MARINE PARK SHORELINE RESTORATION FEASIBILITY

City of Blaine, Washington

January 2011

Prepared By

ELEMENT Solutions

1812 Cornwall Ave., Bellingham, WA 98225 • Tel: (360) 671-9172 • elementsolutions.org

- Page intentionally left blank -

Contents

List of Figures

List of Tables

Acknowledgments

This document was prepared by Element Solutions in cooperation with the City of Blaine. The authors would like to thank the following contributors: The City of Blaine Park and Cemetery Board Members; Susan Meyer, Hugh Shipman and Barry Wenger of the Washington State Department of Ecology; Lisa Kaufman and Doug Thompson of the Washington State Department of Fish and Wildlife; City of Blaine Community Development Services Department Staff; and City of Blaine Public Works Department Staff.

1.0 Introduction

The City of Blaine (COB) Community Development Services retained Element Solutions to perform a feasibility assessment and planning-level design for the restoration and stabilization of the Marine Park shoreline in order to support grant and permit applications. This project will be integrated with the City of Blaine's overall comprehensive Landscape Plan (Cascade Design Group, 2010), the Draft Shoreline Master Plan and Shoreline Restoration Plan (2006), and the Marine Park Wildlife Protection Plan (Eissinger, 2002). Elements of these plans are currently being implemented in addition to recent completion of the Lighthouse Point Water Reclamation Facility.

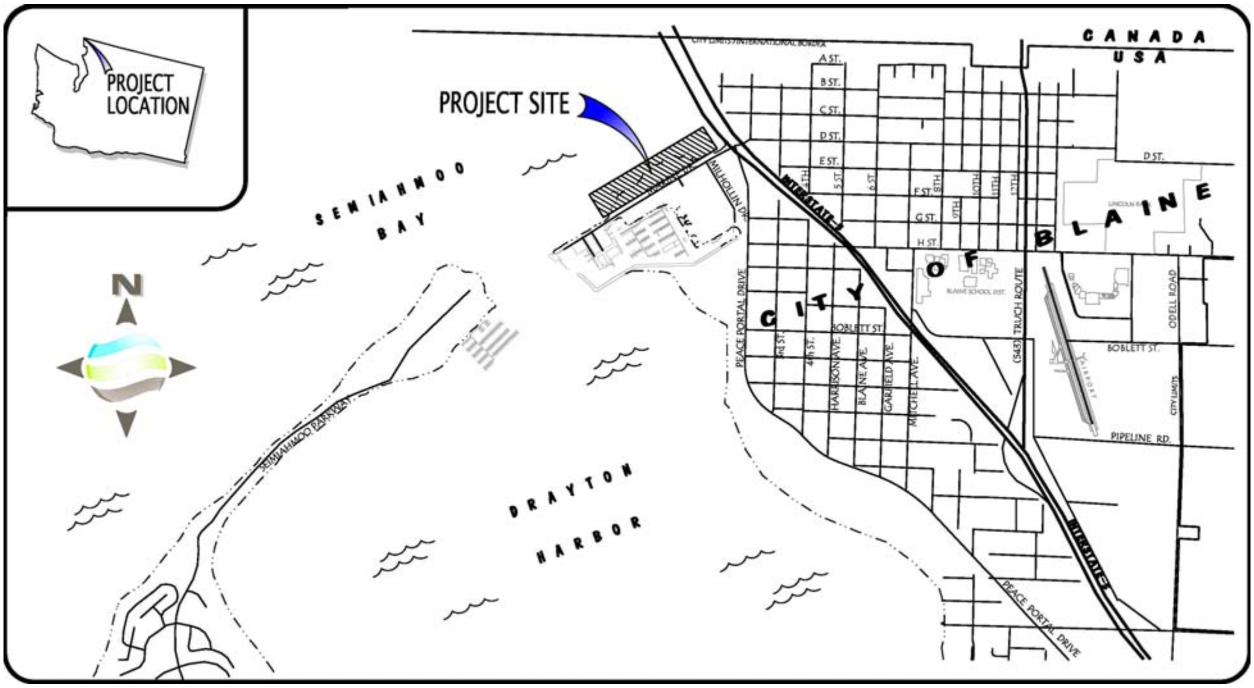
Marine Park along Semiahmoo Bay is located on a historic, man-made landfill that separates Semiahmoo Bay and Drayton Harbor (See Figure 1, Vicinity Map). The landform is vital to the local community and preserving, using and enjoying this public space is a high priority. Although currently degraded, the shoreline along Marine Park has many potential opportunities for improvement.

The City of Blaine wishes to develop a comprehensive shoreline restoration plan that identifies the management strategies for Marine Park that will meet City's objectives and arrive at implementation. The overall project goal is to stabilize and protect the shoreline, restore or enhance habitat, allow for natural processes (to the degree possible), and improve aesthetics and public access along reaches of approximately 1600 lineal feet of Marine Park (Reach 2 in the draft Shoreline Restoration Plan, 2006). The project objectives include:

- Stabilize portion of the eroding shoreline to protect a new sewer facility serving the community and the proposed and existing park improvements;
- Improve the shoreline for public recreational enjoyment by improving access, aesthetics, and safety;
- Enhance the natural beach conditions for ecological purposes by allowing for some degree of natural physical process and utilizing native plantings and bio-engineering techniques wherever practical.
- Provide wildlife habitat enhancement with implementation of restoration plantings and shoreline improvements.

The COB previously developed preliminary shoreline restoration concepts (draft Shoreline Restoration Plan, 2006) for the project area (Reach 2). The City subsequently divided the project reach into segments A through D based in part by land use and in part by general restoration strategy (COB internal document). This study builds upon those preliminary efforts and visions. In addition, this study incorporates the vision and proposed improvements of the aforementioned plans and evaluates those plan proposals for consistency with the shoreline restoration objectives and parameters.

