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Bay-Wide Feasibility Study
Port Gamble Bay
Port Gamble, Washington

Prepared for
Washington State
Department of Ecology

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BAY-WIDE FEASIBILITY STUDY
PORT GAMBLE BAY
PORT GAMBLE, WASHINGTON

1.0 INTRODUCTION

This report presents the results of the sediment remediation feasibility study (FS) performed for the Washington State Department of Ecology (Ecology) at Port Gamble Bay in Port Gamble, Washington (Figure 1). Under the Ecology Toxics Cleanup Program's Puget Sound Initiative, Port Gamble Bay is among seven original sites identified for focused sediment investigation to inform cleanup and restoration decisions, identify potential areas of sediment contamination, and confirm the priority areas for cleanup. The FS follows a remedial investigation (RI) completed for Ecology by Hart Crowser in late 2008 and 2009 to evaluate potential sediment impacts from wood waste associated with historical log rafting, transfer, and milling operations in Port Gamble Bay (Hart Crowser 2010, in preparation). This FS is intended to develop and evaluate cleanup action alternatives to enable cleanup action(s) to be selected for areas of Port Gamble Bay beyond the historical mill area.

RI/FS efforts focused on a former log transfer facility (FLTF) and former Washington State Department of Natural Resources (DNR) lease area (FLA) located along the west side of the bay south of the historical mill area (Figure 1). Based on historical photographs documenting the widespread extent of operations and evidence of more widely distributed wood waste, RI/FS efforts were expanded to a bay-wide study. Investigation results presented in Hart Crowser's 2010 RI and used to develop the current FS are based on field and laboratory work completed for Ecology by Hart Crowser between November 2008 and April 2009.

1.1 Relation to Mill Area RI/FS

Separate RI/FS evaluations of the former mill area were completed as a joint, cooperative effort with Ecology, DNR, and Pope Resources (Anchor QEA 2010a and 2010b). The mill area FS is in preparation. Although the mill area FS issues were addressed separately from this bay-wide FS, each FS document used a common approach to address requirements of the Washington State Model Toxics Control Act (MTCA – Chapter 173-340 WAC), Washington State Sediment Management Standards (SMS – Chapter 173-204 WAC), and other pertinent regulations. For consistency, the bay-wide and mill area FS documents also present common methods for identifying sediment management area (SMA) categories, determining weight-of-evidence impacts from biological and chemical testing, and ranking remedial alternatives based on MTCA criteria.

1.2 Bay-Wide FS Approach

Similar to the mill area FS, the bay-wide FS describes the site setting and conditions (but on a larger scale), summarizes site history, and provides a synopsis of RI results informing the overall FS process. Reference to the bay-wide site is intended to describe the areas separate from the mill area, which is addressed in a separate RI/FS program as noted above. Information from the bay-wide RI supports a conceptual site model (CSM) describing the nature and extent of wood waste material affecting the aquatic environment on a bay-wide basis. The CSM incorporates information regarding the environmental system and the physical, chemical, and biological processes that determine the flux of wood waste and related constituents from sources to receptors. Remedial action objectives are presented including applicable cleanup levels, and SMAs are identified based on a weight-of-evidence scoring system. In accordance with WAC 173-340-350(8), the FS then screens potential remedial technologies and alternatives intended to meet the applicable MTCA threshold and SMS cleanup action requirements. Candidate technologies and remedial alternatives are evaluated based on criteria listed in WAC 173-340-360, and preferred alternatives and associated cost estimates for implementation are presented.

2.0 SITE SETTING AND HISTORICAL ACTIVITIES

2.1 Environmental Setting

Port Gamble Bay is located in Kitsap County and encompasses more than 2 square miles of subtidal and shallow intertidal habitat just south of the Strait of Juan de Fuca (Figure 1). The former lease area (FLA) leased from the Washington Department of Natural Resources (DNR) by Pope & Talbot and used for in-water log storage, and the former log transfer facility (FLTF), where logs were transferred into the bay, are also shown on Figure 1.

There are a number of constructed structures in Port Gamble Bay, including docks, piers, and pilings. Many of these are aging, creosote-treated structures. Abandoned dock structures within the mill area include more than 31,000 square feet of overwater surface. In addition, approximately 21,000 lineal feet of the shoreline is reportedly armored with riprap (NewFields 2007).

The bay and surrounding area support diverse aquatic and upland habitats, as well as resources for fishing, shellfish harvesting, and many other aquatic uses.

The area surrounding the bay remains rural in nature although the northwestern corner of the bay was the site of the former Pope & Talbot sawmill. The Port Gamble S'Klallam Tribal Reservation is located east of the bay, with extensive use of the bay by the Tribe for shellfish harvesting, fishing, and other resources.

