CHAPTER 3

Methods

3.0 Methods

3.1 Introduction

An essential part of this study was the development of a sampling protocol for this marine shoreline sediment survey and assessment (Herrera 2003). The sampling protocol was developed in coordination with the Thurston Regional Planning Council, and was reviewed by the Thurston County Nearshore Technical Committee. The methodology used in this study, and presented in this chapter, is consistent with the sampling protocol (Herrera 2003).

This study consisted of two general approaches: 1) a GIS analysis of existing aerial photographs and digital elevation data to identify sediment sources and sinks, impacts of bulkheads on upper beach areas, and long-term erosion and aggradation trends on the Thurston County shoreline; and 2) field surveys of representative beach profiles to document and categorize the various geomorphic beach characteristics present, to identify the effect of bulkheads on sediment characteristics and erosion, and to aid in identification of sediment sources and sinks.

The major field phase of the study was performed between August 25 and August 28, 2003. In addition, field verification of beach profile data and interpretation of aerial photograph and digital elevation data was performed at representative beach sites in September, 2003.

3.2 GIS Study Elements

The GIS and background information analysis of this study included the following elements:

1. Identification and analysis of existing information and data gaps
2. Mapping of recent and historical mass wasting areas (including spatial extent and estimated date of occurrence)
3. Mapping of large-scale historical shoreline changes, bathymetry changes, and artificial shoreline alterations (i.e., beach erosion or accretion, bulkhead intrusion, and artificial fill)
4. Mapping of structures including boat launch ramps and outfalls that block alongshore sediment transport
5. Digitization of the shoreline geology and stratigraphy from the Washington Department of Ecology's *Coastal Zone Atlas of Washington* (Ecology 1980)

6. Delineation and description of areas to consider for preserving and rehabilitating ecological functions and habitat.

3.2.1 Analysis of Existing Information

The following sources were reviewed in compiling existing information:

- U.S. Army Corps of Engineers historical aerial photographs (USACE 1944)
- Recent orthorectified vertical aerial photographs from Thurston GeoData Center (2000)
- Oblique aerial photographs from Washington Department of Ecology (Ecology 1976–1997, 1992, 2000)
- Historical hydrographic surveys from the National Oceanic and Atmospheric Administration, National Ocean Service (U.S. Coast Survey 1855, 1873–4, 1878–9; U.S. Coast & Geodetic Survey 1913, 1936)
- Drift cells mapped by Schwartz and Hatfield (1982) for Washington Department of Ecology
- Bathymetry data from National Oceanic and Atmospheric Administration for various dates
- Thurston Regional Planning Council GIS map layers associated with Thurston County's marine shoreline
- Washington State ShoreZone Inventory GIS map layers from Washington Department of Natural Resources, Nearshore Habitat Program (WDNR 2001)
- Washington Department of Ecology's *Coastal Zone Atlas of Washington* (Ecology 1980)
- Oakland Bay Hammersley Inlet Nearshore Assessment (Anchor Environmental 2002)
- Channel Erosion Along the Deschutes River (Collins 1994)
- Capitol Lake Adaptive Management Plan (TRPC 2002)
- Geologic maps of the Thurston County shoreline from Washington Department of Natural Resources, Division of Geology and Earth Resources (WDNR 2003a, 2003b, 2003c, 2003d, 2003e, and 2004).

3.2.2 Identification, GIS Mapping, and Assessment of Historical and Recent Sediment Sources

In order to assess historical shoreline changes (i.e., beach erosion and accretion), historical sites delivering sediment to the marine shoreline of Thurston County were identified and mapped, including sites of mass wasting (i.e., bluffs with shallow surficial erosion and deep seated landslides), and stream and river outlets. All GIS mapping was correlated with Washington State ShoreZone Inventory (WDNR 2001) units to facilitate cross-referencing of existing information with the results of this study. Coastal mapping was based on a digital elevation model (DEM) with six foot pixels created with lidar (light detection and ranging), historical and recent rectified aerial photographs, and aerial oblique shoreline photographs available from Washington Department of Ecology for 1976–1977, 1992, and 2000. Sediment delivery sites were mapped as GIS shapefiles.

