1.0 Introduction

The City of Bainbridge Island (COBI) is in need of a tool to inventory and assess the conditions of its marine shorelines. Current data gaps point to a need for a comprehensive assessment of shoreline conditions before decision-making under planning and regulatory programs may proceed effectively. Ultimately, this information will allow planners to assess levels of development impact and resource quality over discrete shoreline management areas (MAs), which will assist with permitting issues and prioritization of areas for conservation and restoration.

1.1 Assessment Need

The Bainbridge Island 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. Of 2,262 shoreline parcels on Bainbridge Island, over 82% have been developed, with single-family residential use representing the vast majority of these cases (Williams et al. 2003). According to the Bainbridge Island Nearshore Structure Inventory (Best 2003), approximately 49% of the Bainbridge Island shoreline has some type of armoring.

The City of Bainbridge Island is currently required to develop mechanisms to protect and restore nearshore habitat, as well as support reasonable and appropriate shoreline uses. However, detailed information is currently lacking on Bainbridge Island's nearshore habitat characteristics and the associated ecological impacts of land-use development and modifications on these habitats. Specific questions include the following:

- What and where are the nearshore habitat characteristics of Bainbridge Island?
- What and where are the physical processes that drive the nearshore environment of Bainbridge Island?
- What and where are the human stressors in the nearshore environment of Bainbridge Island?
- What is the current quantity and quality of nearshore habitat on Bainbridge Island?
- What high-quality habitat remains to be protected?
- What damaged habitat is most suitable for recovery?
- What damaged habitat is the most difficult to recover?
- What nearshore habitats on Bainbridge Island are essential to salmonids?
- What effects do typical shoreline modifications have on nearshore habitat (especially salmonid habitat)?
- What habitats (or habitat conditions) should be prioritized for protection and restoration?

As with most areas in Puget Sound, the lack of good information on Bainbridge Island shoreline conditions (historic and current) provides a poor basis for making management decisions and inhibits a strategic approach to prioritizing and protecting these habitats. Recent reports have concluded that anthropogenic influences are responsible for habitat loss and species declines in nearshore Puget Sound ecosystems (Williams et al. 2001; PSWQAT 2002). However, the Puget Sound nearshore ecosystem is highly complex and unpredictable. Baseline studies and monitoring programs are limited and, in general, have been inadequate in providing the level of scientific information necessary for informed resource management decisions (Williams et al. 2001). Historic maps of the region, originally surveyed in the

1800s, have only recently been located, digitally scanned, distributed, and interpreted to assess change (Puget Sound River History Project 2003).

1.2 Objectives and Benefits

Based on the needs outlined above, the primary objectives of the Bainbridge Island nearshore habitat assessment effort were to

- Delineate management areas (MAs) and appropriate subareas
- Characterize the ecological features and conditions within those MAs
- Provide a baseline assessment of nearshore ecological functions using repeatable methods
- Consolidate this information into a single, GIS-based database that can be used by planners and resource managers.

In addition to a characterization and assessment of these habitats in the main body of the report, separate documents were also developed that address the following:

- A framework for prioritizing restoration and preservation of nearshore habitats
- Recommendations for a nearshore monitoring plan that may detect changes from current baseline conditions.

Ultimately, this information will form the scientific basis for future conservation, enhancement, and restoration efforts, and will assist in revising the City of Bainbridge Island Shoreline Management Master Program and in supporting future non-regulatory and community-based management actions in the nearshore.

1.3 Assessment Approach

This assessment is based on the general assumption that alteration of shorelines often results in a change in nearshore ecological functions. These changes generally lead to a decline in positive attributes of the nearshore ecosystem, although we acknowledge that alterations do not always result in change, nor are the changes always negative. The role of the assessment in the overall nearshore habitat management process is that of a screening tool which can serve as a basis for prioritizing conservation and restoration efforts in the nearshore, as well as a baseline for future comparison and evaluation. The assessment should be considered a living document, with additional data incorporated as ongoing research clarifies our understanding of nearshore ecological processes and functions and as assessment methods are further refined. It should be emphasized that as a screening tool, this assessment provides only a framework for guiding future action. This tool will be used most effectively by involving the local expertise of scientists who are familiar with the Bainbridge Island shoreline, its ecological resources, and the relationship between alteration and impact.

