.2.2 Analysis of the Most Applicable Potential Management Actions

The suite of potential management actions available for sites or drift cells is partially driven by the level of disturbance on these respective scales. For example, a site with a high stressor score within a drift cell that also has a high stressor score has a very low probability of being restored to historical site conditions. High stress at the landscape scale minimizes the ability of the degraded processes in the landscape to form and maintain habitats at sites within the landscape. Conversely, sites within a landscape that are relatively undisturbed probably can be restored to historical conditions. In these cases, sites and landscapes should be protected from further disturbances or measures to conserve the biodiversity within the sites and landscape should be applied.

The potential management options are as follows:

**Protect** = exclude disturbances;
**Conserve** = maintain the current level of biodiversity;
**Restore to historical condition** = restore structure and functions of the sites to historical conditions based on available historical records;
**Enhance** = improve the structure and functions of a site or landscape beyond current conditions;
**Create** = develop a habitat or function that did not formally exist at a site or landscape.

The matrix in Figure 12 identifies the strategies most appropriate under the nine different states of site and landscape scale disturbance. This matrix is based on the concepts initiated by Shreffler and Thom (1993) and integrates the restoration strategies in Figure 11 with two additional strategies of conservation and protection. In developing the matrix in Figure 12, the following logic was used:

- The lower the disturbance on both scales, the greater the reliance on preservation, conservation, and restoration;
- The greater the disturbance on both scales, the greater the reliance on enhancement;
- Under the highest levels of disturbance, a greater reliance on creation.

The strategies most likely to succeed are indicated in each box, as well as strategies that might also be applied with a somewhat lower probability of success. Multiple strategies are potentially viable under any one of the nine states. This matrix provides general guidance as a first approximation of specific management options that could be evaluated within a site or drift cell.

| | | | |
|---|---|---|---|
| **High Site Disturbance** | Restore<br>Enhance | Restore<br>Enhance | Enhance<br>Create |
| **Moderate Site Disturbance** | Conserve<br>Restore | Conserve<br>Restore<br>Enhance | Enhance<br>Create |
| **Low Site Disturbance** | Protect<br>Conserve<br>Restore | Protect<br>Conserve<br>Restore | Enhance |
| | **Low Drift Cell Disturbance** | **Mod. Drift Cell Disturbance** | **High Drift Cell Disturbance** |

**Figure 12. Matrix of management strategies most likely to succeed in a NAU based on the degree of disturbance of the drift cell and the site.**

To apply this prioritization specifically for the East Kitsap County nearshore, the normalized process disturbance score for each drift cell is plotted against the normalized controlling factor disturbance score for the sites (Figure 13) and the normalized process disturbance score for the sites (Figure 14). The scores are broken into three categories (low, moderate, high) based on tercile breaks in the distribution of data points. Each point represents a site (nearshore assessment unit).

Figure 13 and Figure 14 correspond to the matrix of management action strategies in Figure 12 above and can be used to prioritize appropriate management action strategies for those sites. For example, for sites with low disturbance scores on both axes, the most appropriate management strategies would be to protect, conserve, and restore to pre-disturbance conditions. In contrast, for sites where disturbance scores are high on both axes, the recommended management strategies are enhancement of selected habitat attributes or creation of new ecosystems. In areas where landscape disturbance scores are high, but site scores are low (the site is in relatively good condition) any strategy for restoration needs to be considered relative to the ability of disturbed landscape processes to maintain the restored site in the long term. These drift cells with high disturbances to the physical process would be good potential places to evaluate for process-based restoration. Likewise, sites with a high process scores may be appropriate targets for process focused restoration actions. These actions at the site scale could in turn improve processes at the landscape scale. To highlight areas that could be improved by restoration of physical processes, NAUs with a high dominant process score (2 or 3) were given the additional management recommendation of "restore site processes." Specific options (e.g., removal of a bulkhead) ultimately applied to a site or landscape must be based on a thorough site assessment. The scores for each site and drift cell are provided in Appendix B and maps showing the scores and recommended management options are provided in Appendices C and D, respectively. Note that the hatching on the site score maps (Appendix C) represents sites where restoration of site processes is recommended (dominant process score of 2 or 3).