3.2.3 Rivers and Streams

Watershed areas were estimated from a number of sources, including Lombardo et al. (2003) (total watershed area for Totten and Eld Inlets), Golder Associates (2003) (sub-watershed areas for WRIA 14, including Totten Inlet and the western side of Eld Inlet), Tabbutt (2001) (watershed areas for creeks throughout Thurston County), Thurston County (2002) (watershed areas for the different inlets, limited to the areas actually within Thurston County), Ecology (2004b) (watershed areas for the Nisqually and Deschutes Rivers), and Watershed Professionals Network et al. (2002) (watershed area for McAllister Creek). River and stream outfalls in Puget Sound are typically coincident with deltas of fluvial sediments. Stream deltas and delta-like areas were mapped as points. These were identified as areas of fan shaped beaches (in plan form). These areas could be true stream deltas or delta-like areas at the confluence of two drift cells. Three stream deltas were surveyed in the field to help assess the relative importance of fluvial sediment supply in the littoral sediment budget. The following elements also were noted:

- Presence/absence of culverts
- Locations of culvert outfalls
- Locations and widths of stream mouths.

3.2.4 Mass Wasting

Puget Sound beaches are commonly set against steep, forested hillslopes composed of relatively unstable glacial sediments. Feeder bluffs are hillslopes that contribute sediment to the shoreline either through chronic surficial erosion or through periodic landsliding. Vegetation and topographic relief provide a means of identifying feeder bluffs and can be integrated into a basic protocol for classifying coastal hillslopes.

Landslide areas were mapped as polygons in a GIS shapefile in order to quantify the extent of landslides on the shoreline of each inlet. The following information was collected for each polygon:

- Landslide occurrence and approximate age (i.e., less than 2, 3–5, 5–10, and more than 10 years old) based on visual estimation of vegetation age and, where applicable, woody debris age
- Whether a slide contributed wood debris
- Whether the area was actively eroding.

These polygons were used to estimate the relative contribution of feeder bluffs in the littoral sediment budget for Thurston County marine shorelines. The areas of all landslide polygons were recorded and were summarized by inlet.

Initially, landslide sites in Budd Inlet were identified on oblique photos and verified from a boat while in the field in June 2003. Landslides identified in the field were compared to aerial and oblique photography from the year 2000 and four lidar-derived hillshade from 2002 to identify characteristics that could aid in identification and delineation of landslide sites. The DEM (digital elevation model) was examined using different hillshade layers of the DEM with incident light coming from the NW, NE, SE, and SW to refine the accuracy of landslide mapping. Exposed soil, trees on the beach that are perpendicular to the shoreline, accumulations of sediment at the base of hillsides on aerial photographs, and hummocky areas on shaded relief images were identified as typical characteristics of areas that were eroding or had experienced landsliding. Using this information, landslides and eroding areas along the Thurston County coastline were digitized at a resolution of approximately 1:1000 to 1:1500.

Landslides were initially mapped from the DEM and aerial photos, were then checked for consistency and were then spot checked in the field.

Landslides that were not easily identified on photographic coverage, but could be identified by scallop shapes in the hillshade layers were estimated to be over 10 years old and were digitized in a separate file. These are difficult to identify because no soil is typically visible in the aerial photos.

Landslides digitized in this study were compared to those shown on available Washington Department of Natural Resources geologic maps as landslide deposits (WDNR 2003a, 2003b, 2003c, 2003d, 2003e, 2004a). A subset of landslides were not compared to these maps because the Summit Lake geologic map was not published in time to be included in this analysis. WDNR only recorded landslides in areas where the landslide obscures the underlying geology and consequently did not map many smaller landslides which were observed and mapped in this study.

3.2.5 Historic Shoreline Change

Historical vertical aerial photographs (USACE 1944) were georeferenced for comparison with recent aerial photography (Thurston GeoData Center 2000) to identify long term trends in erosion and accretion. Given the relatively low rates of shoreline change in this area, it was unlikely that this would provide detailed information regarding the overall erosion or accretion rates. However, it provided the opportunity to identify any major historic changes which would be extremely important, if present.