1.3.1 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). Regional assessments that involve conceptual models include May and Peterson’s (2003) Kitsap Salmonid Refugia Study, which integrates conceptual models of watershed function and salmon population dynamics to identify those habitats critical to sustaining remaining native salmonid populations. This nearshore assessment builds upon a summary of the best available science (BAS), which summarizes the existing scientific literature as it relates to the nearshore environment of Bainbridge Island (Williams et al. 2003). As such, the assessment employs the conceptual model of Williams and Thom (2001) to build a scientifically defensible framework for assessing the potential effects of changes to nearshore ecological functions caused by human modifications to nearshore habitats (Figure 1).

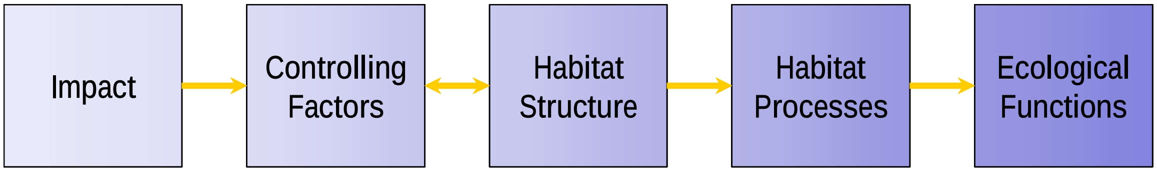

Figure 1. Basis of Conceptual Model (Williams and Thom 2001)

The nearshore conceptual model assumes that shoreline modifications exert effects at varying degrees on an ecosystem's controlling factors (Figure 1; Table 1). Controlling factors (e.g., light level, wave energy) are physical processes or environmental conditions that control local habitat structure and composition (e.g., vegetation, substrate), including where habitat occurs and how much is present. In turn, habitat structure is linked to support processes, such as primary production or landscape connectivity, which influence ecological functions. Thus, impacts that affect controlling factors within an ecosystem are reflected in changes to habitat structure, and ultimately are manifested as changes to functions supported by the habitat. The effect at the functional level depends upon the level of disturbance and the relative sensitivity of the habitat to the disturbance.

Table 1. List of Major Controlling Factor, Habitat Structure, Habitat Process, and Ecological Function Metrics.

Controlling Factors	Habitat Structure	Habitat Processes	Ecological Functions
Wave Energy	Density	Production	Prey Production
Light (Increase)	Biomass	Sediment Flux	Reproduction
Light (Shading)	Length/Size	Nutrient Flux	Refuge
Sediment Supply	Diversity	Carbon Flux	Carbon Sequestration
Substrate	Landscape Position	Landscape Connectivity or Fragmentation	Biodiversity maintenance
Depth/Slope	Patch Shape		Disturbance Regulation
Pollution/Nutrient	Patch Size		Migration Corridors
Hydrology			
Physical Disturbance			

1.3.2 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 are fragmenting natural landscapes into fewer and smaller pieces at an alarming rate, reducing the flow of these materials among habitats and causing local extinction of some populations (Weins 1985; Gonzales et al. 1998; Earn et al. 2000). However, it is clear that most elements of a landscape function best when integrated with all other elements (e.g., watershed approach), and 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. 2001). Knowledge of the behavioral patterns of target species or species groups is essential to refining the site selection and design process for management decisions, such as a 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 riparian zones and connectivity to other habitats around a particular site.

On Bainbridge Island, 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. It is apparent that these shoreline processes must continue to function appropriately across the entire landscape to manage shoreline habitats and ecological functions in a long-term, self-sustaining condition (Williams and Thom 2001;Best 2003). With this in mind, the assessment was designed to examine impacts to nearshore processes at two landscape scales. The larger management area (MA) is scaled to encompass aggregations of alongshore cells, analogous to upland watersheds, which define sediment transport processes that form the primary basis for establishing and maintaining habitat structure and function (Figure 1). A management area is comprised of multiple reaches, which are scaled to current or historic geomorphic conditions. Geomorphology often defines or is commonly associated with distinct biological communities (e.g., halophytic plant assemblages in marsh and lagoon settings).

1.3.3 Geomorphology and the Conceptual Model

The nearshore conceptual model (Figure 1) can be refined by a shoreline's geomorphic setting to provide better predictive relationships between nearshore controlling factors and ecological function (Table 2). Table 2 is based on information contained within the nearshore review of the Best Available Science (BAS) (Williams et al. 2003). The refined model addresses each of five geomorphic classes (defined in Section 2.2.3) typically found along the shorelines of Bainbridge Island, and focuses on nine controlling factors used in the assessment framework (described in Section 2.2.4)