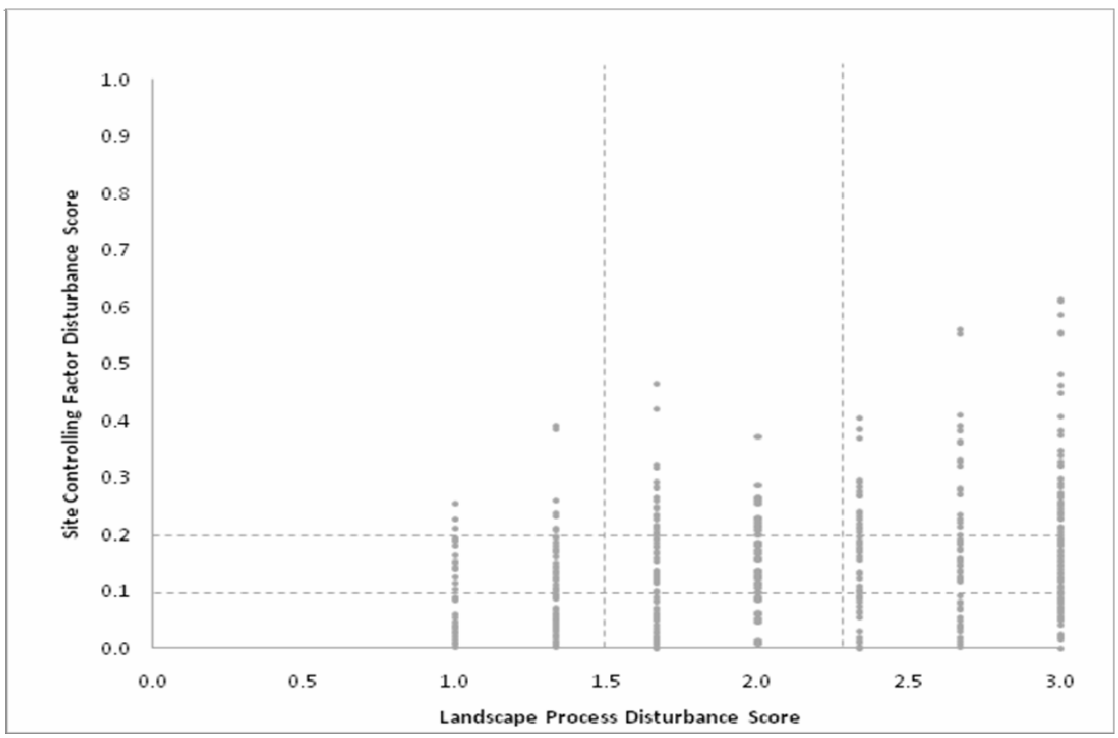


**Figure 13. Comparison of site-scale disturbance of *controlling factors* to landscape scale disturbance. The dashed lines delineate low, moderate, and high categories. Each point represents an NAU.**

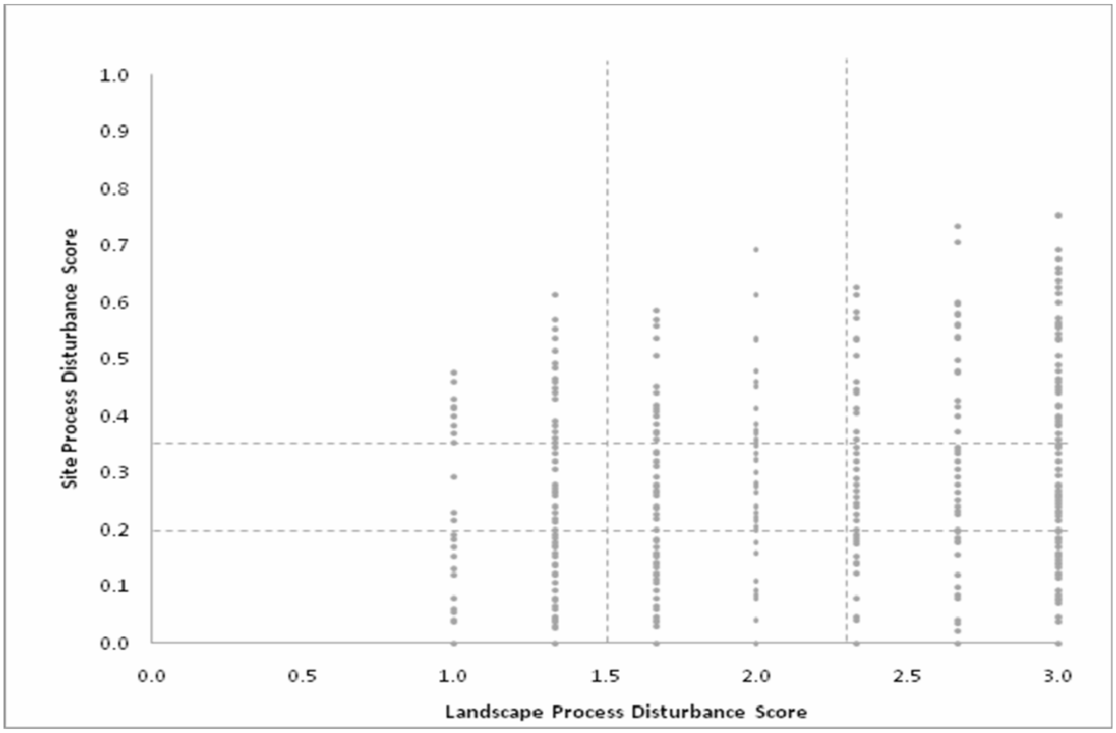


**Figure 14. Comparison of site-scale disturbance of *dominant processes* to landscape scale disturbance. The dashed lines delineate low, moderate, and high categories. Each point represents an NAU.**

## 3.3 Prioritizing Existing and Potential Projects

In order to prioritize management options or restoration projects, we employ a framework consisting of two tiers. The first tier is a comprehensive GIS assessment of existing conditions, including documentation and scoring of the stressors affecting nearshore habitats (the current study). Results of the disturbance-based GIS analysis are meant to be a screening tool that can be used to evaluate the best potential areas for protection, restoration, enhancement, or creation. The tool itself does not identify specific projects for management options; however, the Tier 2 analysis can be used to evaluate potential and existing Kitsap County projects using the results of the disturbance-based analysis.