3.2.6 Historic Bathymetric and Shoreline Surveys

Historic bathymetric and shoreline surveys (U.S. Coast & Geodetic Survey 1936) were georeferenced for comparison with four bathymetry transects measured in the field to identify whether or not inlets are a sediment sink, and for a comparison with shorelines visible in recent aerial photography to search for large-scale accretion or erosion of shorelines (Thurston GeoData Center 2000). Earlier surveys (U.S. Coast Survey 1878-9) were also examined. As with the analysis of historical aerial photographs, this was an investigation that had a low probability of providing new information, but if it did provide new information, this would be extremely significant.

Inlet bathymetric cross-sections were developed using a 30 meter digital elevation model (DEM) of Puget Sound (Finlayson et al. 2000) (Appendix C). Bathymetry cross section measurements were overlaid onto 1936 hydrographic surveys (Coast and Geodetic Survey 1936).

3.2.7 Artificial Shoreline Alterations

Estimated natural shoreline data were used to assess forage fish spawning habitat area that has been lost due to the construction of bulkheads. The natural shoreline, or the approximate shoreline that would have existed without bulkhead intrusion on beaches, was mapped by modifying a Thurston County GIS shapefile in areas where bulkheads have been built on beaches. TRPC created the shoreline boundary of the county border GIS shapefile using Thurston GeoData Center (2000)'s aerial photo set. This GIS shapefile was copied and the shoreline was modified to correspond to the estimated natural shoreline in all areas where bulkheads encroached. Bulkhead-free areas and slope break were used as a guide. Modifying the shoreline was not possible in the Olympia area, where the high level of development and filling makes the natural shoreline difficult to discern. A copy of the original Thurston County GIS shapefile was used with the modified, natural shoreline polygon to identify areas where bulkheads are built on natural shoreline. Areas of the resulting polygons were calculated and summarized by inlet to assess inlet-wide effects on forage fish spawning habitat.

3.2.8 Blocking Structures

Structures that block sediment transport along drift cells were digitized using vertical and oblique aerial photographs (Thurston GeoData Center 2000; Ecology 2000). Drift blocking structures were only digitized for non-permeable structures such as rock groins or causeways and not for pile-elevated docks. These structures typically jut out onto the upper beach at a 90 degree angle to the shoreline. Structures were delineated along the centerline of the structure following a line from the upper beach area to the end of the structure.

3.2.9 Identification of Preservation and Restoration Sites

Using key geomorphologic features that were found in this study to affect sediment and upper beach habitat, preservation and restoration areas were delineated in GIS. General preservation and restoration areas were delineated using field observations, aerial photos, lidar, and ground photos to identify factors that can affect the quality and quantity of forage fish spawning habitat. In addition to general preservation areas, specific preservation and restoration locations were selected for features that are uniquely important to maintaining and improving habitat.

3.3 Characterization of Drift Cells

A drift cell is a reach of the marine shoreline within which sediment erosion, deposition, and transport occur. The different drift cells on a marine shoreline are normally considered independent of each other, i.e., all the sediment sourced within a particular drift cell remains within that drift cell, unless it is lost offshore. Thus, drift cells define nearshore areas of influence based on the sources and sinks of material transported alongshore. Drift cells develop due to local wind-generated waves combined with local bathymetry and geomorphology.

The division of a marine shoreline into drift cells can be an oversimplification because, in some cases, there is a small amount of interchange of sediment between drift cells. However, the division of the shoreline into drift cells is a critical tool for shoreline analysis and management in Puget Sound. For the present study, the following sources were used to characterize drift cells:

- Washington Department of Ecology's *Coastal Zone Atlas of Washington* (Ecology 1980)
- Net shore-drift mapping by Schwartz and Hatfield (1982)
- Thurston Regional Planning Council GIS map layers associated with Thurston County's marine shoreline (TRPC 2003a).

For the purpose of estimating the sediment budget, potential transport rates within drift cells reported in the *Coastal Zone Atlas of Washington* (Ecology 1980) were used as a basis for estimating the upper limits of the transport rates out of the major inlets of Thurston County. For all other purposes, including selecting sites for field measurements, the mapping in Schwartz and Hatfield (1982) was used. (This mapping was also used as a basis for the TRPC GIS layers). This later mapping could not be used to estimate transport rates because it provides no quantitative estimates of transport rates.