Figure 1 – Vicinity Map



Improvement of the Marine Park shoreline faces some management challenges. In part because it is a not a natural depositional feature and the natural process acting upon it act try to erode it back to the sea. Despite this, preservation of the landform is essential and enhancement of natural features are desired. Some naturally accreted beaches have formed in certain reaches and natural conditions have begun to develop. Therefore, the challenge is to create landform stability while also encouraging or enhancing natural processes that continue to foster these beach forms and the resulting ecological and public use benefits.

Additional engineering challenges include management of the concrete rubble that currently armors most of the shoreline and provides some shoreline erosion protection while simultaneously impairing public access and enjoyment, and natural beach processes and ecological functions, see existing site conditions photos in Appendix A. Removal of the concrete rubble will be expensive and removal of the armoring without re-armoring will expose the landfill and erosion will occur at an accelerated rate, thus jeopardizing infrastructure and potentially contributing material detrimental to the existing shoreline ecosystems. The configuration of the shoreline armoring from a plan view perspective should, for the most part, be maintained if the locations of the pocket beaches are desirable, both from a public use and ecological standpoint. The City of Blaine has limited resources and it is unlikely that they will be able to take on all inclusive management strategies and construction projects; therefore, creative and viable management strategies that can be implemented with the resources available are needed.

This report discusses the methodology and results of a feasibility assessment performed to identify project alternatives phasing strategies, develop conceptual designs, and to support the selection of a preferred alternative. The report also presents the planning-level design development of the preferred alternative in support of future grant and permitting applications for the implementation of restoration and stabilization activities. In addition, this report provides clarity and understanding of which activities will trigger regulatory review, including but not limited to Sections 10 and 404 (Army Corps of Engineers), Section 401 (Ecology), Section 106 (SHPO), Shorelines, HPA (WDFW), SEPA, and Critical Areas. The recommendations of this report consider alternatives in which to work effectively and affordably within the regulatory environment.

2.0 Methodology

The methods we selected to evaluate the feasibility of proposed restoration activities include the following:

1. Characterize existing conditions and review of existing information,
2. Conduct a geomorphic analysis,
3. Evaluative restoration design concepts for consistency with existing plans,
4. Develop constructible engineering and restoration designs and costs (planning level),
5. Identify funding and sequencing strategies,
6. Assess project sustainability and maintenance needs

The assessment, plan, and design portions of the project will occur in two phases. Phase 1 (this study) includes the assessment, plan and conceptual designs. Phase 2 will include developing and finalizing specific designs for selected project elements. For this phase (Phase 1) we document our assessment, alternatives, recommendations and conceptual level designs and planning-level engineer estimates that should allow for funding requests and initiation of permitting. The scope of Phase 2 will be defined at a later date, but at a minimum would include construction plans, specifications, and estimates as well as permitting assistance.

A meeting was held on-site on with Michael Jones, Community Development Director, to tour the site and identify project considerations. During the meeting, we discussed preliminary project alternatives for conceptual designs. We have refined and categorized these concepts into the following alternatives:

- Alternative 1: No action
- Alternative 2: Repair failing structural shoreline protection as needed or during emergencies
- Alternative 3: Proactively enhance structural shoreline protection and use affordable techniques that improve design function and meet comprehensive project objectives
- Alternative 4: Enhance (restore) shoreline areas using bio-engineering techniques to improve ecological function

It is likely that some portions or combinations of alternatives will best meet the COB abilities over time. Element developed a preliminary design concept for Alternatives 3 and 4 in order to assess their feasibility, pros/cons and estimated costs. We analyzed the alternatives and provide recommendations for designs for shoreline segments that we feel best address the project objectives and COB abilities.

3.0 Existing Conditions

In order to characterize existing conditions along the Marine Park shoreline, a site assessment was performed by Element to characterize and describe observed conditions and assess geomorphic processes. Characterization of the existing conditions included natural and manmade features, including the presence of riprap armoring, concrete, refuse, erosion or accretion, shoreline vegetation, and drift logs (Appendix A). The City of Blaine had previously divided the shoreline into segments A-D and X and described some of the restoration or improvement concepts (Figure 2). We use the same general segment nomenclature in this report with the addition of sub-reaches called out with subscripts.

Figure 2 – Shoreline Segments Location Diagram

In addition, Element compiled and reviewed existing information, including but not limited to, the draft Shoreline Master Plan and Shoreline Restoration Plan (2006), the Noxious Weed Control Plan (May, 2010); coastal analyses on wave heights and littoral drift; Report on Coastal Processes at Semiahmoo Spit (Westmar, 2004); comparative coastal engineering analyses; GIS data; historic and current orthophotography; recent topographic maps (April, 2010); critical area/shoreline maps; Marine Park Landscape Plan (2010); and pertinent historical records. We reviewed the information for its applicability in this study.

The Marine Park area was created over the past century by landfilling. Uses of the shoreline go back well over a century when docks were constructed to support industry and shipping. Filling gradually replaced the docks. Over time, landfilling has included structural fills, a municipal dump, earthen containment berms, dredged materials, unconsolidated earthen fills, and construction debris. Evidence of the past uses and landfill history are evident. Today, concrete construction debris, riprap armoring, relict industry line the shoreline. In several locations, earthen landfill materials are exposed.

We reviewed the ecological conditions at the site as documented in the Semiahmoo Bay – Marine Park Wildlife Protection Plan (Eissinger, 2002). We revisited, confirmed and updated some of the ecological conditions to be used in permitting applications and to assess potential impacts from certain shoreline management strategies. We confirmed that expansive mudflats at and below the MLLW dominate the aquatic intertidal habitat. The mudflats contain broad areas of eel grass habitat below the MLLW. Two species of eel grass were observed, the native (*Zostera marina*) and the introduced (*Zoestera japonica*) which provide habitat for herring spawning and forage fish (sand lance and surf smelt) rearing. We also confirmed high use of the embayment by waterfowl. The expansive intertidal mudflats and orientation of the beach (in the lee of prevailing southerly winds) make it a suitable habitat for migratory and resident waterfowl (Eissinger, 2002). We observed that the forebeach is characterized by armored sediment that is typical in a supply-limited system (see Geomorphology section of this report). The suitability for forage fish spawning habitat was not evaluated, but because of the armoring it is anticipated to be of low quality. Typically, suitable substrate includes loose sand and pea-size gravel for forage fish spawning. Woody debris in the upper and back beach areas was limited. Some development of riparian and supratidal vegetation (native dune grasses) was observed in the accretionary beach areas; however, the presence of invasive plant species in the riparian area is prolific (see Noxious Weed Report). The lack of woody debris in the nearshore environment can have adverse habitat consequences, as LWD serves to stabilize beaches and help build sand berms and backshore areas that can support dune vegetation (Brennan and Culverwell 2004).