2.2 Historical Summary

Pope & Talbot operated the sawmill at the northwest shore of the bay from 1853 to 1995, with log transfer and rafting activities occurring at various locations on the bay. It has been reported that a hog fuel burner was located on the upland area, based on historical photographs. Temporary log storage and transfer within the 72-acre portion of the FLA and FLTF lease area were reported from 1970 to 2001 (Parametrix 2002); however, log rafting activities also occurred much earlier in this area based on review of historical and aerial photographs. The FLTF log sort yard and ramp reportedly operated from 1970 to 1995 and consisted of a dock, pilings, and an access road (Parametrix 2003). Log rafting ceased in 1995 when the sawmill closed. In 1996, Pope & Talbot removed pilings from the lease area. Log rafting and sawmill activities were not conducted at the FLTF and FLA after Pope & Talbot removed the pilings in 1996.

While it was previously thought that environmental impacts to the bay were likely limited to area surrounding the former sawmill and the FLA to the south, other portions of the bay have not been investigated. Based on the historical background and sensitivity of aquatic resources, there is concern that wood waste from historical activities may extend further throughout the bay.

Log rafting operations resulted in accumulations of wood waste on the bed of Port Gamble Bay near the sawmill. In addition, wood accumulations were suspected at both the FLTF and FLA based on the historical use of these areas.

Recent unpublished diver survey and sampling data, by the Port Gamble S'Klallam Tribe, from the main basin of Port Gamble Bay indicate the presence of wood debris distributed beyond the FLA and FLTF areas.

2.3 Previous Investigations

Log rafting operations resulted in accumulations of wood waste on the bed of Port Gamble Bay under the sawmill and wood accumulations are suspected at both the FLTF and FLA. Parametrix, as a consultant to Pope & Talbot, conducted a series of investigations in Port Gamble Bay from 1999 to 2004 to identify chemical and wood waste impacts from the sawmill operations (Parametrix 2003). In 2006, Anchor Environmental prepared a report compiling existing data for sediment in the vicinity of the former mill site and proposed a supplemental sediment investigation (Anchor 2006a). While much of this supplemental investigation has been performed, results have not yet been published. A Biological Evaluation (BE) was also prepared (Anchor 2006b) as part of a cooperative interim sediment cleanup action involving approximately 16,500 cubic yards of subtidal sediment.

Subsequent to the 2008 RI field investigation, the Port Gamble S'Klallam Tribe collected shellfish from Port Gamble Bay for chemical analysis. Samples collected in 2009 were transferred to Hart Crowser for subsequent preparation and laboratory analysis. Results for the 2009 samples are presented in the RI report. Additional samples collected by the tribe in 2010 were submitted directly to the laboratory by the Port Gamble S'Klallam Tribe and results were forwarded to Hart Crowser. Results for the 2010 tissue data are presented in Table G-1 of Appendix G of the RI report.

2.4 Previous Dredging Activities

Historical dredging likely occurred episodically near the mill area to maintain navigational depth and access. More recently, Pope & Talbot dredged approximately 13,500 cubic yards of sediment with abundant wood waste from nearshore areas adjacent to the former sawmill in 2003. The 2003 dredging occurred over an elevation range of about –12 to –15 feet mean lower low water (MLLW) and was conducted to remove accumulated wood waste that reduced navigation access near shore.

An additional Interim Remedial Action dredging was performed in 2007 in the area to the east of the 2003 dredging area. Approximately 16,500 cubic yards of sediment with abundant wood waste were removed from nearshore areas adjacent to the former sawmill. The 2007 dredging occurred over an elevation range of about –10 to –28 feet MLLW and was completed as a cooperative effort under MTCA by Ecology, DNR, Pope & Talbot, and Pope Resources (Hart Crowser 2008b).

3.0 CONCEPTUAL SITE MODEL

The conceptual site model (CSM) for Port Gamble describes the physical and chemical conditions of the bay-wide study area. A CSM is a representation of the environmental system and the physical, chemical, and biological processes that determine the transport of contaminants or other substances of concern from sources to receptors. The initial CSM typically is a set of hypotheses derived from existing site data and knowledge gained from other sites. This initial model can provide a simple understanding of the site based on available data. Essential elements of a CSM generally include information about sources, transport pathways, exposure pathways, and receptors.

3.1 Historical Sources and Transport of Wood Waste

Wood waste was observed in 44 percent of the combined sediment profile imaging (SPI) and plan view images, and in sediment samples obtained. Although widely distributed throughout the bay, the highest accumulations of visual wood waste were along the west side of the bay from south of the former mill through the FLTF and the FLA. In addition, wood waste was found along the shore on the east side of the bay, adjacent to a former rail line along Little Boston Road that transported logs to a log dump area at the edge of the bay.