For the purpose of planning the beach survey, beach sampling sites were selected in larger drift cells representative of a shoreline. During the field effort, the drift direction at each sampling site was confirmed based on geomorphic features of the shoreline and other field indicators. Field observations of net shore-drift indicators included sediment accumulations up-drift of woody debris, groins, pipes, or other barriers to littoral sediment transport.

Figure 3-1 illustrates the major drift cells in Thurston County.

3.4 Sediment Budget Development Methodology

Within the littoral environment, if more sand is transported away from a beach than toward that beach, erosion results. A sediment budget is a way of quantifying this observation by identifying each process by which sediment enters or leaves an area, quantifying the volume of sediment corresponding to each process, and checking that the results are in balance. A sediment budget is generally expressed in an equation:

$$S_i = S_o + S_s$$

where S_i = quantity of sediment input to the littoral zone, S_o = quantity of sediment output from the littoral zone, and S_s = quantity of sediment stored in the littoral zone. Figure 3-2 is a conceptual illustration of the sources and sinks that are typically identified in a sediment budget. In this figure, beach accretion represents an increase in the quantity of sediment stored in the site; other processes are considered as inputs or outputs.

The first step in preparing a sediment budget is to divide the shoreline of interest into essentially independent cells, or areas whose inputs, outputs, and transport can be investigated independently. Ideally, a sediment budget would be developed for each drift cell of interest. However, the data needed to do this was not available at a sufficient level of geographic detail. Based on the availability of information, the present study developed a sediment budget for each individual inlet and reach: Totten Inlet, Squaxin Passage, Eld Inlet, Budd Inlet, Dana Passage, Henderson Inlet, and the Nisqually Reach. Each sediment budget presented in this report is effectively a sum over the sediment budgets for all of the drift cells within the inlet or reach considered. No exchange of sediment between inlets was considered.

The second step is to identify the different inputs, outputs, and storage areas or reservoirs. The sediment inputs considered were fluvial sources and landslides (this includes identifiable bluff erosion events). The sediment outputs considered were alongshore flow out of the inlets and into the deep channels to the north of the Thurston County shoreline and offshore transport into deep water within the inlets. Only one reservoir was considered, the beaches and nearshore. However, the change in storage was divided into two categories: decreases in storage identified through beach erosion, and increases in storage in response to sea level rise. Sea level rise effectively increases the storage in an otherwise stable beach because that beach would actually have to accrete, i.e., become higher, to keep up with the rising sea level and so maintain the same width and elevations relative to the sea.

These inputs, outputs, and reservoirs are described further in Section 4. As described there, each item was estimated based on some combination of the existing literature, the GIS study, and fieldwork.

The study did not attempt to calculate the rate of beach erosion by evaluating all inputs and outputs to the system and taking the difference. Because both the sediment inputs and outputs are large and only approximately known, such an approach would lead to huge errors. Rather, the sediment budget was used as a framework in which the different sediment sources and transport processes could be evaluated as either “large” (and, therefore, important for management of the system) or “small” (and not important for sediment supply).

3.4.1 Selection of Areas for Sediment Budget Analysis

A major decision in regard to the sediment budget for Thurston County was whether the sediment budget should be developed by drift cell, by inlets, or for the whole of Thurston County. Ideally, the sediment budget should be constructed by drift cell because these are largely independent of one another. However, the necessary information for this could not be obtained with a sufficient level of geographic detail.

The drift cells compiled by Schwartz and Hatfield (1982) suggest that the inlets can generally be defined in isolation. With one exception, the drift direction in the northern one-quarter (or more) of each inlet, on both sides, is to the north and out of the inlet. The only exception is the western side of Henderson Inlet, where the only significant identified drift is into the inlet, near the mouth (see Figure 3-1).

3.5 Field Study Elements

The field phase of the study included the following elements which are listed below and discussed in detail:

1. Beach Sampling Site Selection Criteria
2. Beach Sampling Protocol
3. Beach Transect Sampling
4. Additional Parameter Sampling
5. Identification and Prioritization of Potential Preservation and Restoration Sites
6. Data Compilation and Management.