4.0 Geomorphology

Element conducted a field assessment and observed geomorphic conditions. The assessment included characterizing foreshore and low-tide terraces, beach profiles (slope), drift indicators, sediment size characteristics, sediment source areas, and natural wood deposition. The overall geomorphology of the project site was created by human development and modification. The pre-development geomorphic conditions, based on air photo interpretations, consisted of a shallow marine depositional area and expansive mudflat. This pre-developed condition was altered by manmade landfilling that occurred over the past century and created a new landform. The landform configuration and orientation, sediment type and availability, and the shoreline processes acting upon the landform all affect the shoreline morphology development (headlands, foreshore, pocket beaches, beach berms, and tidal wetlands). Because of the artificial nature of the landform, it is not sustainable without maintenance and over time it would be slowly eroded by wave energy. The Marine Park beach system is sediment supply limited, meaning there is not enough movable sediment that reaches the beach to sustain the forebeach without some form of nourishment, traditionally this has been the erosion of the landfill. In order to create, enhance, or maintain a sandy-gravel beach foreshore, pocket beaches, spits and berms, sediment nourishment is required.

The investigation determined that sediment transport (littoral drift) occurred from west to east and that the sediment supply originates from the eroding landfill material. Supply is limited and we observed that the landfill sediment exposed in eroding areas was dominated by fine-grained sediments likely placed during historic road building and dredging of the marina facility and navigation channel (See Appendix A, Reach C-2 photo). Erosion of this landfill occurs in areas where armoring has failed and from porously armored areas where interstitial mining of fines causes loss of landfill sediment. Some areas of limited deposition and accretion are occurring on the up-drift sides of armored points with the existing supply and transport conditions (See Appendix A, Reach D-1 photos). However, much of the foreshore is armored with coarse, embedded sediment, which supports the notion that the system is supply limited. In sediment supply limitation conditions, beach forms are partly or completely related to the characteristics of the sediment supply from up-drift. Therefore, slight changes in the supply will affect the shoreline system morphology. Similarly, alteration of the shoreline configuration (footprint), will impact transport and deposition patterns and thus shoreline morphology.

We tried to assess erosion rates by comparing current conditions with historical information; however, because of frequent shoreline modifications and projects, we were not able to develop reliable values. We utilized engineering and scientific judgment to predict and assess the sustainability of certain designs and intended outcomes. As part of this exercise, we identified areas where potential erosion rates and hazards are likely to increase risk to existing or proposed infrastructure, public safety or ecological conditions in the near term. The western portion of the project has the greatest risk from erosion because the erosion rates there are greatest and the proximity to important infrastructure increases the consequence. Of this higher risk area, the eastern portion of Zone D has the greatest potential for erosion impacting existing and proposed infrastructure in the near term. However, armoring Zone D, without corresponding sediment nourishment, will negatively impact beaches in Zone C, and ultimately Zones B and A.

Typical beach profiles were developed from existing survey data. Beach profiles indicate that the slope of the foreshore within the project site ranges from approximately 5H:1V to 10H:1V. Beach slope and sediment size decrease in the eastward direction. The Marine Park shoreline has a substantial and expansive low-tide terrace, (mudflat area immediately beyond the foreshore). The low-tide terrace occurs approximately around the MLW to MLLW elevations, increasing in elevation in the eastward direction.

Tides at the site are mixed semi-diurnal. Tidal currents at the project site are interpreted to be negligible and caused by tidal inflow into the shallow and broad Semiahmoo Bay. Subtidal current may result from prevailing northwesterly winds pushing surface water to the east or from ebb-tide outflow.

Local wind-waves are dependent primarily on fetch (the distance over the water the wind blows), the wind speed, and duration of wind. Northwesterly and westerly winds create the predominant conditions affecting morphology of the shoreline (Environment Canada – Tsawwassen Ferry Terminal). These predominant winds generate waves that strike the Marine Park shoreline obliquely to near-perpendicular depending upon beach aspect. Wind wave heights calculated using the Shore Protection Manual (Army Corps of Engineers 1984) and Tsawwassen wind data by Westmar (2004) for the Semiahmoo Spit evaluation. They calculated significant 100-year deepwater waves of 12 feet (crest to trough) from the west and 8 feet from the northwest. "Significant" wave heights are the average height of the highest 33% of the waves. The bathymetry of the low-tide terrace and foreshore slope impacts wave heights and wave run-up forces acting upon the foreshore and upper beach areas (the wave energy that impacts the landfill and beach morphology). Wave run-up models are complex and outside of the scope of this report. However, waves impacting the Marine Park shoreline are anticipated to be less than the 100-year calculated estimates. Anecdotal observations made by City of Blaine staff during large storms, have estimated wave height at the site is approximately 5.0 feet from northerly winds (Michael Jones, personal communication). We compared this value to FEMA coastal flooding estimates for Sandy Point and Point Roberts. The calculated wave heights at those sites are for different fetch and shoreline geometry, so direct correlations cannot be assumed; however the calculated waves (heights and run-up) were within the expected range of the anecdotal wave observations and less than the 100-year deep water wave calculations. Seismic generated waves were not considered.