Wood waste was observed in a wide range of sizes, but most commonly occurred as finely divided particles of millimeter size and smaller. This fine wood waste typically amounted to approximately 5 to 10 percent of the sample volume in sieved surface sediment samples. Coarser chip-like chunks of wood waste were prevalent near the mill, as expected. Scattered small twigs and branches were observed in samples throughout the bay, but in relatively low quantities in comparison to the finely divided particles. In most of the bay, little bark material was noted that could be conclusively identified. Greater amounts of bark material (up to 50 percent visual coverage) were generally observed at the base of the slope around the FLTF and FLA areas where historical log rafting and transfer occurred.

The RI data led to the following conclusions regarding sources and transport mechanisms for wood waste and associated chemicals:

- Historical releases of sawdust, wood chips, and bark were the primary sources of wood waste in sediment near the mill area; these sources were controlled between 1995 and 2004.

- Historical releases of sawdust and wood chips likely migrated from the mill area throughout much of the bay.

- Log-rafting in support of mill operations likely contributed to deposition of wood waste at locations throughout the bay, primarily in the FLTA, FLA, and the area extending from these locations to the east side of the bay where logs were dumped from a rail line and rafted across the bay. Log rafting was extensive in most of the bay as documented by historical photographs. In addition, microscopic examination of sieved surface sediment samples found extensive distribution of fine wood fragments too small to be seen by the naked eye that were likely derived from gribble borings in floating logs.

- Resuspension and loss of dredging residuals from the 2003 and 2007 interim action dredging projects at the Mill Site may have also contributed to releases of fine wood material.

3.2 Distribution of Benthic Organisms

Marine biological organisms, including macroalgae and invertebrates, were identified at most locations, though detailed species richness and abundance were not evaluated. Marine animals, macroalgae, or burrows were identified at 89 percent of the locations, based on reviews of the SPI and plan view images, and sediment core and grab sample observations.

The distribution of benthic organisms generally followed the bottom substrate types and grain size distribution in Port Gamble Bay. Geoducks and other organisms favoring sandy bottom conditions were generally present in shoreline areas and the northern half of the bay. Infaunal deposit-feeding organisms associated with fine-grained, unconsolidated soft bottom classifications were generally observed in the southern end of the bay.

Infaunal transitional organisms, including shallow-dwelling bivalves or tube-dwelling amphipods, were also observed in the middle portion of the bay, where transition from fine-grained, unconsolidated sediments to more consolidated sandy sediment occurs. Infaunal high energy organisms, including tubicolous and surface-dwelling polychaetes, were observed in the northern portion of the bay, where hard, sandy, consolidated sediment with higher bottom current energy are present. Intact eelgrass beds were observed in locations north of the bay entrance and just south of the entrance along the eastern shore. Additionally, sea pens and sea whips were observed in the northern reaches of Port Gamble Bay, where higher bottom currents are present.

3.3 Chemicals of Potential Concern to Benthic Organisms

Phenol was the only detected chemical that exceeded its sediment quality standards (SQS) criterion. Phenol, associated with degradation of wood, was detected in 17 of 40 locations. The highest concentrations were found in the FLA, east of the FLTA, and between the FLTA and the mill site. Locations 8, 22, and 58 had surface sediment concentrations of 720, 610, and 520 ug/kg, respectively. One other chemical associated with wood waste, 4-methylphenol, was detected at only three locations at concentrations below its SQS.

There are a number of creosoted pilings near shore in the FLTA. Due to shallow water depth and difficulty in navigating between pilings, samples were not collected from this area. Therefore, it is unknown if creosote and associated

PAHs are migrating from the pilings into the adjacent sediment at concentrations that may have biological impacts.

While there is no promulgated SMS criterion for wood waste, wood waste is considered a deleterious substance under the sediment management standards (Chapter 173-204 WAC) due to its potential toxicity to marine organisms. Therefore, biological impacts at the site were determined based on interpretations of a suite of confirmatory biological tests performed on surface sediment samples with the potential for deleterious effects collected throughout Port Gamble Bay. Samples submitted for toxicity testing were selected from locations deemed to have a high potential for deleterious effects and were based on evaluation of SPI photographs, presence of visible wood, Microtox screening results, and concentrations of wood waste indicators (TVS, bulk sulfide, and bulk ammonia). The extent of biological impacts is discussed in more detail in Section 5.0.

3.4 Chemicals of Concern for Human Health

The Port Gamble Bay RI initially focused on Ecology Sediment Management Standard (SMS) constituents to determine if there were adverse impacts on bay-wide sediment benthic invertebrates related to former activities at the mill site, the former log transfer facility (FLTA) or the former lease area (FLA). Following discussions with the Port Gamble S'Klallam Tribe, the scope of the RI was expanded to include shellfish tissue analysis to evaluate potential human health risks from shellfish ingestion.