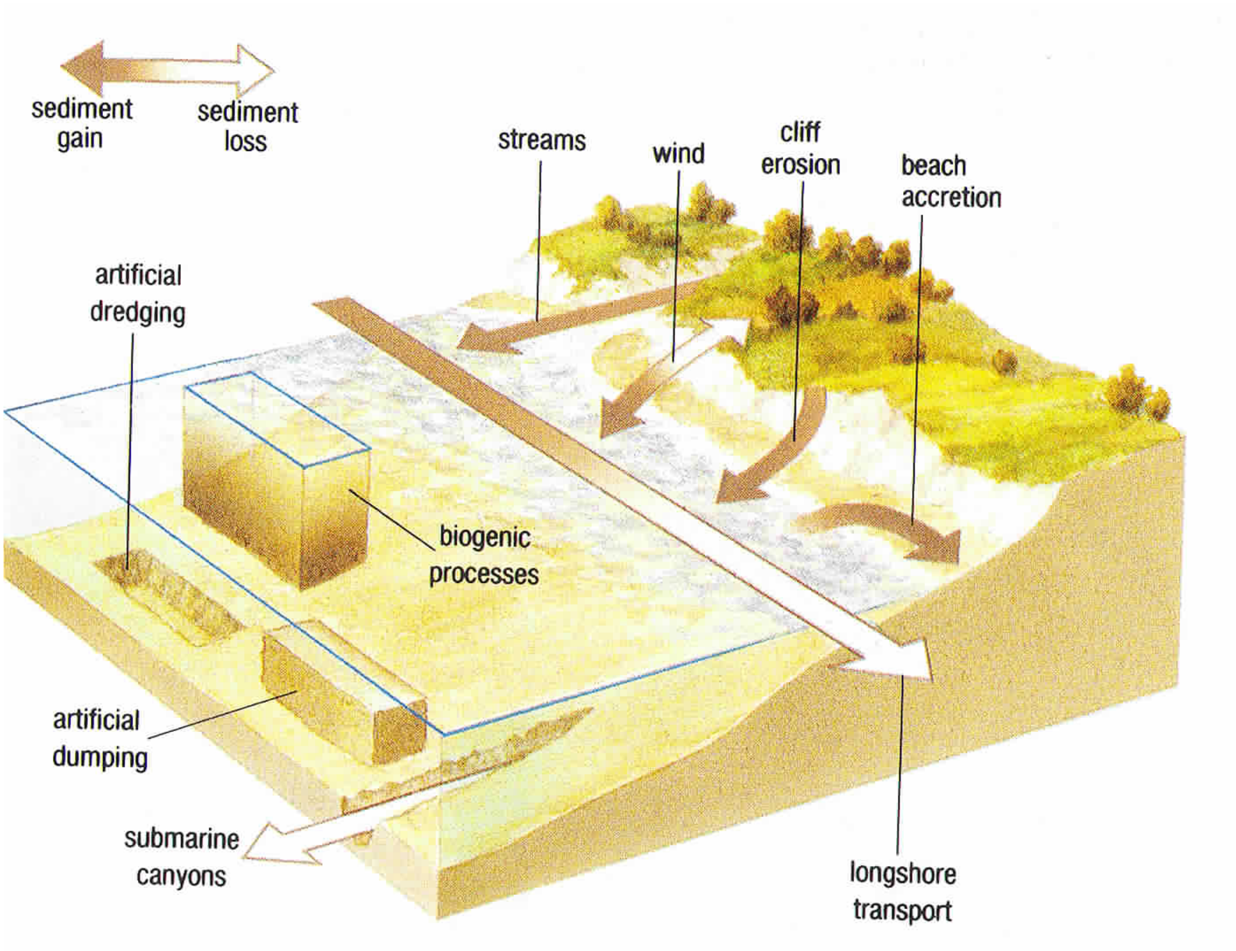

Figure 3-2. Conceptual illustration of littoral zone sediment budget.
From Brown et al. (1989).