### 3.3.1 Tier 1 – Application to Prioritization

The focus of this current study was the Tier 1 analysis; however, as a first step in the Tier 2 process, we evaluated the results of the Tier 1 model for 46 existing and potential projects in East Kitsap County. The results of the evaluation are provided in Appendix G. The table in Appendix G provides the scores for both landscape and site conditions, as well as the prescribed best management options. See the discussion in Section 3.2.2 for explanation of the management options. Aerial photos of a few specific projects and a brief description of the application of the results are also provided in Appendix G.

### 3.3.2 Tier 2 – Refinement of Prioritization

Further prioritization of specific projects for management options such as protection, restoration, or enhancement can be done through a ranking process. This process evaluates information on stressors at site and landscape scales as well as predictions of changes in function and area for a particular management action proposed for the site.

Project-specific ranking is based on the following general formula developed from Thom et al. (2005):

**Site score** = (**Δfunction** x **size** x **success**) ÷ **cost**

Where,

**Δfunction** = change in site ecological functions,
**size** = relevant measure of the area encompassed by the project,
**success** = an estimate of the probability for the site to meet the goal,
**cost** = planning, implementation, monitoring, contingency, management costs.

The factors in the formula are defined below. Keep in mind, each factor incorporates uncertainties. For example, the change (**Δfunction**) term could be defined as the amount of change from the existing condition, or the predicted similarity of the site to a reference site (e.g., plant species cover), or a particular performance criterion following restoration. Other metrics include change in integrity, species diversity, connectance, opportunity for fish access, and capacity to support fish and wildlife.

An Excel spreadsheet can be used to input information to develop the scores for each factor (See example spreadsheet in Appendix H; actual spreadsheet submitted with this Report). Each of the three factors in the equation above (excepting "cost") is subdivided into criteria that contribute to the factor as described below. Scores are developed by inserting a "1" in the most appropriate column for each element. Justification for placement of the "1" is provided in the note in the far right column. Finally, the relative score for the project is calculated and indicated in the upper portion of the sheet. The maximum score attainable is 1.0 and the minimum is 0.0. The Excel spreadsheet contains a formula that provides differential weightings to the various categories of protect, improve, etc. as shown in Appendix H. These weightings can be modified as needed based on the best available science.

<u>Factor 1: Predict Functional Change</u>

The change in function is based on criteria of desired functions. Example criteria are provided in Appendix H, however additional criteria can be added as needed.

- *Complexity* – This criterion refers to the numbers of different types of habitats within a reach. As the number of habitat types increases, so does the number of different species that can occupy an area, and the number of functions supported by the area. Higher complexity typically results in greater biodiversity. For East Kitsap County, sites that have more natural habitats will generally have more associated species. Adjacent sites that differ in habitat type would cumulatively contain greater complexity.

- *Accessibility* – Accessibility refers to unencumbered access by nearshore-dependent aquatic, avian, and terrestrial species. Projects that would allow or enhance access of these species to important nearshore habitats would potentially enhance the feeding, rearing, and refuge functions of the site. Opening a system to fish access can result in utilization of the watershed by these fish. Accessibility for one species (e.g., estuarine fishes) can however have contradictory requirements for accessibility by other species (e.g., freshwater-associated waterfowl).

- *Connectance* – This criterion refers to the degree of natural connection and pathways between adjacent habitats or migratory corridors. Connectance means that an animal can move between adjacent habitats to derive the benefits of each habitat. It also refers to the flow of material such as organic matter between areas of production (e.g., a salt marsh) and areas of deposition (e.g., tidal channels and creek bottom) where the materials are utilized by the ecosystem. In East Kitsap County, connectance can be interrupted by overwater structures, armoring, boat activity, and other features.

In many ecosystems of the Pacific Northwest, functional criteria are focused on benefit for salmonids. In developing ecological assessment criteria for restoring anadromous salmon habitat, Simenstad and Cordell (2000) advocated the use of measures directly relatable to the ecological and physiological responses of juvenile salmonids to restored habitats. They proposed the use of three categories: *capacity*, *opportunity,* and *realized functions* (Table 13). These criteria were developed for assessing completed restoration projects; however, their utility is in part applicable in evaluating potential projects.

- *Capacity* – This criterion refers to habitat attributes that would promote juvenile salmon production through promotion of foraging, growth, and growth efficiency, and/or decreased mortality. The capacity category is an extension of the ecological concept of carrying capacity. Examples of capacity metrics include the productivity and density of prey, physical and chemical conditions that promote high assimilation efficiencies and structural conditions that provide protection from predation.

