Alternative Shoreline Stabilization Evaluation Project

Final Report

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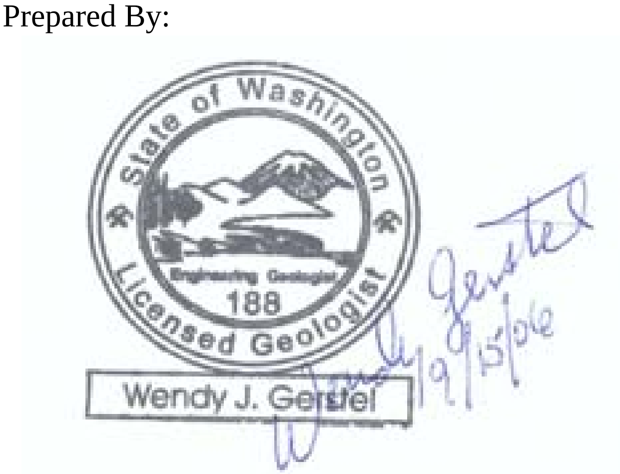

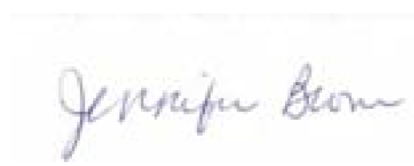

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Table of Contents

1.0 Executive Summary

This study was conducted under Personal Services Contract PSC 200504 with the Puget Sound Action Team. The study is an evaluation of alternatives to traditional shoreline armoring practices and applications in Puget Sound. Alternatives are described for this study as any techniques of shoreline stabilization or erosion control other than conventional concrete, rock, or log bulkheads. This report presents the findings of the study. It includes discussion of project design and application effectiveness in addressing perceived and observed site slope stability and erosion concerns on Puget Sound shorelines and offers some general recommendations for future applications.

A steering committee of state agency staff from Ecology, Department of Fish and Wildlife, and Puget Sound Action Team was convened to guide certain elements of the study. The findings of the study are based on observations made at more than 17 sites, although only the 17 selected by the study Steering Committee are reported on here. Additional 'alternative' sites not included in the study had either insufficient background information, were too recently installed, or had access or ownership barriers. Selected sites were restricted to those constructed or installed in the past 8-10 years. All shoreline treatments and site assessments are site specific and do not attempt to capture the broader, regional-scale coastal issues of slope stability, habitat restoration, or sea level changes within Puget Sound. However, some projects were designed in an effort to minimize these larger scale issues.

Project sites were classified by a combination of the coastal and upland geomorphic setting and the intended application objectives. The resulting four categories into which all 17 sites were classified are as follows: 1.) high bank (>15 ft) stabilization, 2.) low-no bank (<15 ft) stabilization, 3.) bulkhead removal, and 4.) bulkhead protection. A number of sites fall into more than one category because of reach differences within the project area.

Project sites were evaluated through a suite of questions relevant to the project classification, its construction, and site conditions. The questions addressed applicability of the project to site concerns, construction logistics, project performance, habitat conditions, and possible consequences of sea level rise.

Our findings indicate that the process of advocating for, permitting, designing, and installing/constructing alternatives to traditional bulkheads would benefit from more coordinated objectives and guidelines from permitting agencies. It appeared that site characterization in some instances was deficient in assessing geologic, hydrologic, and coastal geomorphic processes contributing to the issues being addressed in the project implementation, and that plantings did not always consider local site conditions.

Perceived issues and concerns of the property owner, those triggering the property owner's initial shoreline modification permitting request, were over-emphasized at some sites, leading to apparent over-design of, and possibly unnecessary mitigation.

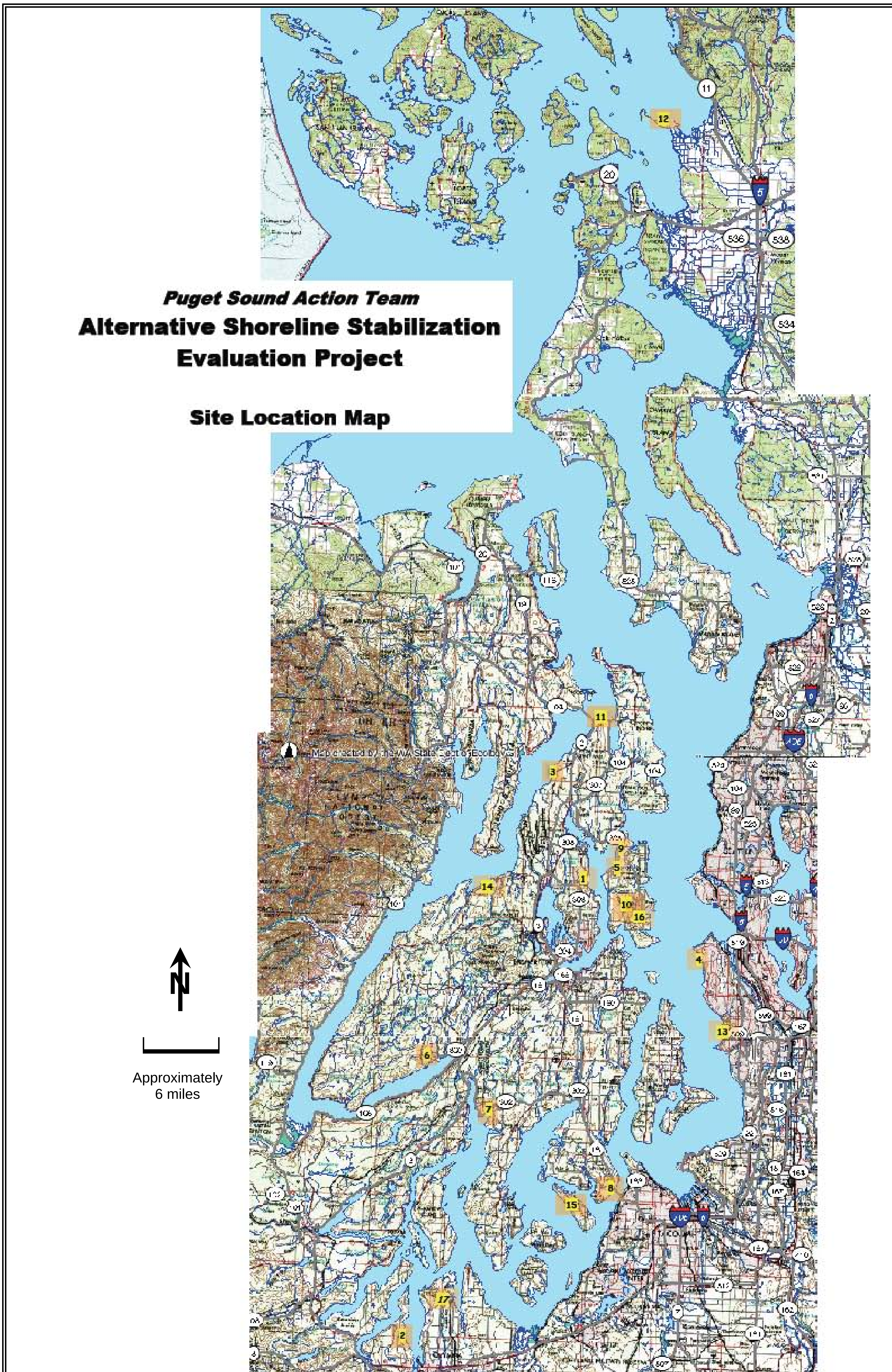

Figure 1. Location map of Puget Sound with the 17 coastal sites evaluated for this study.

Vegetation planted at some sites, even when native to the region, often did not thrive, likely due to unsuitable site conditions. In Table 1 we document our observations on geology, slope processes, and vegetation for each site for comparison between sites.

Requiring more complete, and possibly interdisciplinary, site characterization as part of the permitting process could ultimately reduce project costs and environmental impacts. Additional improvements need to be made in the depth and availability of information provided to shoreline property owners, who are being asked to consider alternatives to the traditional log, concrete, and rock armoring. We found shoreline property owners, although often willing to be test cases, commonly lacked readily accessible information on the rationale for implementing shoreline armoring alternatives, and received minimal guidance on how to pursue implementing these alternatives.

We learned from our interviews with contractors that there is a need for information and guidance on material resources and design specifications for these alternative projects. They felt sediment-size specifications for "beach nourishment" components often seemed arbitrary, and locating sources for the specified materials was difficult. Several contractors commented on the lack of engineering specifications for anchor pull-out design in the beach environment, forcing a "best guess" and possibly overly conservative approach.

Providing this type of information, and stream-lining the permitting process, could lessen the uncertainty, confusion, and frustration currently experienced by homeowners and contractors, and would serve to encourage more alternative projects.

2.0 Introduction

Currently, armoring covers over 800 miles of the shoreline of Puget Sound (PSAT, 2004), nearly 75% of the shoreline in some counties (Herrara Environmental Consultants, Inc., 2003). Known effects of shoreline armoring include shortening, steepening, and coarsening of beaches, inhibiting input of necessary sediments and large wood from nearshore bluffs, interrupting long-shore sediment transport processes, and eliminating long reaches of marine riparian vegetation. Alternatives to traditional shoreline stabilization measures are seen as a way to reduce the extensive shoreline armoring, restore natural shoreline processes and ecosystem function, and ultimately to improve the health of Puget Sound. Consequently, counties and cities are being asked by state regulators to evaluate shoreline armoring permit applications with more scrutiny, and to encourage the use of alternative slope stabilization and beach conservation techniques.