3.5.1 Beach Sampling Site Selection Criteria

Site selection for the project field survey was based on: results of the evaluation of existing information; an analysis of historical change; principal sources of sediment delivery to marine shorelines; nearshore processes; data gaps; and results of the field reconnaissance conducted on June 16, 2003.

In order to sample a representative range of marine shoreline conditions within Thurston County, 29 paired beach sampling sites (a total of 58 beach transects) were selected. The selected beaches were distributed along Totten Inlet, Eld Inlet, Budd Inlet, and Henderson Inlet, as well as on Squaxin Passage, Dana Passage, and the Nisqually reach (Figure 3-3). Note that areas shown as armored shoreline include concrete bulkheads, rock revetments, placed logs, and, in the Nisqually delta, dikes. The majority of shoreline armoring is concrete bulkheads.

To the extent possible, each pair of beach sampling locations had one transect located in front of a bulkhead or other shoreline armoring and the other transect located on an unarmored shoreline without any manmade structures. This sampling approach allowed for comparative analysis such as parametric or nonparametric statistical analysis of paired samples, facilitating direct measurement of localized impacts of bulkheads.

The criteria for beach sampling site selection, based on comparability between pairs, included the following:

- Location in the same drift cell
- Location on a beach with a similar aspect
- Similar geology
- Location at the base of a hill with similar hillslope and bluff relief
- No recent landslide activity nearby
- At least 250 feet of separation between unarmored and armored beach
- Minimum beach length of 500 feet, where possible
- Absence of significant natural or manmade features protruding into the water between the beach site pair.

In addition to the 29 paired beach sampling sites, three beach sites were surveyed at stream delta or drift cell confluences to determine accretion characteristics at these discrete sites and to assess the relative importance of fluvial inputs from small streams. At each delta or drift cell confluence site, a transect parallel to the shoreline was surveyed. The delta profile from a transect of the beach was recorded, and the median surface grain size was measured.

3.5.2 Beach Transect Sampling

All beach transects were laid out perpendicular to the shoreline and extended from the slope toe or bulkhead to the water. To the extent possible, paired transect data were collected during low tide conditions; the beach delta and landslide samples could be collected during mid-tide conditions. The parameters recorded at each transect are detailed in the following subsections.

Field sampling was consistent with general guidelines for marine nearshore investigations (Simenstad et al. 1991; Ruotsala 1979).

Site: Location (GPS) and Time

The location of each transect was recorded using a Trimble® global positioning system (GPS) unit (resolution +/- 6 – 16 feet). The time of sample collection was recorded to determine the tidal elevation. Accuracy of readings was typically within 6 to 15 feet after differential correction. Transect measurements were recorded and stored in the handheld Trimble GPS unit. The transect data were downloaded into a spreadsheet after field work was completed.

Beach Profile

Beach profiles were measured for assessment of beach erosion and accretion. A minimum of four geographical locations were measured for each transect using an Impulse 200® rangefinder. Survey locations were recorded at slope breaks and at changes in sediment characteristics. (The instrument measures distances of 500+ meters with an accuracy of 3 centimeters at 50 meters, and measures angles with an accuracy of 0.1 degrees.)

Beach Sediment Characteristics

Beach sediment grain size was characterized visually along each transect using the sediment classifications in Table 3-1. Additionally, occurrence of hardpan and beach surface coarsening (i.e., a thin layer of coarse sediment over finer sediment) was noted to identify evidence of beach erosion. Beach sediment characteristics were noted at each point along the transects where the sediment characteristics change significantly (e.g., grain size changes by 50 percent or more). These data were used during the assessment of beach coarsening in relation to the presence of bulkheads. Photos of various representative beach sediment classes are provided in Appendix F.

Table 3-1. Grain size classes used to classify sediment types.

Class	Size Range (diameter)
Boulder	> 256 mm
Cobble	64 - 256 mm
Gravel	2 - 64 mm
Sand	0.0625 - 2 mm
Silt	0.002 - 0.0625 mm
Clay	< 0.002 mm

Characteristics of the Upper Beach Area

The nature of the upper beach area was classified as unarmored, bulkhead, riprap, artificially placed logs, or other. The location of the upper beach was defined as the furthest inland point of the transect.