A focused human health risk evaluation was performed to evaluate exposure of tribal members to chemicals in sediment during shellfish gathering and in shellfish using a tribal ingestion of shellfish scenario. Appendix G of the RI report presents the methods and results of the risk evaluation, and calculates risk-based sediment cleanup levels (CULs) for contaminants identified as chemicals of concern (COCs) for shellfish ingestion risks. The sediment CULs are based on MTCA Method B procedures and on parameters for direct contact with sediment that might occur during tribal clamming activities. Concentrations of COCs in sediment and in tissue collected from the site are also compared to available reference data from background locations considered appropriate to Port Gamble Bay.

3.4.1 Sediment Direct Contact Risks

Sediment CULs developed for the tribal clamming scenario were compared with maximum surface sediment concentrations. Maximum concentrations of all surface sediment metal, cPAH, total PCBs as Aroclors, and dioxin/furan TEQs are below the CULs developed for the tribal RME clamming scenario for incidental ingestion and dermal contact.

3.4.2 Shellfish Ingestion Risks

Cadmium and copper are the only COPCs that have non-cancer HQs greater than 1.0 and were carried through for additional evaluation. Inorganic arsenic, dioxin/furans, PCB dioxin-like congeners, and cPAHs are the COPCs with an excess cancer risk above the 1 x 10^{-6} threshold and were carried through for additional evaluation.

3.4.3 Shellfish Comparisons to Background

Concentrations in shellfish tissue from reference locations, which may be considered background values if collected from EPA or Ecology-recognized background locations, were identified for select COCs, where data were available. Reference data were identified for dioxins/furans in crabs, and arsenic in clams and crabs. Although health risks were evaluated for the inorganic form of arsenic in shellfish, the comparison with reference data was evaluated using data on total arsenic. Data are also available in the Ecology EIM database for reference levels of dioxin/furan TEQs in clams, as identified in a DMMP (2009) issue paper; however, all congeners and homolog groups for dioxins/furans were non-detect in clams and oysters from Port Gamble Bay. Therefore, dioxins/furans in clam tissues were not evaluated for reference comparison. PAHs in tissues were not compared with reference tissue levels since background data could not be found.

The dioxin/furan TEQs in crab meat and hepatopancreas from the bay are within background reference levels, although site data are limited to a single composited sample.

Arsenic appears to be below reference values for crab meat and hepatopancreas from background locations, although site data are limited to a single composited sample. Arsenic in clams from Port Gamble Bay is below reference values from background locations in Puget Sound.

3.4.4 Sediment Comparisons to Background

Concentrations of COPCs in Port Gamble Bay surface sediments were compared with representative background concentrations to evaluate cleanup levels for the protection of tribal shellfish ingestion. This approach was based on the assumption that sediment chemical concentrations would represent the source of chemicals detected in shellfish collected from Port Gamble Bay.

Comparison of the sediment levels to background and identifying sediment cleanup levels based on background concentrations would, in turn, be protective of shellfish ingestion from the bay.

Concentrations of dioxin/furan TEQs in sediment of Port Gamble Bay were no different from those in background sediment in Puget Sound. PCB Aroclors detected in Port Gamble Bay sediments and reference areas were too few to allow appropriate comparisons.

For arsenic in sediment, which were all non-detect, the range of detection limits for Port Gamble Bay sediment falls within the range of concentrations in background Puget Sound sediment. Thus, it is uncertain whether arsenic in Port Gamble Bay sediment is within background concentrations.

The range of detected cadmium concentrations in Port Gamble Bay sediment fall within the range of concentrations in background Puget Sound sediment, but the Port Gamble Bay sediment concentrations exceed background. Copper in Port Gamble Bay sediment clearly is below background.

While sediment cPAH concentrations are below MTCA Method B direct contact risk-based concentrations, cPAHs present an excess cancer risk to tribal shellfish ingestion. cPAH concentrations in Port Gamble Bay sediment exceed local background. However, cPAH PQLs for sediment samples collected from Port Gamble Bay were approximately 10 times higher than PQLs for samples collected from background locations. Substitution of one-half the PQL has a significant contribution to bay-wide sediment TEQ calculations and, therefore, there is uncertainty regarding the extent of exceedances (Figure 2). Additional sediment cPAH analysis using lower detection limits is recommended during long-term monitoring.