In response to society's desire to live more responsibly with our natural environment, a small group of shoreline landowners, regulatory agency staff and waterfront construction practitioners began experimenting in the late 1990s with alternative or "softer" methods of protecting marine shorelines from erosion and slope failure. Recommended and applied alternatives have included regrading of previously-modified steep slopes, adding sand and gravel to beach reaches (beach nourishment), anchoring or placing logs on the upper beach, placing at the surface or burying large rocks or concrete blocks, and planting vegetation. These techniques have been used in various forms, combinations, and configurations. The results are promising, but measures of each method's (or combinations thereof) effectiveness are largely anecdotal, and there has been no systematic evaluation of their effectiveness and appropriateness until this study.

This effort to evaluate shoreline stabilization alternatives feeds into the basic framework established under Washington Governor Christine Gregoire's Puget Sound Partnership (signed in December, 2005, and having support from the State Legislature) for improving the health of Puget Sound through actions such as water quality improvements, appropriate land management, and public education and involvement.

2.1 Project objectives

This study arose from the need to evaluate the effectiveness of "alternative" shoreline armoring applications and techniques, and subsequently to develop recommendations on the implementation of future shoreline site modification projects for local and state government planners and permitting staff, homeowners, and private geo-engineering consultants and contractors.

The impetus for this study was long-standing landowner and contractor concerns regarding the liability and minimal investment returns associated with alternative slope and shoreline stabilization techniques. The concerns have reportedly grown with increasing pressure by regulatory agencies to implement alternatives. Consequently, the U.S. Environmental Protection Agency (EPA) funded efforts to compile a document for the public, jurisdictional planners, permitting agencies, geo-engineering consultants, contractors, scientists, and others which would provide recommendations for future shoreline stabilization alternatives. This study supports the larger EPA project by establishing a basis for developing those recommendations through the evaluation of existing "alternative" projects.

To evaluate each of the study sites reported here, observations and information were collected on the geology, geomorphic processes, condition of vegetation, as well as perspectives (gathered through informal interviews) of homeowners, contractors, and state agency permitting staff. The interviews were conducted to obtain perspectives on the success of the project and the institutional barriers (both regulatory and informational) encountered. Gaining the landowners' perspectives also permitted comparison of landowners' concerns with observed site conditions and processes, and ultimately allowed for our assessment of the appropriateness of the applied mitigation design.

The 17 sites evaluated for this study were selected for review by the PSAT Steering Committee, including Doug Myers, Habitat Restoration Project Manager for the Puget Sound Action Team (PSAT); Mary Knackstedt, Education and Public Involvement Manager for PSAT; Doug Canning (State Dept. of Ecology, retired); Hugh Shipman, State Dept. of Ecology; and Randy Carman, State Dept. of Fish and Wildlife (WDFW).

The study builds on a previous one by Zelo, et al. (2000), which describes the design and condition of 15 alternative shoreline projects in their first few years after construction.

2.2 Organization of report

This report is organized to reflect effectiveness measures evaluated at each site within the framework of the classification system established for the study. (The classification system is discussed in Section 3.2.) Rather than site-specific discussion regarding measures of effectiveness, we felt it more useful to summarize the effectiveness of alternatives by project type, setting, and the coastal and upland processes acting on it. In other words, site issues and design and construction comments are addressed collectively by classification category in order to provide a more useful tool for developing site design, education, and policy guidance. All site-specific examples should be considered as case studies, not best management practices for any particular shoreline class.

Appendix A is a glossary of terms relevant to this study. Photographs of each study site before (when available) and after project installation are found sequentially included in Appendix B. Site numbers are referenced throughout the text as examples of various category and condition observations. Table 1, the first tab of the spreadsheet in Appendix C, provides the compilation of background information, site observations, and summary evaluation of findings (listed by site number) for all study sites. Table 2 (tab 2 of the same spreadsheet) groups sites by their classification and gives corresponding applied mitigation techniques. Table 3 (tab 3 of the spreadsheet) summarizes the study findings by site classification.

2.3 Site selection criteria

In conjunction with the Steering Committee, study sites were selected based on:

- original installation/construction date within the past 8-10 years,
- convenient site access (both geographic location and likely property owner cooperation),
- available site design and construction history,
- Steering Committee member site knowledge,
- and, contract budget and time limitations.

Based on these conditions, 17 sites were selected from 6 different counties within the Puget Sound basin. All of the sites were visited by the authors. Additional sites were also visited and considered for study inclusion, but are not included in this report because of insufficient background information or lack of time for a complete assessment. However, the perspectives gained from visiting the additional sites have contributed to our understanding of the complexity of the issue, and have added insight into the overall study results.

2.4 Site review logistics

Each of the selected sites was visited once. Observations were made of the geology (the type and sequence of sediments) at the site, coastal and upland geomorphic processes (the external and on-site natural forces) acting on the site, engineering geology (relative characteristics and performance of the geologic units) affecting the project installation, and natural and planted vegetation of the site. Site history was gathered either on-site or via phone interviews with property owners or permitting agency staff. Invaluable input was provided on site by WDFW staff who accompanied us on most of the site visits.

Travel logistics and necessary schedule coordination with the various project contributors precluded arranging all site visits for low-tide exposure. Although this would have allowed for better assessment of lower beach conditions, at none of the sites did it inhibit our evaluating the effectiveness of the installation. On one or two occasions, we were not able to reoccupy previous photo points.

2.5 Study-relevant geology/hydrogeology of Puget Sound

The geology, hydrology, and geomorphic processes observed and described in this report are offered strictly in the context of their contribution to the issues at the sites being reviewed for this study. Sediments exposed at the sites are described by their observed or interpreted hydro-geologic properties. Neither the objectives nor the scope of this study included correlating described units to regional geologic stratigraphy or glacial history.

The repeated advances and retreats of the Puget Lobe of the Cordilleran ice sheet left behind layers of clays, silts, gravels, and boulders of varying thickness, permeability, and density depending on sediment source, depositional environment, and compaction forces. The character of these sediments and the arrangement of the layers in relation to one another control the movement of ground and surface water, and thereby slope processes and stability, and erosion susceptibility. Denser layers, particularly those with fine-grained components, tend to perch groundwater, increasing the pore water pressures in overlying sediments and weakening them. Any of the sedimentary units may overlie bedrock, whose fracturing and permeability also influence groundwater flow.

Both natural processes and human land-use practices are closely linked in their contribution to upland, shoreline, and nearshore processes. Examples of the many resulting forms of mass wasting, ranging in size from small-scale sapping or piping, to small shallow soil slips, to large deep-seated rotational slump-earthflows, can be seen around Puget Sound (Tubbs, 1974; Thorsen, 1987; Gerstel, et al., 1997). Sites reviewed for this study evidenced some of the smaller, less dramatic of these. For further information on Puget Sound landforms, slope processes, and related topics the reader is referred to the extensive body of literature available through state Department of Natural Resources and university libraries.

Coastal geomorphic processes also contribute to shoreline and beach instability through natural shoreline drift, regular wave action, storm and tidal effects, and responses to natural and man-made shoreline modifications such as large woody debris (LWD) transport and bulkhead construction. An excellent source of information on the coastal geomorphic and ecological conditions and processes, particularly those affected by bulkheads, is the Washington State Dept. of Ecology's website at http://www.ecy.wa.gov/programs/sea/shorelan.html, and the Coastal Zone Atlas of Washington (1978-80).

When comparing property owner concerns regarding slope and beach stability (as described in the site file information) with our own site observations, we often noted a divergence between the two perspectives. We presume this stems from limited review or understanding by the property owner or their contractor of the larger hydrogeologic and coastal geomorphic conditions affecting the site. Because this affected project design criteria and construction, we felt it was important to record the differences in the perspectives. Both are recorded in Table 1; the former under 'Perceived Site Problems/Concerns', the latter under 'Observed Geology/Slope Processes'.

2.6. Terminology

Certain technical and descriptive terms related to this type of coastal work have been borrowed from other disciplines and geographic regions, and their use has caused some confusion, misrepresentation, and at times, controversy. One example is "beach nourishment", generally used to imply the addition of sediment to a sediment-starved beach. This is a long-used practice along shorelines of southeastern U.S. where sand is pumped from offshore "reservoirs", or sinks, onto eroding beaches. However, for at least two of the sites we reviewed, the term "beach nourishment" was used when the goal of importing sediment was to reduce wave energy to the upper beach. In these instances, the added sediment was much coarser than that which occurred naturally, and was not being used to replace eroded sediment.

Another example in the context of this report is "alternative", which is used to imply any design, technique, or structure applied to a site that differ from traditional construction of concrete, rock, or log bulkheads in an attempt to mimic more natural shoreline conditions.

To address the confusion introduced by terminology we have included a glossary of terms (Appendix A) with explanation of their local study-related and in some cases borrowed usage. With the glossary we hope to clarify current local use of the terminology, and bring some of the resulting confusion to light for discussion.

3.0 Overview of sites visited

3.1 Compiled site information

Figure 1 is a location map of the sites reviewed for this study and included in the findings of this report. All site observations and background information for these sites are compiled in Table 1. Site numbers on the map match those listed under 'Map No.' (column A) of Table 1. Names appearing under column heading 'Site Name' (column B) are those of the property owner during the project design and construction. In some cases, properties have since changed hands and, although the project is still referred to informally by the original owner's name, to maintain objectivity and reduce confusion, we refer in this report to sites only by their number.

3.2 Site Classification

We aggregated the 17 sites into four categories and summarize our findings for each category. In order to facilitate use of this evaluation study by property owners and permitting agencies considering alternatives for a specific site, the categories we define each describe an action that is likely to be proposed by a property owner seeking a shoreline modification permit:

- High Bank Stabilization
- Low-No Bank Stabilization
- Bulkhead Removal (or Relocation)
- Bulkhead Protection (or Replacement)

The categories primarily describe an action taken, but also reflect the morphology of the site, and thereby indirectly the processes occurring there. Because of the length of affected shoreline at some sites, morphology and conditions tend to vary along the length of the project, forcing some sites into more than one category (Appendix C, Table 2). Additionally, some sites included more than one action for a given reach, and therefore also fall into more than one category.