Beach Shade Cover

To better characterize the existing forage fish spawning habitat conditions in relation to the actual habitat utilization and to shoreline modification, canopy cover at each beach site was recorded (as shade available or shade unavailable).

Locations and Quantities of Driftwood

The locations and quantity of driftwood at each beach transect were noted and recorded at the following level of detail:

- The width of beach over which logs extend
- Basal diameter of the 10 logs closest to the transect
- General orientation of logs (0, 30, 60, or 90 degrees to the beach)
- Length of beach over which the 10 measured logs extend
- Presence and size of barnacles on the logs
- Total length of beach with similar conditions extending in either direction from the transect line.

This information was also used for the general characterization of forage fish spawning habitat conditions in relation to the degree of shoreline modification.

Barnacle, Mussel, and Shell Fragment Sizes and Locations

Barnacle and mussel distribution and size were characterized visually along each transect to establish the zone in which they occur in relation to beach width and substrate type. These organisms were used as biological (indirect) indicators of the sediment beach disturbance regime. In addition, when present, the shell fragment zone was noted and recorded in relation to the beach cross-section along each transect. These data were used as supporting evidence regarding predictions about beach erosion or accretion.

Exposure of Beach Platform Below Beach Sediment

Areas with beach platform exposure (bedrock/glacial deposits underlying beach sediment) were visually characterized along each transect. This information was used as supporting evidence regarding predictions about beach erosion or accretion.

Beach Erosion or Accretion

In addition to the indirect field indicators of erosion and accretion described above, direct evidence of beach sediment erosion and accretion were noted and recorded at each beach sampling site. The degree of erosion and/or accretion was measured at bulkheads to determine erosion and accretion rates based on available installation date records for specific structures. All of these indicators of erosion and accretion were used to help confirm the historical photographic analysis. In addition, other indirect visual indicators such as scarps and spits were characterized and recorded (using free-text description and photographs).

Shore-Drift Direction

Field indicators of shore-drift direction included spits and sediment accumulation on groins, deposited wood, jetties, and other features located perpendicular to the shoreline. This was used as confirmation of the previous drift cell mapping by Schwartz and Hatfield (1982).

Upland Condition

The upland was characterized as having one of the following conditions: forested, mature or immature; natural pasture; landscaped (ground cover only); or impervious (low- or high-density development). This information was used in an assessment of the degree to which general upland modifications may influence sediment recruitment within the context of the reduction or elimination of landslide potential.

3.5.3 Statistical Data Analysis

Statistical analyses were performed to compare habitat and geomorphic attributes for unarmored and armored beaches that were paired together. For attributes that are measured on a continuous scale, the data for paired beaches were compared using a Wilcoxon paired-sample test (Zar 1984). The Wilcoxon paired-sample test is a nonparametric analogue to the paired t-test. Through the use of a paired test, variability or noise in the data between the unpaired beaches was blocked out of the analysis. In this way, differences between the paired unarmored and armored beaches were more readily detected. A nonparametric test was used in this analysis because the data did not always meet the required assumptions for using a parametric test (e.g., normality of paired differences). The specific beach attributes that were tested using this approach were total beach width, total width of habitat, beach slope, percent of beach showing beach surface coarsening, and height of top of beach. In all cases, statistical significance in these tests was assessed at an alpha (α) level of 0.05.

The width of beach between MTL and MHHW was calculated from MTL to the lower of: MHHW and the top of the beach at the base of the hillslope (unarmored sites) or; the base of the bulkhead or other structure (armored sites). The width of spawning habitat was estimated by evaluating the beach width between MHHW and MTL, and subdividing that portion of the beach according to the dominant substrate type (cobble, gravel, sand, fines [silt and clay], or other such as shells). See Appendix F for photos of these representative sediment types. It was assumed that spawning habitat exists where sand and gravel substrate was present in this elevation range. Beach slope was evaluated from the beach width between MHHW and MTL and the elevation change between these datums. The width of the beach that shows beach surface coarsening between MTL and MHHW was estimated in a similar way.