3.5 Sediment Transport and Deposition

3.5.1 Sediment Characteristics and Transport

The bay-wide distribution of sediment grain size ranged from very soft, clayey Silt in low energy areas to very dense, coarse Sand in high energy areas near the Port Gamble Bay entrance, reflecting the presence of strong tidal currents. In the southern and central portion of the bay, sediments generally consisted of very soft, clayey Silt (85 to 95 percent fines), indicating a low energy depositional environment. Sediments near the shoreline along the edges of the bay consisted of silty Sand to sandy Silt in the shallow subtidal zones and transitioned to slightly silty Sand to fine Sand in the intertidal zones, indicating higher energy due to current activity. There are a number of small creeks and ephemeral streams in the southern half of the bay that may provide seasonal fine sediment inputs.

This grain size distribution may explain why the preferred geoduck habitat lies in the northern portion of the bay. Geoducks are typically associated with habitat types characterized by fine Sand to silty, fine Sand sediments (Dethier 2006; US Fish and Wildlife 1989). Hart Crowser surveys from other marine projects have shown that organism densities tend to decrease rapidly as sediment trends toward clay and silt. Tidal flushing may also contribute to geoduck occurrence, but general experience is that geoduck occurrence is most commonly correlated with substrate type.

3.5.2 Sediment Deposition

Lead-210 dating performed at location 22 in the FLA and at location 51 in the middle of the bay, indicates an overall sediment accumulation rate of 0.21 to 0.28 g/cm2-year. This accumulation rate corresponds to a sedimentation rate of 0.40 to 0.48 cm/year. At this rate, approximately 20 to 25 years would be required to accumulate 10 cm of new sediment. Although, it is unknown how much additional deposition would be required to mitigate the effects of wood waste to eliminate existing bioassay toxicity, apparent biological recovery of mill area sediments between 2002 and 2008 coincided with sedimentation rates of approximately 1 cm/year, corresponding to a total accumulation of about 6 cm (Anchor 2010b). Additional discussion is provided below in Section 6.0.

4.0 CLEANUP REQUIREMENTS

The following sections identify remedial action objectives, preliminary cleanup levels, and potentially applicable regulatory requirements. Remedial action objectives and cleanup levels for the FS were developed to address MTCA and SMS requirements applicable to bay-wide cleanup efforts in Port Gamble Bay. These goals and related regulatory requirements address bay-wide conditions relative to potential impacts to human and ecological receptors, as well as land use, habitat, cultural resources, and other considerations. Project remedial action objectives provide the framework for evaluating remedial alternatives described subsequently in this FS, and for selecting a preferred alternative.

4.1 Remedial Action Objectives

The primary objective for the bay-wide FS and subsequent cleanup actions includes substantially eliminating, reducing, and/or controlling unacceptable risks to human health and the environment posed by chemical constituents of potential concern (COPCs) and deleterious wood waste in the marine environment in accordance with MTCA, SMS, and other applicable regulatory requirements.

4.1.1 Human Health Remedial Action Objectives

Reduction of potential human health exposure risks exceeding MTCA regulatory levels (Hazard Quotient > 1 or 1 x 10^{-6} excess cancer risk) from shellfish ingestion is a primary objective. Potential human health exposure pathways are summarized in Section 3.4. These are based on discussions with Ecology and the Port Gamble S'Klallam Tribe, and completion of the focused risk evaluation presented in Appendix G of the RI report. Where it is possible to develop sediment cleanup levels based on protection of human health, these values are presented. Some additional sediment and colocated tissue analytical data are recommended to more fully evaluate:

- The completeness of the shellfish ingestion pathway relative to benthic biota uptake of sediment contaminants; and
- COC concentrations in sediment relative to local background concentrations with lower analytical detection limits for Port Gamble samples to ensure results are comparable.
- Sediment and colocated tissue sampling should be performed in the intertidal area to determine if sediment chemical concentrations are elevated relative to local background in areas where shellfish are collected.

These uncertainties are discussed in more detail in the Appendix G of the RI report risk evaluation and identified as a data gap for further investigation.

4.1.2 Ecological Remedial Action Objectives

This objective will be achieved by reducing risks to the benthic community that exceed SMS regulatory levels from exposure to wood waste, as indicated by weight-of-evidence data from bioassay testing results and selected chemical indicator parameters.

Related ecological-focused cleanup objectives for bay-wide remediation include:

- Providing suitable substrate for promoting recovery/recruitment of aquatic organisms in remediated areas;

- Preserving and protecting cultural resources potentially affected by remedial actions; and

- Minimizing habitat and water quality impacts during construction.

The above remedial action objectives are presented as target goals to be achieved to the extent feasible and practicable. The point of compliance is represented by the biologically active zone of sediment within the uppermost 10 centimeters (cm) below mudline.