- *Opportunity* – This criterion assesses the ability of salmon to access and benefit from the habitat's capacity (Simenstad and Cordell 2000). Opportunity incorporates the principles of landscape ecology (Forman and Godron 1986). Examples of metrics to evaluate under this criterion include tidal elevation of feeding habitats, extent of morphometric features such as channel edge length, as well as refugia from predation such as low-tide, deep-water refuges.

**Table 13. Capacity, opportunity, and realized functions as measures of ecological and physiological responses of juvenile salmonids to restored habitats (Simenstad and Cordell 2000).**

| Category | Potential Armoring Impact | Potential Impact to Salmon |
|---|---|---|
| Capacity | Altered habitat type<br>Altered habitat forming processes<br>Altered habitat production | Change in prey species<br>Change in prey production<br>Change in prey abundance<br>Change in prey distribution<br>Change in predator abundance |
| Opportunity | Altered access<br>Altered migration route<br>Altered habitat size<br>Altered habitat location<br>Altered refugia from predators | Change in ability to find prey<br>Change in rate of migration<br>Change in predation rate |
| Realized Function | Altered residence time<br>Altered foraging success | Change in growth rate and survival |

<u>Factor 2: Size</u>
Although size appears less uncertain, variation can occur if, for example, inundation of a wetland restoration project is not as extensive as expected. We recommend using the expected area of the protected, restored, or undeveloped project site as the initial estimator of size for the project. If area of inundation is the most important factor for the project, then use that area. Another factor to consider is the amount of buffer area that may be part of the project or adjacent to the project.

<u>Factor 3: Probability of Success</u>
No project is one hundred percent certain to reach its goals. What is known is that certain types of projects (e.g., dike breaches) often result in the most predictable and successful restoration of wetlands (Morlan 1991; Tanner et al. 2002; Thom et al. 2002). However, the actual development to match reference site conditions is always less than perfectly aligned with expectations. In contrast, highly engineered projects (e.g., created sites), or those in which a multitude of factors can affect the outcome (e.g., highly urbanized and disturbed estuaries) are less certain (Simenstad et al. 2006). Finally, the strategies (e.g., "restore to historic conditions" or "enhance selected attributes") vary in potential success. Specific possible criteria for the probability of success include the following:

- *Potential to conform to natural habitat structure, processes, and functions* – This criterion expresses the relative probability that a site can return some or all of the natural habitat structure, function, and processes found on the site historically. As mentioned above, the level of the site and landscape disturbance is important in determining this potential.

- *Potential for self-maintenance* – Self-maintenance addresses the commonly accepted objective in restoration ecology that a site should be able to persist and evolve toward a natural (historical) habitat condition without significant human intervention. As a pre-requisite for this to occur, conditions for controlling factors and processes in the site and in the drift cell must be appropriately developed and maintained. Self-maintenance means that the habitat can persist and develop under natural climatic variation, and that the system has a natural degree of resilience to natural perturbations. This criterion requires knowledge of probable historical conditions and the factors that produced the present conditions.

Overall, this two-tiered approach provides 1) a broad screening level tool that can be applied throughout the County over time to evaluate shoreline management issues, and 2) an analysis of current and existing projects and development of a methodology for evaluation of restoration projects in the future.

## 3.4 Validating Assessment

Literature on salmon and habitat associations in Puget Sound were gathered for the years 2002-2008. The information is summarized briefly below and an annotated bibliography provided in Appendix E. A field validation task was conducted to evaluate structural indicators of ecosystem function. The results are summarized below and an expanded summary of the field data is provided in Appendix F.

### 3.4.1 Fish and Habitat Literature Review for Validation

Habitat associations of fishes in the nearshore waters of Puget Sound are linked to species-specific patterns as well as variation among habitat attributes. Depending on the particular species, fish are capable of making extensive daily migrations (*e.g.,* juvenile salmonids) as well as migrations between habitats to carry out various life history requirements (*e.g.,* spawning locations). When attempting to link nearshore nekton to habitat condition, it is important to understand that the term 'habitat' can incorporate multiple scales of space and time (*e.g.,* site scale vs. landscape scale).

There is a considerable amount of research linking juvenile salmon (*Oncorhynchus sp.*) to estuarine habitats such as river deltas, tidal marshes, and pocket estuaries (Fresh 2006; Bottom et al. 2005; Beamer et al. 2006, 2003; Healey 1982). Within Kitsap County, Fresh et al. (2006) described patterns of fish use in Sinclair Inlet, but did not detect any link between juvenile Chinook salmon (*e.g.,* abundance, size, and diet) and habitat conditions within the Inlet. The lack of freshwater spawning streams within Sinclair Inlet may explain the absence of pink salmon (*O. gorbuscha*), and low numbers of coho salmon (*O.*

*kisutch*). However, the inability to link salmon use and distribution within the area likely stems from the scale of sampling effort (*i.e.*, fish response to habitat may be elicited at larger spatial scales rather than the site-scale) as well as the inability to account for factors such as environmental constraints (*e.g.*, ocean and/or nearby freshwater conditions) (Fresh et al. 2006).