For data that were collected on a nominal scale (i.e., presence or absence), the data from paired beaches were compared using the McNemar’s test (Zar 1984). Like the Wilcoxon paired-sample test described above, the McNemar's test also blocks out variability or noise in the data from unpaired beaches so that differences between the paired unarmored and armored beaches can be more readily detected. The McNemar's test evaluates whether a particular attribute is present in the same proportion at both the unarmored and armored beaches. The specific beach attributes that were tested using this approach were presence/absence of beach surface coarsening, presence/absence of beach platform exposure, presence/absence of barnacles, and presence/absence of shade. In all cases, statistical significance in these tests was assessed at an alpha (α) level of 0.05.

Effects of Armoring on Beach Characteristics

To identify the impact of surrounding bulkheads, armored transects were sorted into four groups based on the percentage of beach that is armored (0-25 percent, 26-50 percent, 51-75 percent, and 76-100 percent) within 300 feet in either direction of the transect location. For each grouping, the number of transects where the top of the beach was near (within 1 foot) or below MHW was recorded. Also, the percentage of armored transects that were more than 1 foot lower than their paired unarmored transect across the uppermost 50 feet of beach (example: Appendix D-7) was recorded for each grouping. Unarmored transects were also sorted into four groups. For each grouping, the number of transects with the top of the beach near (within 1 foot) or below MHW was recorded. The number of transects that were more than 1 foot above their paired transect was also recorded.

3.5.4 Additional Parameter Sampling

Bathymetric Measurements

Bathymetric measurements were performed at four locations in Budd Inlet and Eld Inlet. One transect (including six to ten measurements) was established across each inlet near the mouth. These measurements were collected using the GPS and depth sounder instruments. The horizontal accuracy of the measurements was approximately 20 feet, as determined from the standard deviation of the GPS measurements and dominated by the drift of the vessel; the vertical accuracy was approximately 1 foot, as determined from previous comparisons between this and more accurate bottom-mounted depth sounders.

The results were compared with measurements from the 1936 hydrographic surveys (U.S. Coast & Geodetic Survey 1936). Given the limited accuracy of the depth sounder instrument used in that sediment study, it was not anticipated that any significant differences between the 1936 measurements and the new measurements would be identified. However, a limited investigation of potential changes in the bathymetry was considered important because if there were any major changes, they would have a very large impact on the overall sediment budget for the inlets.

The data density from earlier datasets (U.S. Coast Survey 1873-1874 and 1878-1879) was too low for a meaningful comparison of the bathymetry, and therefore these surveys were not georeferenced.

Inlet Cross-Sections

Inlet cross-sections were prepared using ESRI Spatial Analyst from a 30 meter digital elevation model (DEM) of the topography and bathymetry of Puget Sound (Finlayson et al. 2000). The vertical datum of the cross-sections is NGVD29 (which is equivalent to mean sea level). The dataset contains some inherent inaccuracies due to the difficulties of combining terrestrial and marine topography datasets and due to low topographic resolution within Puget Sound.

Stream Delta Measurements

Additional measurements were collected at three sites corresponding to apparent stream delta locations. At each delta site, a separate transect parallel to the shoreline was surveyed across the stream at approximately the mean tide elevation. The surface grain size at each measurement location was also recorded. This set of measurements was used to assess the relative importance of the fluvial sediment supply from small streams that drain to the Thurston County marine shoreline.

Mass Wasting Characteristics (landslide dimensions)

Based on the information gathered during the GIS analysis, the data related to mass wasting sediment inputs were field-verified. Field surveys were used to estimate the depths of typical landslides, for calculations of landslide volumes from GIS-delineated landslide areas. Mass wasting measurements were made at predetermined sets randomly selected from the GIS-delineated landslide areas.

3.5.5 Identification and Prioritization of Potential Preservation and Restoration Sites

The project team conducted field beach identification, confirmation, and documentation of potential preservation and restoration sites identified during the preliminary survey of available information.

3.5.6 Data Compilation and Management

Field survey data were compiled for inclusion in an electronic data dictionary and (when applicable) in a GIS database. All GIS mapping was correlated with Washington State ShoreZone Inventory (WDNR 2001) units to facilitate cross-referencing and management of existing information with the results of this study. Selected products of the GIS analyses and field work were delivered electronically to Thurston County.