"High" and "Low-No Bank Stabilization" are somewhat subjectively defined as greater than ~15ft bluff height, and less than ~15ft bluff height, respectively. Generally, the high-bank sites are affected by upland slope processes (surface runoff and groundwater movement) as well as coastal processes (wave erosion, and sediment and LWD transport) (sites 1, 5, 9, and 17); whereas the low-bank sites are affected primarily by coastal processes (sites 3, 6, 7, 8, and 10). High and Low-No-bank Stabilization project sites were classified as such by a perceived need to address bluff erosion or beach loss.

Classification of a site as "Bulkhead Removal (or Replacement)" required that for some portion of the project reach some sort of shoreline hardening structure was removed and not replaced (sites 4, 8, 11, 13, 14, 16, 17). At sites 4, 8, and 14 a modified rock bulkhead was relocated landward of the original structure.

Sites classified as "Bulkhead Protection (or replacement)" (sites 2, 4, 12) include sites where an existing bulkhead was being compromised by erosion or other structural failure, and there was no interest by the property owner in redesigning the slope without a bulkhead. These site projects are questionably alternative.

Site morphology and geomorphic processes weigh into how each site was classified. Typical observed slope or shoreline processes for each classification of the sites we visited are as follows:

- High Bank Stabilization - Toppling failures, debris slides, debris flows, surface sloughs, sapping/piping, loss of root strength from vegetation removal,
- Low-No Bank Stabilization – Medium-high energy coastal geomorphic processes, sapping/piping, landform modification,
- Bulkhead Removal (or Relocation) - Medium-high energy coastal geomorphic processes,

- Bulkhead Protection (or Replacement) - Medium-high energy coastal geomorphic processes.

3.3. Applied mitigation methods/techniques

A number of different techniques, tools, and materials are currently applied to "alternative" shoreline armoring or stabilization projects, as evidenced by those reviewed for this study (Appendix C, Table 2). These include:

- Placement or anchoring of large logs (large woody debris - LWD)
- Burial of rock or concrete blocks below beach surface for anchoring LWD
- Installation of structures (rock or LWD) aimed at attenuating wave energy
- Addition of sediment to beach ("beach nourishment" – see Appendix A)
- Modification, removal, or replacement of bulkheads
- Planting of native and non-native vegetation

A common project design includes engineering an arrangement of buried rock or concrete blocks (e.g. ecology blocks or Jersey barriers) in a trench excavated into the beach sediments at the base of the slope. Steel cables or posts are then secured to the buried rock or concrete to anchor LWD or buttress other stabilizing structures (e.g. gabion baskets) built on top, above ground. The beach is reconstructed over the buried rock or concrete with imported sediments, and the disturbed area along the base of the slope is then revegetated. Versions of this project design were applied in a number of different combinations and with varying degrees of complexity. A composite representation of the designs is shown in figure 2.

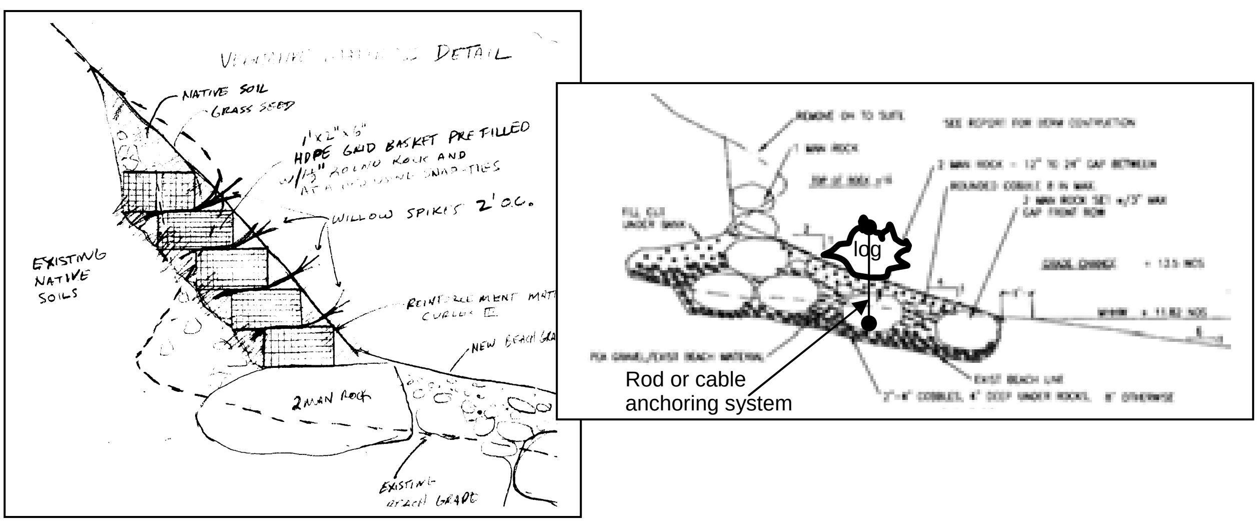

Figure 2. Examples of commonly applied designs where mitigation was intended to address erosion at the toe of the slope, small-scale landsliding of the bluff face, beach lowering, and lack of LWD. Buried rocks or concrete blocks are often used with cables or chains as anchors for the LWD at the surface.

In areas where beach lowering and erosion was a concern, a common practice was to import pebble gravel and sand-sized sediment. Sediment is either trucked or barged in and placed in the high tide zone of the beach. There it is likely to be subsequently reworked and redistributed by wave action.

Vegetation plantings were common to most projects we reviewed, with techniques, plant types, and placement varying greatly between projects. Some project designs focused on establishing native vegetation, while others reflected homeowner aesthetics and view considerations.

4.0 Effectiveness of Projects

4.1 Measures of effectiveness

In consultation with the study steering committee, we established a set of measures of effectiveness both for use in this study to evaluate each project, and as a recommended set of benchmarks for future projects. The measures are based on a series of questions we asked at each site and answered through observations and interviews. Site-specific concerns and conditions dictated which measures were evaluated at any given site. Not all questions were applicable at each site, and different sites warranted different combinations of the following list of questions. Our reporting for this study does not offer specific answers to questions addressed at each site, but rather speaks to the questions collectively for each site category.

1. Was the applied design/construction appropriate for the site?
2. Did the project design address a perceived concern, an observed concern, or both?
3. Is the above-ground project structure holding up?
4. What observable role or impact does the below-ground structure have on the project structure? ..on the beach environment?
5. Are the objectives of the homeowner and permitting agency met?
6. Did the project result in improved coastal nearshore habitat, such as a broadened beach, a marine riparian buffer, or appropriate sediment?
7. Is the project recruiting LWD?
8. Is the planted, remnant, or volunteering vegetation native? Has it survived and is it establishing?
9. Are the desired conditions and/or processes likely to continue? Is maintenance necessary and being conducted?
10. How might the project installation perform and how would site concerns change in the event of sea level rise?

4.2 Monitoring methods/status

Each site was evaluated against the measures of effectiveness listed above. We reoccupied established photo points and, to understand site conditions both pre- and post-construction, had discussions with property owners, permitting agency staff, and project contractors responsible for the design and construction. At three of the sites (sites 12, 13, and 17) systematic beach profile surveys and sediment sampling and analysis had been conducted prior to this study. However, we had no way to assure consistent measuring techniques, or to accurately relocate survey transects or sampling locations, and therefore did not resurvey or resample at these sites. We did measure lowering of the beach surface relative to LWD anchor posts at site 8. There is no previous data for comparison, but data could be collected in the future to determine if conditions persist or change.

Although monitoring had been scheduled in the design plans for some sites, we found that the fiscal and logistical difficulties of regular consistent monitoring resulted in little of it being done continuously, or even regularly. Only at site 12 was beach profile monitoring done, as part of the project contract, for 5 years following construction. The most common and informative monitoring consisted of observations made on-site by property owners and some permitting agency staff involved in the projects. Observations were most commonly captured by repeat photography. We attempted to reoccupy photo locations whenever possible. We feel these will prove the most valuable in project assessment now and in the future. All historic and future photographs should be archived and made accessible for future review.

4.3 Project evaluation by classification

Because sites are being evaluated under the classification system developed for this study (described in section 3.2), this section describing study findings is organized to reflect those categories. Property owner concerns and our findings are compiled and reported here collectively for each class category, and are summarized in Tables 1 and 3.

4.3.1 ***High Bank Stabilization***

4.3.1a Perceived and observed site concerns at High Bank Stabilization sites

The following is a list of concerns and associated processes compiled from sites within the category of "High Bank Stabilization". Sites exhibiting or perceived to have the typical issues of instability associated with this category appear in parentheses. Perceived concerns are given the same weight here as observed conditions because they were typically the trigger for the project permit request.

- Erosion of the toe of the slope resulting in steepened slopes, cavities (or small caves) at the slope toe, sloughing of surface soils and other mass-wasting processes, and loss of vegetation (sites 1, 5, and 9).
- Upland surface water run-off causing rill and gully erosion (site 8) of beach access areas.
- Mass wasting processes including earth topple, debris slides, debris flows, surface sloughs (sites 1, 2, and 9)
- Bluff or slope retreat (sites 1, 2, and 9)
- Loss of beach access (sites 2, 5, and 9)

Examples of the processes associated with this category can be seen in some of the pre-mitigation photos for sites 1, 2, 5, and 9 (Appendix B). Site 17, although assigned to the "Bulkhead Removal" category, shows small-scale landsliding typical of a high-bank site (Appendix B). At this site slopes are presently over-steepened as a result of the bulkhead removal rather than natural slope processes.