Like many areas within the Puget Sound, the shorelines within Kitsap County include several discrete areas used by forage fish for spawning. These species including herring (*Clupea pallasii*), sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*) serve as a prey base for a range of species within the nearshore waters of Puget Sound. Washington Department of Fish and Wildlife (WDFW) oversees the management of these forage fisheries (http://wdfw.wa.gov/fish/forage/forage.htm).

### 3.4.2 Field Validation Scores

The field validation assessment yielded a range of results spanning 15-98% of the total possible score for a given geomorphic type. Of the 14 NAUs assessed, one yielded a score indicative of a low functioning site. The remaining 13 NAU scores were equivalent to moderate and high ecological attribute ratings (Table 14). Original scores for each of the functional indicators as well as the mean NAU score can be viewed in Appendix F.

**Table 14. Field validation assessment results.**

| Geomorphic Type | Nearshore Assessment Unit (NAU) ID | ShoreZone Unit ID | Proportion Relative to Total Score[15] | Functional Attribute Rating[16] |
|---|---|---|---|---|
| Delta | 18 | 3008 | 0.64 | High |
| Rocky Beach | 80 | 3071 | 0.70 | High |
| Pocket Beach | 81 | 3072 | 0.98 | High |
| Pocket Estuary | 114 | 3249 | 0.50 | Moderate |
| Sediment Source/ Transport Beach | 116 | 3252 | 0.49 | Moderate |
| Sediment Source/ Transport Beach | 117 | 3253 | 0.15 | Low |
| Delta Lagoon | 148 | 3284 | 0.55 | Moderate |
| Sediment Source/ Transport Beach | 149 | 3285 | 0.70 | High |
| Sediment Source/ Transport Beach | 150 | 3286 | 0.68 | High |
| Sediment Source/ Transport Beach | 151 | 3287 | 0.66 | High |
| Sediment Source/ Transport Beach | 155 | 3291 | 0.31 | Moderate |
| Sediment Source/ Transport Beach | 156 | 3292 | 0.51 | Moderate |
| Rocky Shore | 178 | 3314 | 0.44 | Moderate |
| Drowned Channel | 211 | 3347 | 0.37 | Moderate |

[15] Proportion Relative to Total Score is the quotient of the mean ShoreZone Unit score and the total possible score for a given geomorphic type.
[16] The Functional Attribute Rating is determined by comparing the scores in the preceding column (i.e., Proportion Relative to Total Score) with the values described in Section 2.6.3.

### 3.4.3 Field Validation Comparison with GIS Stressor Scores

Validating the GIS-based scoring approach by assessing the functional attributes at sites spanning the range of geomorphic types allowed us to evaluate how well the GIS-based stressor evaluation approach summarized actual site level conditions. By definition, sites or ecosystems with lower levels of disturbance should have optimal or near-optimal ecological functions, and vice versa. As described in Section 2, functional scores closest to 1.0 are indicative of highly functioning NAUs and stressor score of 1.0 indicates a highly stressed site (stressor scores closest to zero are evaluated as low stress). Low, Moderate, and High categories describing the functional assessment of a given site were generated from the scoring approach developed for the field validation task and are further explained in Section 2.6.3. The stressor scores are segregated into three categories based on tercile breaks in the distribution of data points.

In general, as expected there was a steep decrease in functional assessment score (site function) as the site stressor score (site stress) increased (Figure 15). This relationship held for controlling factor scores and most process scores. Two NAUs showed a disparity with the general trend for the process scores (Figure 16; NAUs 151 and 156). Although these sites received high process stressor scores, they received moderate and high functional scores. This suggests that although habitat forming and maintaining processes are degraded, the unit still contained habitats that appeared to be functioning relatively well. This disparity may be explained by the relatively minimal dependence of the habitat type on the particular processes that were scored or by a lag time between degradation of the landscape and loss of site functions. In contrast, the relationship between functional scores and controlling factor scores was relatively tight (Figure 17), which indicates that the habitats within these units were more affected by the condition of the controlling factors at the site. Specific management options for these two sites would be based on an examination of the primary stressors affecting both the controlling factors and processes. The data required to support this type of analysis are contained in the database for the assessment. In general, management options should be determined by examining the stressors specifically active within each ShoreZone unit.