4.2 Cleanup Standards and Cleanup Levels

Cleanup standards are established under MTCA based on cleanup levels that protect human health and the environment, and the points of compliance at which the cleanup levels must be attained (i.e., uppermost 10 cm of sediment). Cleanup standards must also incorporate other regulatory requirements applicable to the cleanup action and/or its location.

For the bay-wide FS, MTCA cleanup levels establish chemical and biological quality criteria determined to be protective of human health and the environment under specified exposure conditions. A cleanup level defines the concentration of hazardous substances above which a contaminated medium (i.e., sediments) must be remediated in some manner. For the bay-wide FS, project cleanup levels are defined based on benthic and human health risks.

4.2.1 Benthic Cleanup Levels

The SMS establishes applicable benthic cleanup criteria including sediment quality standards (SQS) and Minimum Cleanup Levels (MCUL). The SQS serves as the cleanup objective when establishing cleanup standards for a site and defines the level at or below which there is no adverse effect on biological resources and corresponds to no significant health risks to humans. The MCUL is the upper level of minor adverse effects to be considered when establishing site-specific cleanup standards.

Exceedances of SMS chemical standards and biological standards were considered for the bay-wide effort, recognizing that the biological outcome overrides the chemical results. For this reason, sediment cleanup levels were largely based on SMS biological testing criteria for protection of benthic organisms, with further weight-of-evidence considerations as described in Section 5. It should be noted that no dioxin/furan screening criteria for sediments are established in the SMS.

Although wood waste is considered to be a deleterious substance under the SMS, there are no promulgated standards for cleanup. The presence of wood waste was noted in many of the bay-wide RI sediment samples at variable estimated quantities. Wet sieving a subset of the samples helped to further identify finely divided wood debris commonly less than 1 to 2 millimeters in size. The visually estimated percentage of wood waste also correlated poorly with biological testing results and other parameters. Alternatively, concentrations of the wood-related indicator compounds including total volatile solids (TVS) and total sulfide exhibited a greater degree of association with biological test results, and were, therefore, used for the weight-of-evidence analysis to define bay-wide SMAs. This approach was the same as used for the mill area, but greater quantities of wood debris in some of the mill area SMAs resulted in consideration of more aggressive remedial approaches (Anchor FS 2010b).

4.2.2 Human Health Cleanup Levels

The Appendix G of the RI report human health risk evaluation presents methods and calculations to develop risk-based sediment cleanup levels (CULs) for COCs related to shellfish ingestion and direct contact. These risk-based sediment CUL calculations follow standard MTCA Method B procedures, with consideration of available Puget Sound background reference data considered appropriate for comparison. As summarized from the risk evaluation, risk-based CULs were determined using the following procedure:

- Identifying the reasonable maximum exposure (RME) scenario;

- Calculating carcinogenic and noncarcinogenic risks for chemicals detected in shellfish using representative tribal ingestion rates;

- Identifying COPCs based on tribal shellfish ingestion risk estimates;

- Evaluating the sediment direct contact exposure route by comparing sediment concentrations of COCs with sediment cleanup levels calculated for a tribal clamming scenario;

- Comparing Port Gamble Bay sediment concentrations of COCs to Puget Sound sediment background levels, using applicable statistical procedures;

- Using applicable statistical procedures to compare concentrations of COCs in shellfish tissue collected from Port Gamble Bay to reference levels considered representative of tissue background concentrations for Puget Sound; and

- Determining cleanup levels for sediment that are protective of human health for the shellfish ingestion pathway according to procedures described in MTCA and supporting guidance.

Based on this process, CULs were established as the highest of the following for the COPCs of interest:

- Risk-based concentration corresponding to less than an excess cancer risk of 1 x 10^{-6} or a Hazard Quotient of 1;

- Practical Quantitation Limit (PQL); or

- Background.

Concentrations of carcinogenic PAHs were elevated above background concentrations in sediment and were identified as risk drivers for the tribal shellfish ingestion scenario. Concentrations exceeded the calculated 6.0 ug/kg background concentrations by up to about a factor of three (Figure 2). Sample results for other locations had elevated detection limits above background and, therefore, represent data gaps. The shellfish ingestion risk pathway further assumed all shellfish uptake of carcinogenic PAHs was from sediment, which may be overly conservative. Resolution of these uncertainties will require further investigation.

Cadmium and (marginally) copper were also identified as exceeding risk thresholds. There is uncertainty as to whether arsenic concentrations in Port Gamble Bay sediment are within background due to elevated detection limits for arsenic.