4.3.1b Evaluation of Measures of Effectiveness at High Bank Stabilization sites

The following findings summarize the qualitative responses from all High Bank Stabilization sites to the measures of effectiveness questions listed in section 4.1 and applicable to these sites, although not necessarily in the same order. Each finding is based on a compilation of site observations and information relating the measures of effectiveness to High Bank Stabilization sites.

- Anchored or placed LWD can protect slope toes, although there are limitations due to site conditions, anchoring methods, type of wood used, and durability of construction.
- Beach nourishment, or addition of sediment, is often short-lived if there is no structure to limit longshore sediment transport. Additionally, imported sediment mis-matched with local beach environment can result in habitat modification.
- Structures intended to attenuate wave energy (shore-parallel rock or logs) may serve this purpose at some sites (site 9), although may have little long-term effect in protecting a bluff from damaging wave energy. At low wave-energy sites they are likely unnecessary or ineffective (site 5). They may better serve as sediment traps or sills.
- Burying rock or ecology blocks to anchor LWD causes substantial substrate disturbance during project construction, and may result in long-term damage of natural beach processes and subsurface ecology (sites 1, 2).
- Beach access generally remains vulnerable, especially if mass wasting, surface runoff, and groundwater issues are not appropriately addressed (sites 1, 2, and 9)
- Planted native vegetation can establish, but techniques used resulted in coverage that is substantially less dense than found on neighboring natural shoreline (site 1).
- Remnant and volunteering vegetation is generally a mix of native and fairly aggressive exotic species (sites 1, 5 and 9)
- If plants are present before and during construction, and not subsequently pruned, a marine riparian buffer appears to be developing (sites 1 and 9); otherwise a buffer is not developing (site 5).
- Without proper upland infrastructure management and assuming predicted sea level rise, bluff retreat through mass wasting and erosion will continue and may increase (all high bank sites).

4.3.1c Successful/problematic design and construction practices at High Bank Stabilization sites

- Site-appropriate upland development and infrastructure management resulted in project success to date (site 9). This is most true where site planning included adequate set-back for buildings, capture and routing of surface runoff to the base of the bluff, and efforts to minimize impact on groundwater volume and movement.
- Anchoring logs to buried rocks or concrete blocks might not be necessary in many cases and comes with the side effect of disturbing beach ecology during construction. It may take years for native beach fauna to recruit back into the disturbed area. More success in recruiting LWD for beach sediment stabilization might be achieved by (re)establishing natural beach processes and riparian zones, assuming LWD is available for recruitment.

- At sites in higher wave energy environments, imported beach sediment was relatively short-lived on the site (sites 2 and 9). If the additional beach sediment is an important measure of project success, such sites will require more long-term project maintenance.
- At the low-wave-energy site, imported beach sediment did not reflect natural environment or substrate (site 5).
- Project design needs to better incorporate upland morphology and site history, particularly where the site had been historically modified and slope gradients did not reflect "natural" conditions (site 8). In such cases, active coastal processes work to reestablish a shoreline that might be inconsistent with the project vision.
- Permitting agencies need guidelines for themselves and property owners on what types of shoreline modification projects are considered 'alternative' or 'soft' (site 2).
- The absence of vegetation after construction, or pruning of existing or planted vegetation, does not allow for development of a functioning marine riparian buffer (sites 1, 2, 5, and 9).

4.3.1 d. Recommendations for future mitigation for High Bank Stabilization sites

- Require construction set-back that will avoid the risks associated with bluff retreat.
- Develop and maintain upland infrastructure carefully and with consideration of potential effects on slope stability.
- Manage all surface water to contain and direct it appropriately to the base of the bluff.
- Evaluate and design for groundwater flow issues.
- Evaluate coastal geomorphic processes, and consider natural and locally modified processes in project design and construction.
- Consider specific site design options relevant to site conditions, setting, and uses.
- Supplement beach sediment where necessary or beneficial with in-kind grain size.
- Preserve existing native vegetation during construction, or actively and densely revegetate with native species.
- Continue maintenance of vegetation to ensure native composition and establishment.

*4.3.2. **Low-No Bank Stabilization***

4.3.2a Perceived and observed site concerns at Low-No Bank Stabilization sites

The following is a list of concerns and associated processes compiled from sites within the category of "Low-No Bank Stabilization". Sites exhibiting or perceived to have these issues are listed in parentheses. Perceived concerns are given the same weight as observed concerns because they were often the trigger for the project permit application.

- Risk to site infrastructure from wave run-up, and sediment and LWD transport (sites 3, 6, 7, and 15).
- Disrupted or undesirable public or private beach access (sites 4, 8, and 13).
- Erosion of shoreline and lawn area (site 7).
- Loss of beach through erosion caused in part by adjacent bulkheads (site 14).

Examples of these conditions are best viewed in the pre-mitigation photos for sites 3, 4, 6, 8, and 11 (Appendix B).

4.3.2b Evaluation of Measures of Effectiveness at Low-No Bank Stabilization sites

The findings below summarize the qualitative responses from all Low-No Bank Stabilization sites to the measures of effectiveness questions listed in section 4.1 and applicable to these sites, although not necessarily in the same order. Each finding is based on a compilation of site observations and information relating the measures of effectiveness to Low-No Bank Stabilization sites.

- Project design and construction were generally appropriate for the site, although some may have had success with simpler approaches (sites 3, 6, 7, 13, and 15).
- Project design occasionally reflected and over-emphasized a perceived problem that was not observed during the field visit (sites 7 and 10).
- Anchored or placed LWD can successfully protect infrastructure, although there are limitations due to site conditions (specifically proximity of structure being protected), anchoring methods, type of wood used, and durability of construction.
- Structures intended to attenuate wave energy (shore-parallel rocks or logs) were found to be unnecessary and habitat-altering in the low-energy environment (site 10).
- Burying rock or ecology blocks to anchor LWD causes much substrate disturbance during project construction, and may result in long-term damage of natural beach processes and ecosystem (sites 6 and 7).
- Beach access was generally easily maintained.
- Since construction, LWD has not entered living rooms and or damaged critical infrastructure (sites 3, 6, and 15). It is important to consider this observation in light of the relative storm intensities recorded during the period of evaluation (see sections 7.0 and 9.0 for further discussion).
- LWD was successfully recruited at sites 4, 6, 7, 11, 13, and 15. Those that did not (sites 3, 8, and 14), may not have an available up-drift supply.
- Beach width was broadened at some sites (sites 4, 7, and 14).
- Planted native vegetation is generally getting established, but this is slow (sites 8 and 16). Planted non-native vegetation can suffer from salt spray damage (sites 4 and 14).
- A marine riparian buffer is generally well-established where plants were already present before and during construction, and if they were not pruned subsequently (site 13); otherwise marine riparian buffer is minimal or absent (sites 6, 7, and 15).

4.3.2c Successful/problematic design and construction practices at Low-No Bank Stabilization sites

- Greatest success at minimizing risk to infrastructure comes from appropriate setback from shoreline (site 7).
- “Ramping”, or grading of the shoreline to allow for wave run-up, proved successful in reducing erosion and shoreline retreat. This was particularly true where a gravel-filled geogrid fabric used as an underlayment (site 7).
- Adding beach sediment to small or pocket beaches worked better than at more open beach reaches to preserve the imported sediment on site (sites 4 and 14).
- Anchoring logs may not be necessary (or appropriate?) where coastal processes and available LWD allow for naturally recruited LWD (site 7).

- At sites in higher wave energy environments, imported beach sediment was relatively short-lived on the site (sites 6 and 8). If the addition of beach sediment is an important factor in project success, such sites will require more long-term project maintenance.
- At the low-wave-energy site, imported beach sediment did not reflect natural environment or substrate (site 10).
- Project design needs to better incorporate upland morphology and site history, particularly where site had been historically modified and coastal slope gradient did not reflect "natural" conditions (site 8). In such cases, active coastal processes work to reestablish a shoreline that might be inconsistent with the project vision.
- Permitting agencies need guidelines for themselves and property owners on what falls within the scope of "alternative" in encouraging or allowing shoreline modification projects, particularly in the case of new construction (sites 3 and 15).
- Most projects fell short of including the planting of native, salt tolerant species that will create a healthy marine riparian buffer.
- Lawns maintained to the shoreline edge preclude development of a marine riparian buffer (sites 3, 6, 7, 8, 11, and 15).
- A healthy marine riparian buffer is more likely to be successful where existing shoreline vegetation was preserved during and after construction (sites 10 and 13).

4.3.2d Recommendations for future mitigation for Low-No Bank Stabilization sites

- Require construction set-back that will avoid the risks associated with slope or bank retreat.
- Discourage back shore filling to create new home construction sites.
- Consider surface and groundwater issues in project design.
- Evaluate coastal geomorphic processes and accommodate these in project design.
- Consider specific site design options relevant to the site.
- Supplement beach sediment with in-kind grain size where it is deemed necessary to improve habitat.
- Consider appropriate native plantings, in addition to dune grass, to establish healthy marine riparian buffers.
- Require on-going and appropriate maintenance of vegetation to prevent invasion by exotic species and to facilitate development of a functioning marine riparian buffer.

*4.3.3. **Bulkhead Removal (or Relocation)***

Bulkhead removals are commonly initiated or encouraged by permitting agency staff working with a private property owner or public jurisdiction showing interest in restoring natural shoreline processes. In the case of bulkhead removal projects, the relationships of trust and collaboration between participants seem particularly important. The initial involvement of the permitting agency may have been triggered by a permit request to replace a failing existing bulkhead. It should be noted that at two sites in this study (sites 4 and 14) a new armoring structure was located shoreward of the original structure, expanding the beach width.

4.3.3a Perceived and observed site concerns at Bulkhead Removal sites

The following is a list of concerns and associated processes noted for all study sites within the category of Bulkhead Removal, and triggering all project permit applications in this category.

- Compromised existing bulkhead requiring some bank modification, erosion control, or bank stabilization.
- Interest in shoreline restoration or naturalization.
- Desire to maintain beach access.