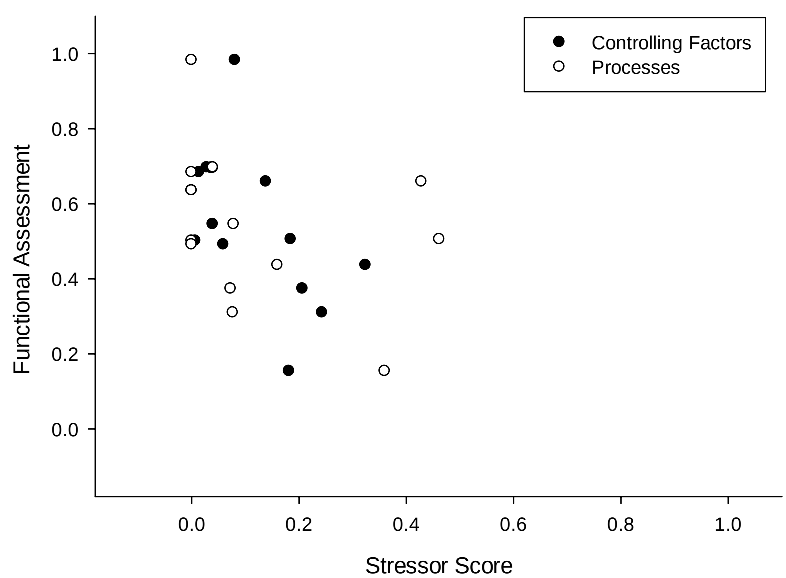


**Figure 15. Functional assessment scores vs. GIS-based stressor scores for 14 NAUs.**

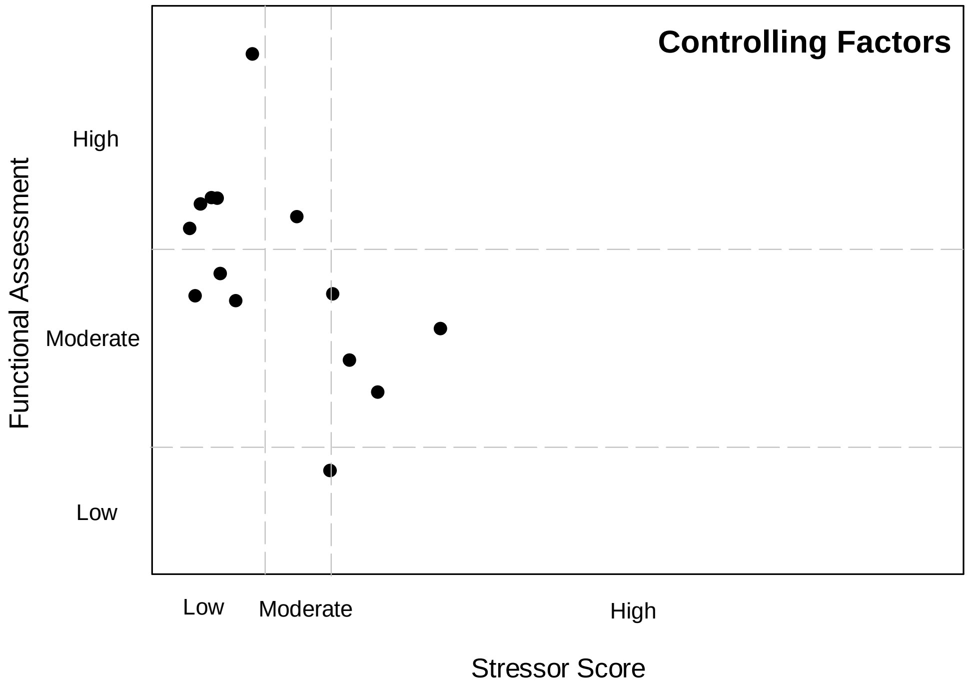


**Figure 16. Functional assessment scores vs. GIS-based stressor scores for 14 NAUs as they relate to controlling factors.**