1.3.4 Summary

Landscape ecology and geomorphic context were critical tools for applying the conceptual framework to Bainbridge Island shorelines. The assessment was conducted on a "reach-by-reach" scale, fairly small definable landscapes, which were determined by homogeneous stretches of shoreline as defined principally by the WDNR ShoreZone database (WDNR 2001). The advantage of this approach was that most information was preexistent, detailed, relatively current, and widely available. When used in concert with aerial photographs (WDOE 1977, 1992, 2000) and local knowledge, geomorphic context allowed us to refine predictive relationships between shoreline modifications and nearshore functions. Fine-scale, georeferenced data recently collected by COBI (COBI 2002, Best 2003) were used as the basis for quantifying nearshore habitat modifications and habitat structural attributes. This dataset provided detailed information (e.g., extent and number of modifications, encroachment into the intertidal zone, marine riparian vegetation cover and type, stormwater outfalls) that assisted in quantifying impacts to controlling factors within a particular reach of shoreline. Aerial imagery and historic photographs provided additional information for verifying assumptions and completing the picture of nearshore conditions.

Table 2. Conceptual Model Applied to Geomorphic Classes by Each Controlling Factor Metric.

Geomorphic Class	Habitat Structure	Habitat Processes	Ecological Function
Wave Energy			
Rocky	Generally not an issue, but may affect structure of attached macroalgae community.	Only as it affects macroalgal productivity.	May affect biodiversity maintenance.
Marsh/Lagoon	Generally not an issue in these wave protected habitats, though habitat structure of marsh plant community could be affected.	Loss of primary production and altered sediment flux.	
Spit/Barrier/ Backshore	At critical tidal elevations or areas exposed to waves, turbulence may displace rooted aquatic vegetation (e.g., eelgrass), suspend and coarsen fine sediment, reduce LWD retention	Loss of primary production. Increased sediment and carbon flux. Landscape fragmentation.	Loss of associated habitat functions, including salmon prey production and refuge. Loss of eelgrass affects herring spawn; altered sediment composition may affect forage-fish spawning substrate.
Low Bank			
High Bluff			
Loss of Natural Shade			
Rocky	Light increase generally not an issue (little riparian vegetation)	N/A	N/A
Marsh/Lagoon	Loss of riparian vegetation affects habitat complexity. Increased light levels reaching marsh/mudflats increases desiccation and temperature regimes.	Loss of primary productivity from riparian litterfall. Carbon flux alteration and landscape fragmentation.	Loss of biodiversity, prey production (terrestrial insects), and refuge. Increased water temperatures in lagoons may affect herring embryo development.
Spit/Barrier/ Backshore	Same as Rocky (low growing dune vegetation).	N/A	N/A
Low Bank	Same as Marsh/Lagoon.	Same as Marsh/Lagoon.	Same as Marsh/Lagoon. Increased temperatures and desiccation affects beach spawning forage-fish embryos.
High Bluff			

Geomorphic Class	Habitat Structure	Habitat Processes	Ecological Function
	Artificial Shade		
Rocky	Total light loss would impact attached macroalgae communities, including patch size, density, and shape.	Loss of primary productivity from macroalgae. Landscape fragmentation.	Loss of associated biodiversity, prey production, and refuge. Darkness may inhibit salmon migration.
Marsh/Lagoon	Total light loss would impact vascular marsh plant, macroalgae, and eelgrass communities, including patch size, density, and shape.	Loss of primary production. Carbon flux alteration. Landscape fragmentation	
Spit/Barrier/ Backshore	Total light loss would impact eelgrass and marine vegetation, including patch size, density, and shape.		
Low Bank			
High Bluff			
	Sediment Supply		
Rocky	Generally not an issue, though blockage of alongshore transport may change some substrate characteristics.	Only as it affects sediment flux, if present.	May affect biodiversity.
Marsh/Lagoon	Excessive supply from fluvial sources likely to be issue. May affect beach slope and smother eelgrass beds and marsh vegetation.	Altered sediment flux. Loss of eelgrass and riparian primary production, carbon flux, and landscape connectivity.	Loss of eelgrass associated salmon refuge and prey production. Excessive sediments may smother benthos, reducing biodiversity .
Spit/Barrier/ Backshore	Impoundment of backshore sediments may cause beach erosion, coarsening of sediments, and loss of rooted vegetation.		Loss of eelgrass associated salmon refuge and prey production. Substrate coarsening affects biodiversity. .
Low Bank	Impoundment of backshore sediments may cause foreshore and alongshore beach erosion (due to loss of sediment source), bank steepening, and sediment coarsening. Loss or change of rooted vegetation.		