Sites in this category include 4, 8, 11, 13, 14, 16, and 17, with illustrative pre- (when available) and post-mitigation photographs in Appendix B).

4.3.3b Evaluation of Measures of Effectiveness at Bulkhead Removal sites

These findings summarize the qualitative responses from bulkhead removal sites to the measures of effectiveness questions listed in section 4.1 and applicable to these sites, although not necessarily in the same order. Each finding is based on a compilation of site observations and information relating the measures of effectiveness to bulkhead removal.

- For the most part, project design and construction were appropriate for site issues; these projects resulted in the positive outcome of bulkhead removal and efforts at shoreline restoration, at least on a site scale.
- The high bank site (site 17) was experiencing small-scale landsliding in the first year after removal. Low bank sites 8, 11, and 16 were relatively stable over a similar time period. Long term effects of bulkhead removal, and rates of expected associated slope adjustment, will be variable and dependant on site conditions and processes.
- Plantings of native vegetation were establishing successfully (site 16), although development of a riparian buffer is quite slow unless vegetation existed at the top of the bulkhead and was not removed during construction (only site 13).
- Continued monitoring will help determine the success of bulkhead removal projects in improving coastal nearshore habitat. Some sites have monitoring programs (sites 13 and 17), with preliminary results at site 13 suggesting improved forage fish spawning habitat (Doris Small and Dan Pantilla, WDFW; Mark Plunket, Seattle Aquarium, personal communication, 2006).

A necessary consideration in evaluating the effects and effectiveness of bulkhead removal is how newly-exposed slopes will respond and adjust in the short and long-term. At site 17, the highest rate of slope retreat of the varied project shoreline is occurring as small-scale landsliding along the portion once armored by small rocks. There was immediate observed response to the large February 4th, 2006 storm/high tide event. This portion of the project reach has a slope height of about 15 ft., and was left steep and unvegetated after bulkhead removal and through this first winter (2005-06). It has a southern exposure, and receives significant wave impact during the characteristic winter storm events. However, the somewhat cohesive nature of the slope sediments and the reestablishing vegetation on the upland surface suggest the observed slope instability might be short term, and that over time, site slopes might achieve a dynamic equilibrium. This potential equilibrium would be controlled by material properties (including those contributed by the vegetation), upland conditions, and sea level, wave, and storm surge effects. Any site being considered for bulkhead removal should consider these factors both in the short and long-term timeframe of the project. Site 17 clearly requires a longer period of monitoring to better evaluate how these and similar slopes might respond to bulkhead removal.

4.3.3c Successful/problematic design and construction practices at Bulkhead Removal sites

- Overall, this is a very positive approach to mitigation of perceived and observed shoreline concerns, although it may not result in beneficial habitat restoration in the larger context because of adjacent shoreline modification.
- Consideration must be given to natural shoreline morphology and processes during design and deconstruction to accommodate shoreline response to the changes.
- Removing part of a bulkhead at a site creates problems at the point where the restored beach and old bulkhead meet.
- Maintaining a lawn to the edge of the shoreline does not allow for a vegetated buffer to establish; additionally, poor maintenance of vegetation prevents establishment of a healthy riparian buffer.
- Planting or landscaping with ornamental species does not form a riparian buffer.

4.3.3d Recommendations for future mitigation for Bulkhead Removal sites

Much more information is needed on the effects of bulkhead removal on the immediate site, as well as the adjacent coastal reach, both up and down drift. Brennan and Culverwell (2005) argue that healthy beach habitat requires a healthy marine riparian buffer, and that coastal restoration efforts should be focused on reducing shoreline armoring through bulkhead removal, restoring native vegetation, and reestablishing marine riparian zones.

4.3.4 ***Bulkhead Protection (or Replacement)***

Only two of the reviewed sites fell into this category (sites 2 and 12). Although they do not fully meet the criteria of alternative shoreline stabilization as we define it for this study, they were included in the study because they incorporated some of the design concepts and techniques common to non-bulkheaded sites; specifically, the addition of beach sediment, and planting of native vegetation.

4.3.4a Perceived and observed site concerns at Bulkhead Protection sites

- Loss, damage, or erosion of existing bulkhead structures.
- Loss or degradation of beach access.
- Erosion or loss of beach area.

4.3.4b Evaluation of Measures of Effectiveness at Bulkhead Protection sites

These findings summarize the qualitative responses from Bulkhead Protection sites to the measures of effectiveness questions listed in section 4.1, although not necessarily in the same order. Each finding is based on a compilation of site observations and information relating the measures of effectiveness to bulkhead protection or replacement.

- For the two sites in this category, and considering site objectives, project design and construction met site objectives and were appropriate in addressing site concerns. These two projects did not result in the desired outcome of a more ‘natural’ shoreline.
- At both sites the bulkheads are currently functioning as they were intended and are no longer at risk of failure in the short term.
- At site 2, planted vegetation has been pruned and replaced a number of times to include some native and some non-native, all repeatedly pruned to maintain upland views. Planted native vegetation (dune grass) at site 12 is present but not very extensive; additionally, lawns generally extend to the edge of the bulkhead.
- Slope at site 2 is currently stable to homeowner’s satisfaction. Infrastructure at the top of the slope, and rock bulkhead at the base would not meet current county design objectives for coastal bluff property.
- The increased beach elevation at site 12 appears to be recruiting LWD.
- The current conditions and/or processes are likely to continue at site 2 without much additional maintenance beyond vegetation, and similarly at site 12, as long as the sill constructed at the down-drift end of the project is maintained.

4.3.4c Successful/problematic design and construction practices at Bulkhead Protection sites

The primary issue here is whether or not the design and construction practices applied to these projects should be considered alternative and recommended in the future. For site 2 the original vegetation plan did not suite the property owner’s objectives and has been in constant revision. Site appropriate native plants are not well-established.

4.3.4d Recommendations for future mitigation for Bulkhead Protection sites

We recommend that the type of project represented at site 2 not be considered as an acceptable alternative to bulkhead construction. Although the upper slope is planted with vegetation (some of it native, some not) it required extensive reinforcement (soil nailing) to achieve stability and an irrigation system to assure vegetation survival. Long term vegetation planting and maintenance plans should become an integral part of site designs.

Adding beach sediment to a site can improve site ecological conditions with appropriately sized material and designed sediment stabilization. Site 12, although not exactly an alternative to bulkhead construction, does appear to have created a broader and possibly healthier beach (at least in the short term) through the addition of beach sediment with a down-drift retention structure (sill). However, the effects on neighboring down-drift beaches of retaining sediment at this site are unknown.

4.4 Overall conclusions on measuring project effectiveness

- Each site had distinct issues and conditions which contributed to the complexities of determining how best to measure the effectiveness of the installation.
- Interpreting the geologic and hydrologic conditions and processes of the site is key to evaluating the relative importance of perceived site concerns, establishing observed site issues, and evaluating the ultimate effectiveness of the installation.

- WDFW objectives applied as part of the Hydraulic Project Approval (HPA) for a given site and installation design were not always clear, nor was there necessarily much consistency in objectives between sites.
- Mitigation proposals and designs, particularly in the case of private property applications, evolved with repeated denial of and/or negotiation for permitting, even throughout the life of the project, and depending on its performance. Because of this, "as-built" information was rarely available. In other words, there was generally no documentation of the final above- and below-ground installation. Therefore, fully evaluating the impact and ultimate effectiveness of these projects was difficult.
- Most property owners interviewed were generally willing to try alternatives if the rationale for doing so was made clear early in the permitting process, and if the site risks were manageable. Those opposed, agreed to alternatives only because they would otherwise have been denied any shoreline modification permits.
- Property owners were generally overwhelmed by the permitting process unless contractors were hired to obtain the permits.
- Several site designs had recommended maintenance such as repeated "beach nourishment", but few if any property owners were carrying through with the recommendation, and some sites were showing early signs of beach lowering and erosion.
- Materials used at a site were more often those most readily available during project installation, rather than those outlined or recommended in the permit application site design. This affected our ability to evaluate the effectiveness of project components such as imported sediment size, gradation, and quantity, LWD anchor strengths and depths, or success of original plantings.

5.0 Homeowner satisfaction rating

The findings listed below are qualitative and focus on the attitudes and informal interview responses of the owners and residents of privately-owned property.

- Even with successful "alternative" projects, some homeowners still suffer from "bulkhead envy" and consider their beach and boat access undesirable. Others were happy with their beach access, and found that access remained reliable. Owner satisfaction generally relied on stable bank conditions, simpler access structures, or site conditions of no bank.
- Some high bank property owners continue to be concerned about bluff or slope retreat, even with more than adequate infrastructure/home set-back.
- A number of property owners who attempted to secure permitting themselves, found the process confounding and frustrating. Those who left permitting issues to the contractor were glad not to be involved in that process.
- A number of private property owners expressed concerns about maintaining their views; this was evident in the number of sites with pruned, topped, or thinned vegetation.

- The necessary willingness to acknowledge and commit to continued project maintenance varied among property owners and managers. This included, but was not limited to, adding sediment to the beach, removing exotic vegetation, and allowing for natural native-plant succession.
- Several property owners were pleased to have been involved in designing and constructing alternative solutions to managing shoreline erosion and willing to show-case their project.
- Several property owners commented that the cost of alternative mitigation was close to double the estimate received for the original conventional bulkhead proposal. This makes the action accessible to only a few from a cost perspective, unless there are creative funding solutions available, such as at site 12 where 16 adjacent landowners pooled resources.

Most reviewed sites classified under “Bulkhead Removal (or Relocation)” were publicly owned; city, county, or state. This is likely due to the relatively high cost and risks to upland infrastructure that can more easily be absorbed on public property than on private. However, discussions with monitoring scientists and local citizens following bulkhead removal on public lands indicate favorable response to such efforts of coastal restoration.