As detailed in the RI Appendix G, sediment dioxin/furan TEQs for the 95th percent confidence level on the mean was less than the 90th percentile concentration for local background. Under MTCA, up to 10 percent of sample locations can exceed cleanup criteria as long as no sample exceeds two times the criteria. All but two stations were found to be below background and dioxin TEQ concentrations at these two locations were less than two times the local background sediment concentration. In addition, dioxin/furan TEQs in the single crab sample from the bay was below the background crab tissue concentration; all dioxin/furan congeners were non-detect in all clam and oyster samples from the Bay. Since tissue dioxin levels in Port Gamble were non-detect or below background reference values, dioxin was not considered further as a COC and the development of sediment cleanup levels is not warranted. Despite this, long-term dioxin monitoring should be considered for the two stations, one in the former mill site (#92) and one in the central portion of the bay (#51), where sample concentrations exceeded the local background sediment concentration.

In addition, the sediment direct contact pathway (incidental ingestion and dermal contact) was evaluated based on a tribal clamming exposure scenario and MTCA Method B unrestricted soil cleanup levels. Maximum concentrations of all COPCs were below the CULs developed.

4.3 Potentially Applicable Regulatory Requirements

MTCA and SMS regulatory provisions form the primary basis for evaluating and implementing FS alternatives for bay-wide components of site remediation. Following selection of a preferred alternative from the FS, MTCA requirements guide the process for preparing a cleanup action plan (CAP), engineering design report (EDR), and engineering plans and specifications that address specific MTCA, SMS, and other regulatory requirements. It is anticipated that the cleanup for the bay-wide component will be performed as an Ecology-directed action, or under an administrative agreement with the state. Such cleanup actions are exempt from procedural requirements of certain state and local laws and related permitting requirements, unless Ecology determines that the exemption would result in loss of approval by from a federal agency necessary for the state to administer any federal law.

Applicable exempted state laws include:

- Chapter 70.94 RCW – Washington Clean Air Act;
- Chapter 70.95 RCW – Solid Waste Management – Reduction and Recycling;
- Chapter 70.105 RCW – Hazardous Waste Management;
- Chapter 75.20 RCW – Construction Projects in State Waters;
- Chapter 90.48 RCW – Water Pollution Control; and
- Chapter 90.58 RCW – Shoreline Management Act.

The exemption also applies to local government permits and approvals associated with the remedial action. Although the bay-wide remedial action is expected to be exempt from these procedural requirements, compliance with substantive provisions of these regulatory programs is required. Construction actions associated with cleanup are further subject to requirements of the State Environmental Policy Act (SEPA – Chapter 43.21C RCW).

MTCA does not provide a procedural exemption from federal permitting. Federal permitting for in-water work could likely be conducted under the Nationwide 38 permit program administered by the US Army Corps of Engineers (USACE), or, alternatively, under a Clean Water Act Section 404 permit. Additional permitting requirements pertain under Clean Water Act Section 401 (Water Quality Certification), and the Endangered Species Act (agency consultation). In addition, the Port Gamble Bay region is known to be archaeologically sensitive, and USACE involvement in Clean Water Act permitting triggers provisions of Section 106 of the National Historic Preservation Act of 1966, and the Archeological and Historical Preservation Act (16 USCA 469). Ecology will coordinate with state and local agencies regarding substantive compliance issues, and USACE and other federal agencies for federal permitting issues. Ecology will also work closely with the Port Gamble S'Klallam Tribe and the Washington State Department of Archaeology and Historic Preservation (DAHP) on cultural resource and archaeological matters.

Further coordination or combining of permitting/substantive compliance efforts for the bay-wide and mill area remedial actions may also possible. The benefits and feasibility of coordinated permitting for the mill and bay-wide cleanups require further evaluation based on the actions to be selected, scheduling considerations, and other factors. Potential joint permit coordination for the bay-wide and mill area cleanup actions will be further evaluated during CAP preparation and subsequent design and construction planning.

4.3.1 Regulatory Requirements Summary

The following sections summarize further information on regulatory and substantive compliance requirements that are potentially applicable to bay-wide remediation activities.

Solid and Hazardous Waste Management – Chapter 70.105 RCW and Chapter 173-303; and Related Federal Resource Conservation and Recovery Act – 42 USC 6921-6949a and 40 CFR Part 268, Subtitle D

Triggering Activity: Potential for generating, handling, and disposing of dredged material containing designated Hazardous Wastes.

Based on a substantial amount of physical and chemical characterization data from the bay-wide and mill area RIs and older mill area reports, there is no indication that materials potentially designatable as Hazardous Wastes are present. In the unlikely event that such materials are encountered during the remedial actions, they will be handled accordingly.

Water Quality Standards for Surface Waters of the State of Washington – Chapter 90.48 RCW and Chapter 173-201A WAC

Triggering Activity: Potential for construction activities for the bay-wide remedial action to adversely affect surface waters of the State.