Recent observations collected by the City of Blaine show that significant high tides can occur, and if they occur in conjunction with strong, sustained northerly wind patterns, it is possible that significant erosion of the shoreline could result in a short period of time. 100-year high tides predicted for Sandy Point were 7.9 feet NGVD 1929 (Phillip Williams and Associates, 2003). By combining the 100-year high tide value with the estimated observed significant storm wave heights (0.5 times a 5-foot wave height = 2.5 feet), we estimate that a large storm can create waves that reach, and potentially exceed, approximately 11 feet (NGVD 1929). Localized shoreline geometry may create wave heights and wave throw that exceed this. Infrequent, but extreme storm events that coincide with high tides may also exceed these estimations. Furthermore, extreme wave heights (2.3 times the "significant wave height") are a documented phenomena (Smith, 2007). The OHWM as delineated by Northwest Ecological, showed that the common waves marking the shoreline occurred at elevations of approximately 9.0 feet (NGVD 1929) or less.

5.0 **Marine Park Uses**

Marine Park is important both from an ecological perspective and from a public use perspective. Ecologically, Semiahmoo Bay and the tidal mudflats are vital to the migratory waterfowl. The shallow, protected water and eel grass habitats provide both refuge and food for numerous species of birds using the Pacific Flyway (Eissinger, 2002). The eel grass beds are important habitat for spawning herring and rearing forage fish (sand lance and surf smelt). From a public use standpoint, the beaches offer great views and a place to enjoy recreation. Instances exist in which the two perspectives are not necessarily compatible, and often the ecological uses are negatively impacted by the public uses (Eissinger, 2002).

Recognizing this, the City of Blaine has one overall vision to improve both ecological and public conditions at the park. The eastern portion of the shoreline is set aside to protect and enhance wildlife conditions. The western portion of the shoreline is intended to allow for improved public access and design features to draw in managed public uses. Development to encourage recreational uses of the shoreline area is proposed and is an important consideration in the design and overall goal of the project (see Appendix C, Landscape Plan, 2010). The City has set aside two-thirds of the Marine Park shoreline for wildlife habitat as part of a management plan, due to the importance for migratory waterfowl (Eissinger, 2002). Currently, rubble, debris, relict concrete piers and pilings can be found throughout the shoreline area, but are highly concentrated in the park area designated for public access. The existing conditions impair the potential recreational use. The eastern portion of the beach has a passive shoreline designation and recreational use there is discouraged in order to minimize impacts to migratory waterfowl that use the area (see Figure 2 above). Public use in the western portion of the site is encouraged and the Landscape Plan identifies several features to help encourage public use and enjoyment of the shoreline. Implementation of some of the Landscape Plan is currently underway. For this study, we reviewed the Landscape Plan and considered the consistency and feasibility of the restoration and shoreline protection designs relative to the Landscape Plans proposed improvements, ecological goals and shoreline stabilization goals of the project.

6.0 Shoreline Engineering and Restoration Designs

Element developed a range of conceptual to fully developed shoreline engineering and restoration designs (Alternatives 2 through 4) to manage the shoreline in ways that maximize the City of Blaine's objectives and work within the regulatory environment. The designs recognize the need for comprehensive integration of benefits achieved and project costs. Phasing or sequencing plans were also incorporated into the designs and implementation strategies. Use of bio-engineering, where applicable, was utilized to create a more natural shoreline, both visually and process-wise. A shoreline planting plan was already prepared for the site as part of the Marine Park Landscape Plan and the recommendations from that plan are referenced in the designs.

6.1 Planning-level Design and Basis of Design

Based on the findings of this study, recommendations are presented regarding the basis of design for Marine Park Phase I restoration feasibility. Recommended restoration applications are proposed based on site factors including the site is protected from prevailing southerly winds, has a limited fetch and is oblique to the predominant northerly wind and waves originating from the Strait of Georgia. The broad low-tide terrace also provides some benefits of disrupting wave energy at certain tides.

The Marine Park shoreline was delineated into multiple reaches based upon existing conditions and desired restoration objectives, and an applicable typical design approach strategy applied to each reach. Planning-level typical design drawings of the preferred alternatives for the restoration of Marine Park shoreline are provided in Appendix B, and include the following typical design approach categories:

- **Structural Shoreline Stability Areas**
- **Headland and Revetment Structural Shoreline Stability Areas**
- **Shoreline Restoration and Depositional Areas**
- **Shoreline Restoration - Pocket Beach Creation Area**

These typical design approaches incorporate various design elements, described in further detail below, including the application of strategies for: (1) obtaining shoreline structural stability, (2) shoreline restoration, (3) sediment nourishment, (4) bioengineering, and (5) vegetation planting and management.

1. **Shoreline Structural Stability**
   Shoreline structural stability is achieved by applying one, or a combination of, the following strategies:
   - Repair failed armoring with standard riprap armoring.
   - Use of existing armoring (concrete rubble) or imported riprap, covered with cobble-gravel armoring.
   - Reduce the slope angle and armor with cobbles.
   - Stabilization utilizing large woody debris (LWD), anchored as necessary.

Larger storm waves for the Marine Park site are estimated to be approximately 5 feet in height, but larger waves are possible. The energy carried by a wave is proportional to the square of its height (Demerbilek *et al*, 2006). For example a one-foot high wave results in approximately 250 foot-pound-force per square foot, whereas a 2-foot high wave is nearly 4 times that force. To ensure that the existing and proposed infrastructure is not compromised during large wind events, structural protection of the shoreline should be provided. Our conceptual designs to accomplish this use a riprap toe (existing or imported angular rock and, rubblized concrete) capped with a rounded rock (natural boulders to cobbles with gravel foreshore facing) and a geotextile encased earthen fill with vegetation above the MHHW. The incorporation of anchored LWD may be applicable in select reaches. In addition, sediment (in the form of nourishment) should be added to protect the revetment and improve habitat conditions (see below).