The two reviewed private sites where bulkheads were removed represent opposite ends of the spectrum in terms of project scale. Site 14, with elaborate landscaping contracted by the property owner, establishes a pocket beach between neighboring concrete bulkheads extending farther seaward. Site 16 creates a long (several thousand meters) beach where a log yard and vertical log bulkhead used to be. The latter site is used recreationally by local residents, but is still in the process of environmental clean up.

6.0 Institutional barriers

We separated the primary institutional barriers encountered by both property owners and contractors into two distinct components; regulatory (or permitting) and informational. Regulatory barriers are those that involve any and all permitting and supporting paperwork required to gain approval for a shoreline modification project. Informational barriers are those suggestive of the lack of information readily accessible (or even available) to property owners to explain permitting agencies’ reluctance to allow bulkhead construction, and the agencies’ rationalization for advocating alternatives. Here we present the feedback we received on each component of the institutional barriers in the context of; 1) acquiring the required project permits; 2) understanding regulatory agency objectives; and, 3) acquiring site-appropriate and stipulated material resources for the project.

6.1 Regulatory/permitting

Because of the daunting, and at times seemingly conflicting, regulatory requirements of the numerous necessary permits, most property owners chose to leave the permit acquisition process to the contractor. Those who did were relieved not to be involved. Those who took it on themselves seemed to enjoy the challenge. These are some of the specific comments we received from either private property owners or project contractors regarding the permitting process:

- Reasons for initial project application denial are not always clear. Applicants would like a better explanation than "no".
- Agencies need to streamline regulations and permitting process. It is currently cumbersome, time-consuming, and often conflicting.
- Permitting process should develop a consistent sequence of evaluation, comment, and finally, record of decision (with permit conditions if necessary) to eliminate vacillation by agencies on project decisions.
- More support, guidance, and outreach for these projects are needed from county planners, since they are generally the hub in the permitting process.

These comments speak to the need for site visits, with both state and local permitting staff, which would occur prior to permits being filed. This would help determine the appropriate response to a real or perceived erosion or slope stability concern and assure that both state and local permitting considers the same proposal.

6.2 Agency objectives

Some of the reviewed projects transitioned from initial traditional bulkhead design to softened versions. This generally took place with negotiation and collaboration between the property owner, permitting agency staff, and the contractor. The exact process of the transition was not always clear, but generally required an innovative and persistent wildlife biologist and a willing property owner. In some cases, the biologist had to be the primary advocate for the alternative design. In one or two cases, the biologist was contacted by the property owner when the initial permit application was denied.

Most property owners we spoke with felt that the shoreline improvement objectives of regulating agencies are not well defined and that staff does not consistently implement any objectives. Contractors we spoke with felt similarly. Permitting agency staff feel there is little agency guidance and support for them to advocate and implement broad agency objectives. The end result then is well-intentioned project participants with little direction and much uncertainty on project goals, design and construction specifications, associated risks, cost commitments, and long-term project performance.

Geotechnical reports, with complete site characterization and description of site infrastructure at risk, could help clarify how responsibility for project success would be distributed among participants (regulating agency, property owner, designer, and contractor). Currently, it is difficult for a regulatory agency to require or suggest using an alternative if there is any suggestion of infrastructure being at risk.

6.3 Contractor Resources

All of the contractors we interviewed commented on the need for the following:

- Consistent regulation between agencies, and between staff of any single agency.
- Necessary support from county planning departments to force alternative techniques, rather than leaving it to the contractor to promote and develop them without guidance.

- Design specification guidance for LWD placed on site. If deemed necessary, establish recommendations or specifications for anchor capacities for anchoring of LWD. (Literature currently focuses on the use of anchored LWD in river restoration projects with little to none addressing coastal applications.)
- Information on the location and availability of project material resources that meet the recommended size and gradation specifications for gravel, rock, and LWD. Most desirable LWD would be large pieces of cedar that include root wad structure.
- Necessary commitment from all parties involved to carry out stated objectives of regulatory agencies for alternative shoreline projects. This should include cost-sharing measures.
- A system to ensure consistent and continued monitoring and maintenance of alternative projects, with built-in feedback for adaptive management and design specifications.

7.0 Study Conclusions

A number of complex and interrelated processes contribute to coastal slope instability, slope retreat, shoreline erosion, and beach degradation throughout Puget Sound. These processes include upland surface water runoff, local and regional groundwater movement, wave impacts from storms and high tides, wave effects from watercraft, vegetation removal, waste disposal, and other land use practices. Our findings suggest that project initiation, objectives, and design often reflect a perceived concern, rather than one accurately represented by existing geologic, hydrologic, or other contributing conditions (Table 1). In many cases it appears that careful characterization of local geologic, hydrologic, and geomorphic processes prior to construction might reveal triggers of slope instability that could be better addressed with appropriate upland management and reduced or minimal structural shoreline modification. At a large number of the sites, project cost and site disturbance might be reduced with this more comprehensive site characterization. To this end, we advocate that current county and state shoreline planning and permitting processes be evaluated and potentially revised to encourage a more thorough characterization of regional and local geology and hydrogeology affecting a site. Additionally, providing more public outreach education on these topics could give landowners a perspective of less concern regarding potential risks to their property, resulting in fewer shoreline modification permit requests.

Many “alternative” shoreline stabilization techniques currently in use appeared to be intrusive and disruptive to natural shoreline and nearshore processes. For example, where anchoring of LWD was an integral part of the mitigation design large (“2-3 man”) rocks or concrete blocks were buried in the beach as anchors. This required excavation of the beach from 5-10 ft below the beach surface along the length of the project, and the off-site removal of large amounts of beach sediment. Extensive damage to beach habitat can result. Continued application of these techniques would benefit from refinement of designs, including testing of less intrusive and less structural solutions that support coastal processes and the maintenance or establishment of a natural marine riparian buffer.

We also note that project designs, if they specified vegetation at all, apparently did not restrict plantings to native vegetation, focusing instead on landowner esthetics and maintenance of viewsheds. This often resulted in limited survival success of the plantings, particularly those not tolerant of salt spray. Those sites maintaining the obvious existing native vegetation, or planting the most appropriate native plants for the site, had the healthiest and densest vegetation cover. However, since vegetation plans were commonly not included as part of the project design, we could not always be confident about which plants were growing on the site before construction, which were planted during project installation, and which were replacements for earlier unsuccessful plantings. Vegetation success could be increased with project design plans that consider local site conditions. And project success would be greatly improved if plantings were selected to contribute to the stability of the site, with the ultimate goal of building and maintaining healthy marine riparian buffers. Since none of the plans stated this ultimate goal as an objective of the project, we could not treat it as a measure of project effectiveness.

Several sites showed damage to project infrastructure attributed to the February 4th, 2006 storm accompanied by high winds, high tide, and in some areas a storm surge. Observed damage included erosion around bulkhead rocks, gullying of beach access trails, small-scale landsliding and minor slope retreat, and relocation of non-anchored LWD. For most of the sites this was probably the largest storm event during their period of record. None of the observed damage resulted in any upland damage to homes or out buildings, as far as we could tell. Good descriptions of site conditions immediately prior to the storm would be necessary to offer more detailed assessment of the storm damage at each site.

In general, it is difficult to ensure that detailed monitoring data are collected at sites where alternative stabilization techniques are used; this situation is not likely to change in the future, based upon the difficulty of systematically collecting these kinds of data at other types of restoration projects (e.g. wetland, stream, and upland). Additionally, while we were conducting this study, it became apparent that many “soft” or “alternative” projects have been implemented that we did not evaluate and that were unknown to the study steering committee. These two factors suggest that it would be far better to focus on extensive, rather than intensive monitoring as a way of tracking the effectiveness of alternative projects. A database should be kept of the ever-expanding list of sites fitting this description and efforts should be made to assess the measures of effectiveness identified in this report at regular intervals at most of these sites. This would require thorough “as-built” documentation. The data will be most valuable in revising and developing design guidelines for future projects. The data will also help determine through analysis of project successes and failures whether or not any shoreline modification is necessary to address certain stability concerns, or whether other actions might be taken to improve natural ecosystem function even where there is no infrastructure risk or stability concern.

8.0 Recommendations

These recommendations are intended as general program ideas to advance information dissemination, streamline regulatory hurdles, develop cost-saving stabilization alternatives, and provide general project and program design guidelines. We are hopeful that the appropriate use of alternative shoreline stabilization techniques can reduce both ecological and economic impacts of traditional bulkheading practices. The following is a list of recommendations developed throughout this study to address the objective to discourage conventional concrete, rock, or log bulkhead construction, and to encourage the restoration of natural shoreline ecosystems.

- Expand local community workshops to better address coastal property owner concerns, provide more information on the detrimental effects of traditional bulkheading, and provide clear information on the rationale for seeking alternatives. This should include informational literature on coordinated agency objectives for restoring the health of Puget Sound.
- Provide public outreach education, specifically targeting shoreline property owners, on geology, hydrology, and coastal processes contributing to slope instability and shoreline erosion, and landscaping options to improve stability. Include information on maintaining or promoting native vegetation, site-appropriate planting, and root strength properties of different plants. Proaction and gained insight by property owners could result in fewer shoreline modification permit requests.
- Conduct training for WDFW and local permitting staff on these same topics.
- Develop and nurture relationships of trust and collaboration between permitting agency staff and shoreline residents interested in modifying their shoreline property. Search out opportunities for show-casing alternatives.
- Assure necessary commitment from all parties involved to carry out stated objectives of regulatory agencies for these alternative shoreline projects. This should include cost-sharing measures.
- Include in Shoreline Management Plans standards for geotechnical reports that include those for a geologic site assessment for shoreline modification projects that would consider both coastal and upland characteristics and processes.
- Encourage (require?) interdisciplinary site visits early in the permitting process by a team including state and local permitting staff, project designer/engineer, geologist with experience specific to these issues, contractor, and landowner to assure a coordinated project proposal and permit application.
- Develop a comprehensive cost analysis and comparison by project component (project materials, waste removal, excavation, and construction – per lineal foot or volume of material) of traditional and alternative shoreline armoring or stabilization.
- Provide guidance for accessing and acquiring preferred project resources (LWD, rock, native vegetation).