Geomorphic Class	Habitat Structure	Habitat Processes	Ecological Function
High Bluff	Major issue. Same as Low Bank, but may be more significant along high bluffs, which are often important feeder bluffs.		
Substrate Type			
Rocky	Generally not an issue; modifications are often rock cobble or concrete.	N/A.	N/A
Marsh/Lagoon	Change from soft sediments to novel hard substrates (e.g. rock, concrete, steel, wood) associated with structures. Attached macroalgae and biota (e.g., mussels and barnacles) subsume soft sediment-associated vegetation and animals.	Reduction in sediment flux and alteration of landscape connectivity. Also affects source of primary production and carbon flux.	Alters local biodiversity (especially vegetation and invertebrate communities) in favor of those attaching to hard structures. Also, potential loss of beach spawning habitat for forage fish.
Spit/Barrier/ Backshore			
Low Bank			
High Bluff			
Depth - Slope			
Rocky	May alter distribution of attached macroalgae and biotic (e.g., mussels, barnacles) communities depending upon encroachment. May also simplify habitat complexity.	May reduce landscape connectivity.	May alter biodiversity maintenance and salmon migratory corridors.
Marsh/Lagoon	Change in distribution of eelgrass, salt marsh vegetation, and mudflat channels. Impacts to associated landscape metrics.	Same as above, as well as modification of sediment flux and reduction of primary production.	Same as above, as well as alteration of salmon prey production.
Spit/Barrier/ Backshore	Encroachment and slope increase narrows distribution of eelgrass and other vegetation, simplifying or reducing habitat structure.		
Low Bank			
High Bluff			

Geomorphic Class	Habitat Structure	Habitat Processes	Ecological Function
	Pollutants/ Nutrients		
Rocky	Nutrients may initiate nuisance algal blooms and epiphyte growth. Herbicides, contaminants, or water quality impacts may affect kelp vegetation, cause disease outbreaks, and affect growth.	May fragment landscape, affect sediment nutrient, and carbon flux, and reduce habitat connectivity and primary productivity..	Direct toxicity to organisms, especially relevant to herring spawn, juvenile salmon, and their prey. Loss of vegetation causes reduction in salmon prey production and refuge. Affects biodiversity maintenance both in subtidal and riparian settings.
Marsh/Lagoon	Especially relevant in these settings with low flushing rates. Same impacts as noted above, especially as related to eelgrass, marsh, and marine riparian vegetation.		
Spit/Barrier/ Backshore	Same impacts as noted above, especially as related to eelgrass and dune vegetation.		
Low Bank	Same impacts as noted above, especially as related to eelgrass and riparian vegetation.		
High Bluff			
	Hydrology		
Rocky	Generally not an issue.	N/A	N/A
Marsh/Lagoon	Constrictions may impact tidal influence and flushing rates, affecting the distribution and diversity of riparian, eelgrass, and marsh vegetation.	Affects primary production, carbon, nutrient, and sediment flux, landscape connectivity	Affects associated plant and animal biodiversity and disturbance regulation. Vegetation change alters migration corridors for birds, mammals, and fishes.
Spit/Barrier/ Backshore	Encroachment into intertidal zone may alter tidal hydrology and displace dune vegetation		Same as Marsh/Lagoon. As well, altered hydrology may affect

Geomorphic Class	Habitat Structure	Habitat Processes	Ecological Function
Low Bank	Alteration of groundwater and surface flows may impact riparian vegetation distribution and slope stability, whereas tidal encroachment by structures and location of outfalls may displace or scour intertidal salt marsh vegetation and eelgrass.		spawning success of forage fish (both via modifications to groundwater seeps and surface flow scour).
High Bluff	Same as Low Bank, though likely greater impacts to slope stability.		
Physical Disturbance			
Rocky	Benthic disturbances alter patch size, shape, and density of attached macroalgae and invertebrates (e.g. barnacles, mussels).	May fragment landscape and affect primary production associated with eelgrass or marsh communities. Altered carbon, nutrient, and sediment flux.	Biodiversity maintenance and natural disturbance regime.
Marsh/Lagoon	Unnatural or frequent disturbance of benthic habitats affects the distribution, size, shape, and density of eelgrass beds, macroalgae, and benthic communities.		Bottom disturbances affect benthic community biodiversity, salmon prey production and refuge, as well as disturbance regulation. May also affect spawn of forage fish. Human noise, activity, and sound may impact nesting and migration corridors of mammals and birds.
Spit/Barrier/ Backshore			
Low Bank	Same as above. Also, vegetation removal affects structure and complexity of riparian cover.	Same as above. Also, reduced contribution of riparian primary production.	
High Bluff			