<u>Riprap</u>**:** Riprap, historically, has been extensively used as shoreline protection. Use of riprap makes structural sense on high-energy beaches where erosion can compromise shoreline stability and existing infrastructure. However, traditional riprap designs can be modified to better dissipate wave energy and incorporate alternative stabilization techniques, such as bioengineering. Re-use of existing riprap as well as the placement of structural LWD may help to offset costs of importing new riprap. In addition, supplementing the revetment structure and creating a drainage system within the structure could be done by rubblizing existing concrete debris associated with the fill material that will be removed (see below).

The riprap armoring can be designed to be more compatible with shoreline processes by reducing the amount and slope of the rock face and utilizing infiltration to absorb wave energy backwash. Covering the riprap with a cobble-gravel veneer improves the aesthetics, function and longevity of the riprap structure. LWD can also be used to help dissipate wave energy and encourage additional wood recruitment (see below). A well designed, constructed and maintained shoreline revetment will allow for more natural process and the dissipation of energy similar to a natural beach. Therefore a well designed, constructed and maintained shoreline revetment will have less impacts on adjacent habitat conditions. Asphalt and other deleterious fill materials or debris should be removed from the shoreline area. In addition, sediment (in the form of nourishment) should be added to increase the design life, improve habitat conditions, and maintain beach areas downdrift. Sediment used for nourishment should be sized appropriately and delivered to the shoreline in desired quantities and rates. We did not do site-specific sediment nourishment plans for this report.

1812 Cornwall Ave., Bellingham, WA 98225 • Tel: (360) 671-9172 • elementsolutions.org

Rubblized Concrete: The reuse of existing on-site concrete by rubblizing it is a possible method to reduce the need for imported materials and reduce the quantity of material being transported to landfills, thereby reducing project costs. The rubblized concrete could be used to offset riprap imported for structural designs. The typical designs we developed use the rubblized concrete as part of the structural toe and the material is shown covered up by rounded armoring (riprap and cobbles) and beach nourishment materials. The reuse of the concrete may be subject to permit restrictions.

Anchored LWD: The planning-level design includes the potential use of LWD incorporated into structural protection. Anchored LWD protection consists of a series of intertwined and partially buried structural logs with root wads. The anchoring techniques and methods should be evaluated on a site-by-site basis. The anchored LWD functions to dissipate wave energy and has some habitat value.

1. **Shoreline Restoration (non structural)**

Large woody debris (LWD) and the wrack (drifting organic matter) that often accompanies it are commonly deposited on beach berms and in accretionary beach areas. LWD is an important component of the nearshore supratidal (i.e., at and above mean higher-high water) ecosystem. At the Marine Park site, wood has gradually and naturally accumulated in the central pocket beach in Reach C and on the spit and tidal marsh in Reach A. Therefore, unanchored wood can be placed on the beach as part of the restoration plan. Wood naturally deposited is typically found with the long axis of the tree parallel to the beach and waves that placed it. The use of anchored wood could be considered depending upon its purpose and size. In addition to wood providing a structural component, it may also serve to aid in the recruitment of floating woody debris to benefit habitat structure and slow the erosion that will inevitably occur. It is likely and anticipated that natural process will rearrange the configuration of the LWD and in certain conditions it may be evacuated from the site. To minimize the loss of LWD added to the beach, some members of the LWD can be partially buried into the beach. A typical design is offered for this alternative.

Additional restoration opportunities exist from cleaning up the piling, rubble, rubbish scattered throughout the shoreline area. Many of these activities are low impact and low cost, but will greatly enhance the aesthetics of the shoreline area.

2. **Sediment Nourishment**

The use of sediment nourishment can serve several purposes:

- Prevent the structural shoreline protection (existing concrete or riprap, or proposed revetment improvements) from being engaged by prolonged wave action, thus increasing project life.
- Create, maintain and/or enhance pocket beaches.
- Improve nearshore habitat.

Beach nourishment is used in the planning-level design to maintain and restore back and upper beach area (where forage fish spawn) and to provide a source of sediment (fine gravel and sand) to adjacent beach areas. The nourished area separates the landfill from the active beach, so the riprap will not be engaged as frequently by waves. Without some form of nourishments, the existing beaches will become armored and eventually diminish in size and quality.

3. **Bioengineering**
   Biodegradable erosion control blankest or matting, along with vegetative planting shall be implemented as necessary, with more details to the application of this design strategy forthcoming in final design plans for the restoration project.

4. **Vegetation Planting and Maintenance**
   All design components utilize vegetation planting to increase shoreline stability and minimize erosion. Existing vegetation at the site is not necessarily with native or non-invasive species that have good root structures that bind soils. Vegetation on the eroding shoreline areas is almost entirely lacking. On accretionary beaches, vegetation starts just above the MHHW. Vegetation planting along all shoreline areas, especially disturbed areas, has immense value and is very affordable. Maintenance of the vegetation is often necessary for several years until it becomes established and can compete with the invasive species. Higher survival rates can be achieved by planting in the dormant season (November – March) and watered intermittently but for a long sustained duration during the first summer to encourage deeper root growth. Once the plants become established, they should not need watering because the species selected are adapted to low moisture conditions.

   The Landscape Plan utilizes zoned planting modules that will be planted in phases and by volunteers (Appendix C). The planting module zones are defined by erosional shoreline areas above OHWM, depositional areas at or above MHHW, and upland areas. This study references the Landscape Plan for specific planting prescriptions. In areas where planting occurs in conjunction with the construction of a revetment or where soils are very steep and/or disturbed, we recommend using geotextiles, such as coir fabric, to help stabilize the soils until root strength is obtained.

   Vegetation management shall incorporate the Noxious Weeds Control Plan included for reference in Appendix E.

6.2 Potential Environmental Impacts and Permitting

The low-tide terrace, where eelgrass is present, (approximately MLLW) is not anticipated to be impacted by the placement of fine sediment on the upper beach in nourishment activities. The mudflats are already a depositional environment and the eel grass can adapt to that; however, deposition rates that are too high can impact its ability to persist. The sediment nourishment size fractions and volumes proposed in the projects are minute compared to the scale of the mudflat and will not negatively impact the existing eel grass mudflats. Other macroalgae species that can occur in the intertidal beach area (i.e., *Fucus* sp and *Ulva* sp), are additionally not anticipated to be impacted by nourishment activities. Coordination with the Washington Department of Fish and Wildlife may be needed to discuss nourishment and demonstrate that no impacts to these algae species are anticipated by proposed activities. More importantly, sediment nourishment will likely benefit foraging fish habitat by creating suitable substrate for spawning.