- Develop generalized design concepts to meet the stated objectives of regulating agencies. Incorporating native vegetation should become a condition of permitting.
- Conduct engineering analysis in coastal environments, or systematically evaluate existing applications of anchoring and burial systems in the coastal environment to establish design recommendations and avoid over-design and excessive cost.
- Research options and feasibility of “Incentive Programs” that, particularly in low risk situations, transfer the liability for infrastructure damage away from the landowner and the public agencies. One option could be to develop an insurance program of sorts; in situations where the risk of infrastructure damage is low, based on a careful assessment of the geologic and hydrologic conditions at the site, landowners who agree to try certain types of alternative approaches are provided with “insurance” against damages. The holder of such policies could be a non-profit organization or even, with some research into market forces, another type of institution.
- Consider developing a program or funding positions within local or state jurisdictions for locally-based individuals who can provide technical guidance to property owners and others regarding shoreline stabilization, erosion control, and related issues.
- Create lists, guidance documents, and curricula for required site-appropriate vegetation relating to site condition assessments, planting criteria, maintenance, root strength properties, etc.
- Investigate the disturbance effects of beach substrate excavation for anchor installations.
- Use public coastal lands as testing and demonstration areas for bulkhead removal and/or alternative stabilization and erosion control projects. Take advantage of these locations to test designs and techniques under a range of coastal and socio-political conditions.
- Develop more extensive, but not necessarily more detailed, monitoring programs to track the results, making sure that “as-built” information is well documented.
- Feed the results of monitoring into research proposed for measuring and evaluating bulkhead removal effects (D. Myers; email communication, June 30, 2005).
- Pursue funding for updating and expanding the Coastal Zone Atlas to include, but not be limited to, current large-scale geologic mapping, current landslide mapping, shoreline location maps, tsunami inundation mapping, shoreline modification maps, vegetation zone maps, forage fish spawning and habitat distribution maps, and predicted sea level rise inundation maps.

9.0 Implications of Sea Level Rise

The following discussion is by no means inclusive or extensive, but speculates on potential site- and landform-specific consequences of predicted future sea level rise. The extensive body of research and literature on climate change indicate that the effects of sea level rise should be incorporated into planning and policy for coastal development in the Puget Sound region (Canning, 2001, and references within). With the expected effects there will likely be an increase in the amount of infrastructure and number of homes at risk to coastal processes, and with that, an increase in the number of applications for shoreline stabilization structures. Accommodating these requests would set the Puget

Sound on a different trajectory than that currently planned for within the Puget Sound Management Plan and local implementation of the Shoreline Management Act, as well as that envisioned by the Governor's Puget Sound Partnership to improve the health of the Sound.

It would be reasonable to expect that low-lying coastal areas could see increased flooding, and exposed shoreline banks and slopes could experience increased erosion and associated slope retreat, particularly during extreme storm events coinciding with high tides. In the short term these effects would be localized to sites currently susceptible to such processes. However, in the long term, broader coastal geomorphic processes will affect regional changes, so the following discussion on possible site-specific changes can only be speculative.

The High Bank Stabilization sites 1, 8, and 9 evaluated for this study and located in high-energy wave environments, could be subject to overtopping of present stabilization installations, infrastructure failure, and accompanied increased rates of erosion and slope retreat. Other High Bank Stabilization sites located in lower wave energy environments, such as sites 2 and 5 of this study, would be less at risk because of their location. Low-No Bank Stabilization sites constructed on flood plains, deltas, or filled back beach embayments (particularly sites 3, 6, 7, 11, and15), and beach front Bulkhead Protection site 12, might be inundated by high tides and storm surges.

This winter's concurrent high tide storm surge and strong winds on February 4th, 2006 is blamed for the damage to project infrastructure observed at some of the study sites. Although preliminary analysis of the relative intensity of the storm and tides by National Oceanographic and Atmospheric Administration scientists suggests the intensity of this event has a recurrence interval of 10-20 years, it was probably the largest storm event to date experienced by most of the projects evaluated for this study. Keeping in mind that the growing body of climate and sea level change literature argues for a general trend of sea level rise throughout Puget Sound, anyone designing coastal mitigation projects should be considering potential short and long-term effects of strong storms, big waves, and more extreme high tides.

10.0 Report Limitations and Intended Use

The findings and recommendations presented in this report are based solely on the site conditions observed during our field reviews, review of limited design and construction documentation, and discussions with landowners and resource and regulatory agency staff. Detailed ecological, geologic, or engineering assessments and analyses of each site were not within the scope of this project, nor was it the intention to provide detailed documentation of as-built conditions.

This report is also not intended to be a critique of individual installations, but rather a comparative study of intended and actual performance of alternative mitigation measures employed under widely varying site conditions. It is understood that in many instances the constructed mitigation evolved through necessary design modifications brought on by regulatory constraints and material availability limitations. It is also understood that constructed designs were often collaborative among interested parties – landowner, designer, contractor, and regulator, and that the designs were based on the best information available during design and construction.

The intended use of this report is principally for resource and regulatory agency staff to evaluate project design effectiveness, identify additional areas of needed study, and provide guidance for future projects and programs relating to the issues described herein.

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http://www.padillabay.gov/pdfs/SoftShore.pdf

Johannessen, J. 2000. Alternatives to Bulkheads in the Puget Sound Region: What is Soft Shore Protection & What is Not? In: Proceedings of Coasts at the Millenium, Coastal Society's 17th International Conference

Seahurst Park:
http://www.engr.washington.edu/epp/psgb/2005psgb/2005proceedings/Papers/F7_HUMME.pdf

Puget Sound Nourishment:
http://www.psat.wa.gov/Publications/01_proceedings/sessions/oral/4b_shipm.pdf

Bluff Erosion:
http://www.ecy.wa.gov/biblio/0106019.html
http://www.ecy.wa.gov/pubs/0406029.pdf

Appendix A: Glossary

The following terms are defined in the context of their application to this study and their common usage in shoreline modification work and coastal geologic studies.

Alternative (or soft) **–** Techniques of shoreline stabilization and erosion control other than traditional concrete, rock, and log bulkheads. Usually includes some sort of vegetation plantings to soften an engineered solution where vegetation may also contribute to soil and slope stabilization.

Anchoring – Securing large logs to the project beach area with cables or chains, often to buried rocks or concrete blocks.

Armoring – Any hard structure, usually rock, concrete, and sometimes wood, used to blanket a shoreline susceptible to erosion.

Backshore – The portion of the beach beyond most high tides and landward of the berm.

Beach nourishment – A process of artificially adding sediment to a beach with material from another location.

Bulkhead/Seawall – A wall, usually of concrete, rock, or wood, built parallel to the shoreline to protect the bank or slope from wave erosion and to retain soils.

Engineering Geology - A specialty of geology affecting the planning, design, operation, and maintenance of engineering works and other human activities where geological factors and conditions impact the public welfare or the safeguarding of life, health, property, and the environment.

Geology – The investigation and reporting of rock and or sediment characteristics (grainsize, strength properties, groundwater capacity, etc.) at a given location, and their positional relationship to each other.

Geomorphic Processes – Any natural or human-caused internal or external forces that affect the shape of the earth's surface, at scales anywhere from regional to site-specific.

Groin – A structure built perpendicular to the shoreline and designed to trap sand moved along the shore by long shore drift.

Hydrogeology - The study of the occurrence, circulation, distribution, or remediation, of water or its role as a natural agent that causes changes in the earth, including data regarding the interaction of water with sediments and rock units.

Mitigation – Alleviation of site concerns through some action usually involving engineering.

Modification – Any change made to the pre-existing site conditions. Pre-existing conditions may be either natural or previously altered (or modified).

Native [vegetation] – Plants that occur naturally in the region. More specifically for site design, these should be naturally occurring plants that grow in the surrounding area under similar conditions, including amount of sun, type of soil, amount of soil moisture, and types of neighboring plants.

Natural – Conditions, processes, or components of a site that would prevail without human intervention or effects.

Project Infrastructure – Any component of the slope or shoreline modification construction or installation evaluated for this study.

[Shoreline] protection – Generally used to imply techniques or structures applied to a site to reduce impacts from erosion, rather than in an ecological sense.

Sapping/Piping – Localized retrogressive erosion due to dispersed groundwater flow (from upland or marine source) along a contact. This can occur along a broad length of shoreline, resulting in a slope-toe cavity, or be confined to a few inches or less, resulting in the formation of 'soil pipes' or small tunnels.

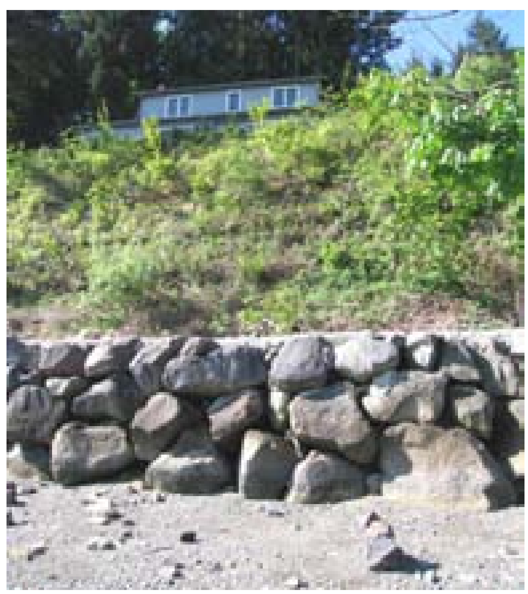
Sill – A groin built level with the beach surface and designed to allow bypassing of littoral sediment while maintaining a prescribed beach grade.