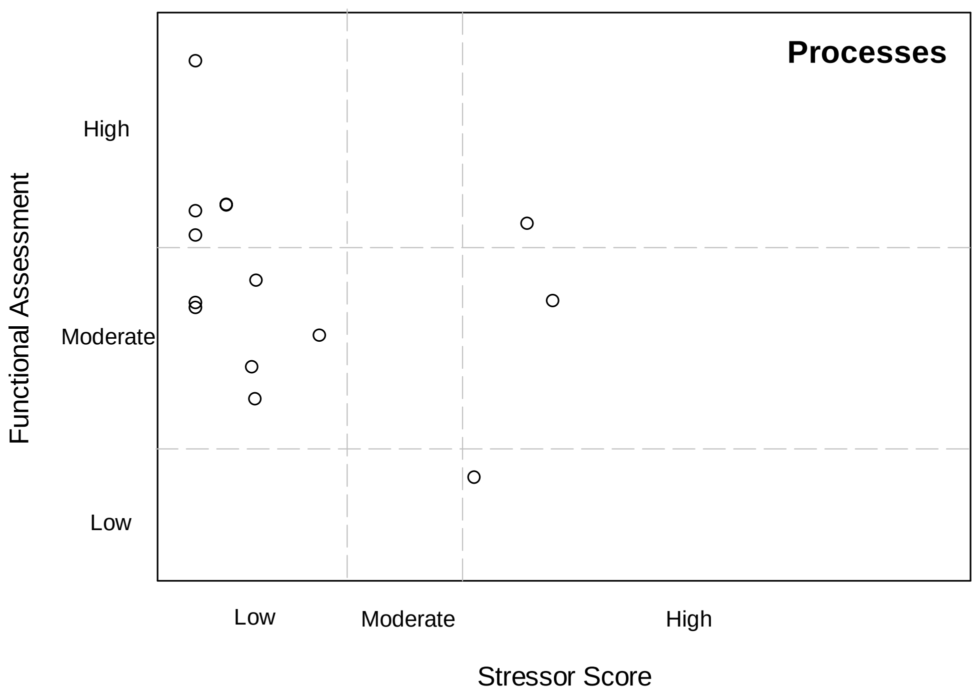


**Figure 17. Functional assessment scores vs. GIS-based stressor scores for 14 NAUs as they relate to nearshore physical processes.**

### 3.4.4 Use of Functional Scores from Validation in Management Planning

The relationships between functional scores and stressor scores in Figure 15 indicate that with improvement of controlling factors and processes, ecological functionality will improve. For example, moving a stressor score from 0.4 to 0.2 would predictably result in improvement in functionality from the existing low-moderate score to high moderate or high functionality score. Since the validation study was conducted with independently selected sites (e.g. not based on the results of the GIS model), the relationship can be considered a subsample of sites in the region. Until more data are developed on more sites, this subsample provides a first approximation model for illustrating and quantifying potential functional improvements in response to reduction of stressors.

# 4.0 Summary Conclusions and Recommendations

This assessment is intended as a screening tool for prioritizing management options county-wide, and should be considered a living document that can be continuously refined as the knowledge base increases. The assessment framework is comprised of the following components:

- A conceptual model based on the best available science for the nearshore ecosystem, which organizes the verified linkages between human impacts/options, controlling factors and physical processes, habitat structure, and ecological functions;
- Two ecologically-relevant spatial scales: site and landscape (drift cell and watershed);
- Geomorphic context based on the dominant physical processes at the site level;
- A scoring system based on the status of nine controlling factor metrics;
- A management action prioritization framework based on a two-tiered approach;
- A validation of the scoring utilizing field data on ecological indicators of functions.

Key findings of the nearshore assessment were as follows:

- East Kitsap County's shoreline represents a microcosm of the range of conditions in Puget Sound, with moderate levels of impacts to nearshore resources, but extreme examples of high and low impacts as well. Most drift cells were considered moderately impacted by human activities.
- Of 97 drift cells in East Kitsap County, 12 were considered highly altered (score = 3.00); these are located in the most populated inlets in the County.
- Of the 516 NAUs, 96 (19%) were highly altered and 140 (27%) were relatively unaltered.
- The most altered process among the physical processes evaluated was wave erosion in embayments.
- The site-scale data provided allows managers to determine which stressor is having the greatest effect on nearshore ecological condition, which supports decisions as to the most appropriate options needed to improve conditions.
- Preliminary validation efforts suggest that as expected, high disturbance scores based on the GIS framework are often correlated with reduced habitat structure metrics (indicators of ecological function) calculated from field-collected validation data. The validation indicates that improving processes at the site and drift cell scale will improve ecological functions. Closer examination of outliers may assist in refining assessment techniques and selecting a more appropriate suite of parameters for monitoring.

The results of the scoring supported recommendations for management options for East Kitsap County nearshore habitats based on the following points:

- Five fundamental strategies for improving ecosystem functions of nearshore systems include habitat creation, enhancement, restoration, conservation, and preservation.
- Landscape ecology considerations were included in defining appropriate management options. Management action recommendations are assigned according to the level of disturbance at both the site and landscape scales. If damages are great at both scales, fewer management strategies are likely to be successful. Conversely, if damage is relatively low on both scales, there is a broader array of management options. For example, it would make little sense to restore the ecosystem at a

heavily damaged nearshore site if the landscape (drift cell) upon which this site depends is also heavily damaged. A more appropriate strategy would be enhancement of selected attributes of the site.

- To better refine management options for a particular site (or portion of a site), criteria can be used to enhance ecosystem structure and function based on landscape ecology and restoration ecology principles. The criteria include site size, change in ecosystem function, probability of success, and cost.
- The assessment and prioritization framework will be most effective when it involves the local expertise of those who are familiar with the East Kitsap County shoreline and its ecological resources.

## 4.1 Lessons Learned and Recommendations

Over the course of the assessment, several gaps were identified. In the future, assessments could be improved by the inclusion of the following data layers:

- Disturbances to hydrologic connectivity (e.g., tide gates, dikes, roads, culverts, etc.)
- Location of nearshore fill
- Riparian vegetation

While the latter category is not a disturbance, it may be useful for evaluating physical processes and/or ecosystem function.

## 4.2 Applications

Restoration planning
This assessment tool provides a means to evaluate the best potential locations for preservation, conservation, restoration, enhancement, and creation based on the recommended management options. In addition, the tool can be used to determine the best locations for various types of restoration such as sediment source restoration, for example. In this case, the data on the dominant physical processes coupled with the data on armoring could be used to identify areas where sediment sources have been adversely impacted. In this way, restoration efforts can target high priority locations.