6.3 Funding and Sequencing Strategies

The draft Shoreline Restoration Plan (2006) identifies restoration partners. These partners include: Lummi Nation, Nooksack Tribe, Nooksack Salmon Enhancement Association (NSEA), Whatcom Conservation District, Puget Sound Partnership, Washington Department of Ecology, Washington Department of Fish and Wildlife, Washington State Department of Natural Resources, the Recreation and Conservation Office, the Marine Resources Committee, Washington State University Cooperative Extension, Whatcom County, Port of Bellingham, Drayton Harbor Shellfish Advisory Group, and the Semiahmoo Resort Association. In addition to the listed partners, the U.S. Environmental Protection Agency (EPA) and U.S. Fish and Wildlife Services are two additional potential partners.

Implementation strategies will likely evolve around potential funding opportunities. Certain project elements are more likely to receive funding than others, especially projects that can demonstrate ecological lift for listed species. Potential sequencing strategies for Phase I project elements are provided based on previous prioritizations (Shoreline Restoration Plan) or for risk from shoreline erosion. The results of this sequencing strategy are shown in Table 1 and are identified by Reach-Subreach. These individual project elements can be referenced for how they fit into the complete and comprehensive plan as well as presented as individual, or stand-alone projects. The information presented in this report should be adequate to be used for funding requests and preliminary project permitting. Final design, permitting, and construction packages will come from Phase II efforts.

Table 1: Proposed initial project sequencing strategy (See sheet C2 in Appendix B)

Project ID	*Description*	*Rationale*
REACH D-1 (Reach D east)	Shoreline stabilization and nourishment	Unarmored shoreline is susceptible to erosion and the water treatment facility is located a short distance away. Nourishment will enhance the restoration activities in Reaches C-D.
REACH C3, C2, and X	Shoreline stabilization, nourishment, and restoration	Shoreline armoring is damaged and impacts to this reach will have negative impacts on the ecological conditions in Reaches A and B. Nourishment will enhance the restoration activities in Reaches C-D.
REACHES C4, B and A	Shoreline restoration	Addition of sediment nourishment from up-drift reaches and use of LWD drift logs, beach cleanup, native plantings, and cobble stabilization will improve impaired ecological functions for fish and birds.
REACH D4 and D2	Reinforce shoreline stabilization and sediment nourishment	Existing shoreline stabilization is anticipated to degrade and ultimately fail. Repair of these reaches is anticipated in the near-term.
REACH D3 Pocket Beach Construction	Construct Pocket Beach	Prior to or in conjunction with installation of the pocket beach in this reach, Reaches D4 and D2 should be stabilized.

6.4 Sustainability and Maintenance Needs

Element evaluated potential maintenance of proposed designs and management activities to determine short and long-term maintenance needs and issues. Some project elements have a low initial capital investment; however, the long-term maintenance needs and commitments become large over time. Conversely, some project designs have a large upfront capital investment, but the longer life span of the project will reduce the overall project cost. For example, beach nourishment has a fairly low upfront capital investment, but conducting frequent beach nourishment for long periods of time has a large cumulative investment. The project has been designed to avoid frequent nourishment activities, while still being responsive to the sediment issues that are occurring on this manmade shoreline.

6.5 Consistency with Existing Plans

Element integrated planning level designs with existing plans where applicable to maintain consistency with the overall community vision and to reduce overlap in project assessments and planning efforts. The primary documents used for this framework were the Shoreline Master Program updates, the Wildlife Protection Plan, and the Landscape Plan. For example, the Landscape Plan provides for shoreline access and includes elements of native plantings to help address erosion, manage public use, and improve wildlife habitat. This study incorporates those recommendations into its conceptual designs.

7.0 Planning Level Construction Cost Estimates

Element developed planning-level cost estimates (A&E) based on the conceptual designs we developed. These estimated costs are for assumed preliminary project scopes. Actual project scopes and costs may vary. We developed unit cost estimates that can be used to generate planning level costs by determining unit multipliers. As referenced in Section 6, the project can be completed in phases or individual project elements and constructed incrementally over time as either need or financial abilities exist. We provided unit costs in our estimate so that modifications to our estimates can be made to the degree that units are scalable. These costs per unit value are presented in Appendix D. Actual project costs are dependent upon project design and other variables not necessarily accounted for in this estimate. It should also be noted that prices vary widely depending upon permit conditions, changed physical conditions, changes in material or construction costs, or if contamination is encountered in the fill material that requires remediation.

Table 2 provides a summarized cost estimate for an assumed 100-foot project length and then breaks this estimate into a lineal foot (LF) unit cost. This estimate shows the conservative ranges of all estimated items, including a 15% contingency and full design elements used in the project (See Appendix B). These costs do not account for using recycled or reusing existing on site materials. It is anticipated that many site-specific projects could be reduced in cost. We have provided an interactive planning level cost estimation calculator in Excel format to the City of Blaine for use in project development, planning and budgeting purposes. It is not of sufficient detail to be used for Engineering Cost Estimates.

TABLE 2: Hypothetical 100-LF of project length with 1,000 SF of disturbance, 10 CY of cleanup, and 50 piles removed constructed per conceptual design using cost estimates provided in Appendix D.

Section	*Approximate project cost per Typical Section*	*Rounded Costs per LF*
A	$169,760	$175 /LF
B	$130,193	$130 /LF
C	$81,207	$85 /LF
D	undetermined	

NOTE: Includes full design without reused materials and 15% Mobilization, 8.4% Tax, 15% Contingency, and 20% Engineering costs

8.0 Recommendations

Conceptual designs were developed for the Marine Park shoreline reach. The designs and the associated project notes are included in Appendix B.