Upland infrastructure – Any homes, out buildings, fences, pipes, power lines, roads, driveways, etc. at a site. The implication for this study is that any of them might contribute to or be at risk from the slope instability and erosion occurring at a site.

Appendix B: Site Photographs

(All construction site photos taken prior to this study are credited to Jim Brennan, Dave Molenaar, Hugh Shipman and Doris Small.)

Site 1 is private property located in Kitsap County, north of Brownsville. The property faces east onto the Port Orchard canal in a med-high wave energy environment, and is classified in this study as a High Bank Stabilization project. Photo on the left shows the site during construction in August, 2000. Photo on the right shows the site during our review in June, 2006. Vegetation has established well, but less dense than on adjacent slopes. Effects of excavating the beach to bury rocks at the base of the stabilized slope are unknown.



Site 2 is private property located on Butler Cove near Olympia, Thurston County. It faces north onto Budd Inlet in a low-medium wave energy environment, and is classified in this study as both a High Bank Stabilization and Bulkhead Protection or Replacement project. Photo shows the site during our review in June, 2006. The rock bulkhead, soil nailed slope, and modified vegetation make it hard to compare this site to other High-Bank alternative designs.

Site 3 is private property in Kitsap County, south of Lofall. It faces west onto Hood Canal in a medium wave energy environment, and is classified in this study as a Low-No Bank Stabilization project. Photo on the left shows the site during construction in 1999. Photo on the right shows the site during our review in June, 2006. This and similarly situated sites (such as 6, 7, 12, and 15) could be at increased risk from tide and storm damage with predicted sea level rise.

Site 4 is Cormorant Cove City Park, a neighborhood park owned by the city of Seattle and located south of Alki Point, facing west onto Puget Sound in a high energy wave environment. This site is classified as both a Low-No Bank Stabilization and a Bulkhead Removal (or relocation) project (the former because of project objectives, the latter because it involved relocating a rock bulkhead landward approximately 50-60 ft, allowing for the creation of a pocket beach). Photo on the left shows the site shortly after construction in 2000. Photo on the right shows the site during our review in June, 2006. Sediment and wood appear to have been recruited within the pocket beach, however, storm waves and surface run-off have caused erosion of beach access pathways.


Site 5 is private property on Bainbridge Island, Kitsap Co. It faces west on an inlet of Manzanita Bay in a low wave energy environment. The site is classified as a High-Bank Stabilization project. Photo on the left shows the site shortly after construction in 1998. Photo on the right shows the site during our review in June, 2006. Logs were anchored in the beach to address a perceived problem of wave erosion at the toe of the slope. We interpreted the slope-toe cavity of concern to have been a result of sapping or piping. Additional mitigation of lining the cavity with geotextile and hand placed rock likely did more than the anchored logs to address this concern.


Site 6 is private property in Mason Co. a few miles southwest of Belfair. It faces south onto Hood Canal in a medium to high wave energy environment. The site is classified as a Low-No Bank Stabilization project and was constructed in 1999. Photo on the left shows the site shortly after construction in 1999. Photo on the right shows the site during our review in June, 2006. This installation held up well in the February, 2006 storm and protected the house in spite of its proximity to the storm tide inundation zone, however, it could see more wave and storm impacts to site infrastructure with predicted sea level rise. As with other similar project design applications of buried LWD anchors, effects on beach substrate and ecology of extensive excavation to bury LWD anchors is unknown.

Site 7 is private property on Case Inlet in Pierce Co. It faces west onto Rocky Bay and Case Inlet in a low to medium wave energy environment. The site is classified as a Low-No Bank Stabilization project and was constructed in 2005. The photo, taken from the homeowner's helicopter, shows the site during our review in June, 2006. Past modifications to the lawn area and adjacent tide flats are a long-time consequence of shellfish harvesting activities. The homeowner and project designer is now creating a more natural looking and functioning shoreline from one strongly influenced by human activities. Another positive aspect of this site is the large set-back of the home, significantly lowering the risks associated with storms, high tides, and predicted sea level rise. Note boat ramp (just left of the helicopter dials), underlain with gravel-filled geogrid fabric.

Site 8 is the Narrows County Park in Pierce Co. It is located on the west side of The Narrows waterway facing south in a medium to high wave energy environment, with a view to the northeast of the Tacoma Narrows Bridge construction. The site is classified as both a Bulkhead Removal and a Low-No Bank Stabilization project. Photo on the left shows the site shortly after construction in 2004. Photo on the right shows the site during our review in June, 2006. Small inset photo shows the monitoring conducted during our review of erosion occurring along anchored LWD. Erosion of the imported beach sand is occurring around the log anchor chains.

Site 9 is private property in Kitsap Co. north of Manzanita. It faces west onto Agate Passage in a medium to high wave energy environment. The site is classified as a High Bank Stabilization project. Photo on the left shows the site shortly after construction in 1998. Photo on the right shows the site during our review in June, 2006. There has been little apparent change in the processes or slope configuration of the photo-proximal portion of the project. However, erosion from the February 4, 2006 storm formed a small gully on the pathway leading to, and a cavity within in the pathway over, the rock bulkhead adjacent to the pier. The line of rocks, intended to attenuate wave energy reaching the base of the bluff might also be serving as a sill of sorts, helping maintain a relatively stable beach profile. The home at this site has a large set back and is not at risk of damage due to shoreline processes any time in the near future.

Site 10 is private property in Kitsap Co. west of Winslow on Bainbridge Island. It faces east onto Eagle Harbor in a low wave energy environment. The site is classified as a Low-No Bank Stabilization project. Photo on the left shows the site shortly after construction in 1996 (1997?). Photo on the right shows the site during our review in June, 2006. This site brings to light the need to evaluate the objectives and impacts of adding sediment that does not match that natural to the site. The added cobble gravel seen here steepens the beach and provides a different substrate habitat than along adjacent shoreline.

Site 11 is the Salisbury Point County Park in Kitsap Co. It faces north onto Hood Canal in a medium to high wave energy environment. The site is classified as both a Bulkhead Removal and Low-No Bank Stabilization project. Photo on the left shows the site shortly after construction in 1995. Photo on the right shows the site during our review in June, 2006. Bulkhead removal at this site had the positive effects of improving beach access, increasing beach width, and recruiting LWD, without incurring much risk to expensive upland infrastructure.

Site 12 consists of 16 adjoining private properties in Skagit Co. All face north onto Samish Bay in a high wave energy environment. The site is classified as a Bulkhead Protection project. Photo on the left shows the site shortly after construction in 1998. Photo on the right shows the site during our review in June, 2006. The sill at the down-drift end of the participating properties (behind the photographer) has preserved the added beach sediment and beach profile, reduced erosion of existing bulkheads, reduced the risks to waterfront homes, and helped to recruit LWD. Home-owners are very happy with the results. The adjacent beach down drift to the east (not shown in these photos) appears to be migrating landward.

Site 13 the Seahurst County Park in Burien, King Co. It faces west onto Puget Sound in a moderate to high wave energy environment. The site is classified as a Bulkhead Removal, High Bank, and Low-No Bank Stabilization project. Photo shows the site during its construction and our review in June, 2006. This site has had a healthy riparian zone, but it was somewhat separated from the beach by the bulkhead. With the bulkhead removal and regrading of the lower slope, it should be more effective at contributing LWD to the beach. The city of Burien is investigating removal of additional seawall and bulkheading to the north of the shoreline reach pictured here.

Site 14 is private property in Kitsap Co. near Seabeck. It faces north onto Hood Canal in a moderate to high wave energy environment. The site is classified as a Bulkhead Removal project. Photo shows the site during our review in June, 2006. This site illustrates the potential for successfully creating a pocket beach within a reach dominated by concrete bulkheads, and the possibility of restoring some beach habitat, even if not necessarily an adjacent riparian zone.

Site 15 is private property on Fox Island in Pierce Co. It faces southwest onto Carr Inlet in a moderate to high wave energy environment. The site is classified as a Low-No Bank Stabilization project. Construction date is uncertain. The photo shows the site during our review in June, 2006. We observed evidence of periodic overtopping of the berm onto the lawn by storm waves. The site is located on a filled backshore at the base of a steep slope prone to landsliding.

Site 16 is an EPA Superfund Site currently undergoing clean-up. It is located on Bainbridge Island, Kitsap Co., south of Winslow. It faces north onto Eagle Harbor in a relatively low wave energy environment, although it is exposed to ferry boat waves. The site is classified as a Bulkhead Removal project, with the initial removal of the log pile bulkhead occurring in 2001. Photo shows the site during our review in June, 2006. Some erosion of the berm in the foreground has occurred, but otherwise the beach appears to be relatively stable and recreational use of the site is apparently common.


Site 17 is a State-owned Natural Resources Conservation Area in Thurston Co. Being located on a small peninsula in Henderson Inlet, it has shoreline exposure to the north, east, and south in a low to medium wave energy environment. The site is classified as a Bulkhead Removal project. It was completed in 2005. Photo on the left shows the site during deconstruction in 2005. Photo o the right shows the site in March, 2006, shortly after the high-tide storm event of February 4th, 2006. Landslides of this type can be expected on recently-exposed unvegetated slopes, over-steepened following bulkhead removal. Slope retreat is an expected consequence in the short term, but rates of retreat should slow in the long term, under current climatic/sea level conditions.

Appendix C: Three-tab Spreadsheet of Report Tables (see separate Excel file accompanying this document)

Table 1. Site information, field observations, and project evaluation summary.
Table 2. Site classification and corresponding applied mitigation.
Table 3. Evaluation summary by site classification.