Restoration project evaluation
Similar to the evaluation done as part of this assessment, potential restoration projects can be evaluated using the two tiered approach. The results of the GIS analysis (Tier I) can be used to inform potential project success and the other criteria in Tier II can be used to evaluate sites relative to other sites in the region to determine preservation, conservation, and restoration priorities.

Permit evaluation
The results from this assessment can be used as a means of evaluating the level of disturbance spatially to help inform decision-making for permit applications. In the example above, an armoring project was evaluated based on estimates of disturbance from armoring in similar geomorphic settings. In addition, the cumulative impacts of disturbances can be evaluated in an area of a permit proposal to determine the potential additional effects on nearshore processes.

Alternative futures assessment
The disturbance scores from this assessment could be used to develop alternative futures scenarios. In a previous study, the scoring results from the nearshore assessment of Bainbridge Island (Williams et al. 2004) were incorporated into an evaluative model using Envision futuring software (OSU Biosystems

Analysis Group). Through Envision, the nearshore scoring model for disturbance was temporally and spatially linked to landscape change. As alternative future scenarios were run, changes in impervious surface, land cover, population growth, and even density of over water structures inform the nearshore model and result in predicted changes in ecosystem stress. This type of assessment allows policy makers to evaluate how changes in growth and development would alter land use and shoreline use and potentially impact the level of disturbance in the nearshore. This information can be used as part of Shoreline Master Program update as well as assisting in identifying areas for development, restoration, or conservation.

## 4.3 Dealing with Uncertainties in Potential Management Options

There are uncertainties surrounding any management action. An adaptive management approach can and should be applied, as needed, for decisions involving the management options defined in this assessment: protect, restore, enhance, and conserve. Restoration is difficult, expensive, and has uncertainties in terms of actual outcomes. Adaptive management represents an efficient approach to become more certain about outcomes (i.e., increase the certainty of predictions). Becoming more certain about management action outcomes increases the probability that the nearshore ecosystem in East Kitsap County will show net improvement though time.

Although this assessment employs the best available science in an objective science-based framework, uncertainties still occur in the science base, the field-collected data set, the assessment of stress level, and the outcome of a management action. Where these uncertainties have the most relevance is in the process of making critical decisions on what actions to take within a given site or drift cell. To deal with uncertainties we recommend the following:

1) Clarify the decision and the factors critical to understanding the decision.
2) Specify the key uncertainties affecting the decision, and the type of information needed to reduce the uncertainties.
3) If possible, acquire this information.
4) Apply this knowledge to the present decision and future decisions.

*Adaptive Management Example*
A decision is needed on whether to allow armoring using heavy riprap on a beach to protect property. The critical uncertainties include the following:

a) whether the armoring will effectively protect the property from erosion;
b) whether armoring will affect the quality of the natural habitat on the beach;
c) whether the quality of the habitat on other adjacent beaches will be affected; and,
d) whether other alternative erosion control technologies are available that could provide adequate protection while avoiding impacts to the nearshore habitats.

The nearshore assessment database presented here provides fundamental information that can be used to address most of these uncertainties. Information that addresses effectiveness of riprap to stop erosion can be obtained from similar actions in areas that are located under similar wave energies and geomorphological types (from this nearshore assessment, and from experts). Information from similar settings in East Kitsap can be used to predict whether the beach in front of the property will be altered and whether the adjacent beaches in the drift cell will be affected. The use of alternative erosion control may not have been attempted in a similar setting, and thus needs investigation. In this instance, a demonstration project, with follow up monitoring of a set of key metrics (e.g., beach slope, sediment composition), can provide the most direct evidence to indicate both the effectiveness of the alternative stabilization technology as well as the impacts on the nearshore habitats. In this case, the decision is to invest in a demonstration project because it will help in the present decision. The results of the demonstration project will determine if the alternative shore protection method should be required.

If designed appropriately, the information gained by the demonstration project could be applied to other sites in the region. It is important to document this learning and make it available to others. Furthermore, it is useful to develop a practice within an agency to communicate such learning on a regular basis.

This example describes the essential elements of an adaptive management approach to management of nearshore ecosystems. The elements are as follows:

1) A decision demands action.
2) Significant uncertainties surround the decision.
3) The problem is refined to a single critical uncertainty through a systematic approach.
4) A focused approach is developed to address the uncertainty.
5) The learning is applied to the decision at hand, and is communicated to others to assist in similar decisions.

## 4.4 Final Thoughts

This assessment provides the ability for planners and resource managers to evaluate the nearshore ecosystem relative to existing disturbances, restoration potential, and future scenarios. The assessment results can be used to reduce uncertainties in decision-making, an important step in improving restoration success through the application of adaptive management principals. We hope this assessment will be widely used to facilitate decision-making in the many facets of natural resource management critical to improving conditions in the nearshore ecosystem.

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