Typical Structural Design
We identified areas where structural designs were needed and developed recommended typical concept designs (Sections A and B). The typical structural erosion control designs attempt to incorporate the intent to mimic natural shoreline processes and function to the best degree possible given the site limitations. Designs try to utilize low slope angles on the beach front and high porosity to absorb and dissipate wave run-up and high infiltration rates reduce wave backwash velocities which can rob the foreshore of sediment. Where applicable, we try to reduce the impact for lateral sediment movement across the foreshore. Where the designs are to stabilize points to trap lateral sediment, we designed low profile structures that can hold sediment but also allow for some sediment to pass through and are suitable for walking over and look more natural. We called for a sizable buried armored toe with a natural cobble armoring. Some designs incorporate the use of LWD to further reduce and dissipate wave energy and add some ecological value to the design. If feasible and permittable, rubblized concrete could be used with the riprap as a structural member in some reaches. It should be noted that all structures, even well designed and constructed revetments, need maintenance over time. If designed and constructed properly, this should be infrequent and occur on a decadal scale.

Typical Shoreline Restoration Areas
We identified areas in which restoration activities could take place without structural components, with the exception of possible LWD anchoring. The typical conceptual restoration designs are shown with Section C. Much site variability exists and design modifications for these site specific conditions will be needed.

All designs have a planting component to them to stabilize the disturbed soils, develop root strength and erosion resistance, and to increase the ecological value of the project. The use of biodegradable geotextiles can help facilitate successful soil stabilization in the first year or two following the project construction. The success of the plantings' ability to provide the desired benefits relies upon dedicated maintenance and soil amendments until such time that the plants have become established. In addition, we anticipate dedicated and long-term eradication efforts to manage the invasive species that will overrun the more desirable native plants specified in the designs. (See Appendix E.)

Beach nourishment is shown as a component of the structural designs (Sections A and B) in order to emulate sediment recruitment from eroding headlands and natural redistribution and sorting into down-drift depositional areas. Sediment nourishment will be a necessary design element in order to preserve and enhance the pocket beaches and spits currently formed along the shoreline. The sustainability of sediment nourishment depends upon many variables, such as quantity, sediment size, weather patterns, and time. Site specific nourishment designs should encourage a slow, incremental delivery of sediment if at all possible. This may mean that some banks are designed or allowed to erode, or that coarser sediment fractions are used, or that nourishment is placed in areas where it is only infrequently accessed by waves.

Nourishment will be an ongoing maintenance need unless the entire shoreline is to be armored. Therefore, regular nourishment may be required. If proper estimates of transportation rate and well sized nourishment materials are specified, it is likely that nourishment can occur on a decadal scale.

Constructed Pocket Beach Area
In Reach D, a pocket beach is proposed. We developed conceptual design to try to create a pocket beach that will meet the City of Blaine's objectives and provide stability for the design life under reasonable physical conditions (Section D). The construction of the pocket beach will require substantial structural components and beach nourishment. We presented a design which has structural armoring "headland" points, an armored foreshore "sill" and a sandy back-beach zone inundated only during events above the OHWM. It is possible that this design will be adapted during the permitting process or during Phase II design work. This design is proposed a possible sediment delivery point for intermittent nourishment.

Design modifications
Site specific conditions will need design modifications from the typical designs provided in Phase I. Armoring sizes, quantities, elevations, potentially reused materials, and materials encountered during excavation will need to be conducted on a site by site basis to develop plans, specifications and estimates for construction. Often, designs are modified during the permitting process or by budget constraints.

Special Considerations
Potential Soil Contamination – Encountering potentially contaminated soils could occur, especially in the areas where historic municipal landfilling occurred, notably along the eastern and central portions of the site. We observed that some potential landfill materials may already be exposed from shoreline erosion. An encounter may require sampling and analysis to determine potential presence of contaminated fill in the areas proposed for removal. This would include sample cores to analyze and address disposal requirements.

Permittability and Permit Conditions – Construction techniques and methods could be altered in such a way as to reduce the need for some permits, such as doing work above and outside of the OWHM. Conversely, construction techniques and methods may need to be altered in such a way as to increase anticipated project costs, on limit some proposed actions. Consultation with agency regulators for site-specific project designs and proposals will need to be visited early on in the design process.

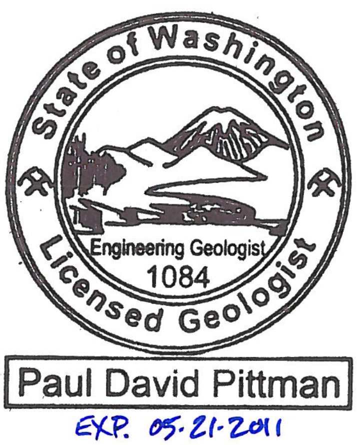
Design Limitations and Expectations

It is expected that erosion will continue at the site, even with the construction of engineered armored revetments. Beaches are dynamic environments and wave energy is very powerful. Maintenance and design modifications should be an anticipated part of each project component.

This Report was submitted by:
Element Solutions

Paul D. Pittman, L.E.G.
Earth Sciences Manager

Brian Walker
Environmental Specialist



Statement of Limitations
This document has been prepared by Element Solutions for the exclusive use and benefit of the City of Blaine. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents Element Solutions best professional judgment based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the geologic engineering profession currently practicing under similar conditions. No warranty, expressed or implied, is made.

References

Army Corps of Engineers. 1984. Shore Protection Manual 4th edition, prepared for Department of the Army, US Army Corps of Engineers, Published 1984 by Dept. of the Army, Waterways Experiment Station, Corps of Engineers, Coastal Engineering Research Center.

Brennan, J.S. and H. Culverwell. 2004. Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems. Published by Washington Sea Grant Program. Copyright 2005, UW Board of Regents, Seattle, Washington. 34 p.

City of Blaine Shoreline Inventory and Analysis Report, City of Blaine Shoreline Management Master Program. September 18, 2006, Updated March 3, 2010.

Demerbilek, Zeki and Linwood, V., 2006. "Water Wave Mechanics" Part 2, chapter 1 in volume 2 of US Army Corps of Engineers Coastal Engineering Manual, Coastal & Hydraulics Laboratory, Vicksburg, Mississippi. Revision 1.

Eissinger, E. 2002. Semiahmoo Bay – Marine Park Wildlife Protection Plan. Technical Report prepared for City of Blaine Dept. of Community Development, Blaine, Washington. August 15, 2002.

Ecology. 2009a. Washington Coastal Atlas. Available at: <https://fortress.wa.gov/ecy/coastalatlas/viewer.htm>.

Herrera. 2009. Ediz Hook Restoration, Phase III – Project Alternatives. Technical memorandum prepared for WDNR and the Elwha Tribe by Herrera Environmental Consultants, Inc., Seattle, Washington. June 30, 2009.

Restoration Plan, City of Blaine Shoreline Master Program Update. December 2006

Smith C. 2007. Extreme Waves and Ship Design. 10th International Symposium on Practical Design of Ships and Other Floating Structures.

Westmar, 2004. Report on Coastal Processes at Semiahmoo Spit, Blaine, Washington. Technical report prepared for Trillium Corporation by Westmar Consulting Engineers, North Vancouver, British Columbia, Canada. December 13, 2004.

Appendix A

Site Conditions Photo Log

Appendix B

Planning-level Design Drawings

APPENDIX C

Landscape Plan Drawing and Planting Module

APPENDIX D

Planning Level Unit Costs Calculator using Lineal Feet and Square Feet Dimensions

APPENDIX D

Planning Level Unit Costs Calculator using Lineal Feet and Square Feet Dimensions

Note: This spread sheet is provided to the City of Blaine in Excel format to assist with planning

KEY	CF = Cubic Feet
Materials	SF = Square Feet
Activities	LF = Lineal Feet
Input Cells	CY = Cubic Yard

Item	*Construction Element Description*		*Assumptions*				*Unit Costs*	
1	**Structural Armoring**							
	Riprap (import)	3-ft minus	$11	per Ton	0.06	Tons per CF*	$0.66	per CF
	Riprap Placing/excavating	300 series excavator	$150	per Hour	0.3	Hrs. per 250 CF	$0.18	per CF
	Riprap Total	at	250	CF per LF			**$210.00**	**per LF**
2	**LWD Anchored**							
	LWD	30-ft stick w/ 6-ft rootwad	$1,000	Each (delivered)	0.2	Trees per 100 Ft	$200.00	per LF
	LWD Placing and anchoring (excavator)		$150	per Hour	1	Hrs. per Each	$30.00	per LF
	LWD Total			at	20	trees per 100 Ft	**$230.00**	**per LF**
3	**LWD Unanchored**							
	LWD	30-ft stick w/ 6-ft rootwad	$1,000	Each (delivered)	0.18	trees per LF	$180.00	per LF
	LWD Placing (excavator)		$150	per Hour	0.3	hours per Each	$8.10	per LF
	LWD Total			at	18	Trees per 100 Ft	**$188.10**	**per LF**
4	**Cobble Armoring**							
	Cobbles	4-8" rounded washed	$20	per Ton	0.06	Tons per CF	$1.20	per CF
	Cobble Placing	300 series excavator	$150	per Hour	0.5	Hrs. per 250 CF	$0.30	per CF
	Cobble Armoring Total	at	100	CF per LF			**$150.00**	**per LF**
5	**Nourishment**							
	Material	clean sand to gravel	$16	per Ton	0.06	Tons per CF	$0.96	per CF
	Nourishment Placing	300 series excavator	$150	per Hour	0.3	Hrs. per 250 CF	$0.18	per CF
	Nourishment Total	at	120	CF per LF			**$136.80**	**per LF**

6	**Planting**							
	Plants	per stem (ave)	$1	each (delivered)	75	Plants per 100 SF	$0.75	per SF
	Planting		$30	per Hour	0.06666667	Hrs per Plant (4 min.)	$1.50	per SF
							$2.25	**per SF**
7	**TESC/Site Security**							
	silt fence & visibility fencing, installation and O&M						**$6.00**	**per LF**
8	**Site Stabilization**							
	fabric, topsoil (6"), hydromulch						**$8.00**	**per SF**
	Other Activities & Costs							
9	Grading		$150	per hour	1	hrs per 1000 SF	**$0.15**	**per SF**
10	Rubblizing		$200	per hour	0.75	hrs per 250 CF	**$150.00**	**per CF**
11	Mobilization		**Assumes an individual project of approximately ~$100,000				**15%**	**Each project**
12	Pile Removal/Disposal						**$300.00**	**each**
13	Debris Removal						**$30.00**	**CY**
	Estimates should also include:						**8.4%**	**TAX**
							15%	**Contingency**
						Plans, Specifications, and Estimates	**20%**	**Engineering**

For full designs as shown in Appendix B, each conceptual typical section, as designed, uses the following items as listed above:

Section A uses Items 1, 2, 4, 5, 6, 7, 8, 9, and 11. Items 10, 12, and 13 are optional.
Section B uses Items 1, 4, 5, 6, 7, 8, 9, and 11. Items 10, 12, and 13 are optional.
Section C uses Items 2 and/or 3, 6, 7, 8, 9 and 11. Items 12 and 13 are optional.
Section D uses Items 1, 2, 4, 5, 6, 7, 8, 9, and 11. Item 1 has a multiplier of X because of the increased armoring and Item 2 has increased length because of two rows of LWD

Modifications of the conceptual typical designs are possible measures to manage project costs. To validate costs, we compared these estimates to regionally similar works with similar designs and construction methods (Herrera, 2009).

Appendix E

Noxious Weed Control Plan

Appendix F

Historical Site Photos

Appendix G

Review Comments Summary from Agencies for incorporation into final designs