Potential water quality concerns are associated with in-water construction activities involving dredging and capping. These activities are subject to applicable water quality criteria established under state and related federal Clean Water Act laws and regulations to minimize or eliminate potential water quality degradation. Water quality issues would be addressed through standard in-water work windows, controls on construction means and methods, best management practices (BMPs), and monitoring. Applicable water quality standards, in-water work restrictions, and BMPs will be addressed based on substantive compliance with typical Section 401 Water Quality Certification requirements.

Clean Water Act Sections 303, 311, 312, 401, and 404 – 33 US Code (USC) 1252 et seq.

Triggering Activity: Placement of sediment capping materials within navigable waters of the United States, and protection of surface water quality.

Placement of in-water capping materials or potential dredging is expected to be addressed through the USACE Nationwide 38 permit program or a Section 404 permit, as described above. Water quality protection issues will be addressed via identification of water quality standards, in-water work restrictions, BMPs, and monitoring addressing substantive compliance with Section 401 and state regulatory requirements.

Puget Sound Dredged Material Management Program – DMMP

Triggering Activity: Potential open water disposal of dredged materials at a designated Puget Sound location.

The DMMP is a cooperative program administered by the USACE in coordination with EPA, DNR, and Ecology. DMMP requirements and corresponding sampling characterization testing protocols under the Puget Sound Dredge Disposal Analysis (PSDDA) program would apply if dredging and open water disposal of dredged materials became needed for bay-wide remediation. Additional characterization data of the potential dredged materials would be required to meet PSDDA requirements; however, the expected nature of the potential dredged material (including wood debris) would likely be acceptable for open water disposal. Acceptance of the material for disposal is subject to a suitability determination by the PSDDA agencies.

SEPA – Chapter 43.21C RCW, Chapter 197-11 WAC, and Chapter WAC 173-802

Triggering Activity: Permit application or proposed regulatory cleanup action under MTCA or SMS.

Provisions of WAC 197-11-250 provide for integration of the MTCA and State Environmental Policy Act (SEPA) procedural requirements to reduce duplication and improve public participation, including common public review and comment. Key components for addressing SEPA requirements include submittal of a SEPA checklist, threshold determination for whether potential environmental impacts are deemed as significant, and identification of potential mitigation measures if necessary. A determination would also be made as to the need for an Environmental Impact Statement to more comprehensively evaluate potential impacts.

Shoreline Management Act – Chapter 90-58 RCW and Chapter 173-27 WAC)

Triggering Activity: Construction work within the shorelines zone.

Ecology will conduct a review of planned bay-wide cleanup actions for consistency and substantive compliance with applicable local shorelines programs/master plans. Substantive requirements apply to in-water work and related upland work, if any, within 200 feet of the shoreline.

Coastal Zone Management Act – 16 USC 1455

Triggering Activity: Construction activities requiring federal approval must be consistent with the State's Coastal Zone Management Program.

Coastal zone management issues will be addressed through review and substantive compliance with the local shorelines management program.

Washington Hydraulics Code – Chapter 70-95 RCW and Chapter 173-304 WAC

Triggering Activity. Use, diversion, obstruction, or change in the natural flow or bed of Port Gamble Bay from in-water work for the bay-wide remedial action.

Ecology will conduct a review of planned bay-wide cleanup actions for consistency and substantive compliance with applicable conditions typically associated with Hydraulic Project Approval (HPA) permits issued for in-water construction projects. HPA permit conditions address activities that could create adverse conditions for fish and aquatic resources. It is anticipated that substantive requirement conditions will identify acceptable in-water work windows and minimum required construction best management practices (BMPs) to minimize potential impacts.

Rivers and Harbors Act – 33 USC 403 and CFR Parts 320 and 322

Triggering Activity: Alteration of waters of Port Gamble Bay as a navigable waterway.

Remediation activities could result in expected minor changes to the bathymetry of Port Gamble Bay. Bathymetric changes associated with such activities are subject to review by Ecology in coordination with the USACE and other agencies during the FS and design approval process. It is unlikely that the expected minor bathymetric changes would have a substantial impact on navigation, given the current and expected future vessel use in Port Gamble Bay.

Endangered Species Act – 16 USC 1531 et seq.

Triggering Condition: Presence or suspected presence of threatened or endangered species near the project site at the time of anticipated work.

Triggering conditions associated with certain cleanup actions may require federal consultation and a biological assessment.

National Historic Preservation Act of 1966 Section 106 – 16 USC 470 and 36 CFR Part 800

Triggering Activity: SEPA regulatory compliance; and federal permitting, assistance, and related involvement for the bay-wide remediation component.

Section 106 requirements include determining an Area of Potential Effects where, if present, historic properties could be affected. Potential project impacts would be determined in consultation with the State Historic Preservation Officer (SHPO) at the DAHP, the Port Gamble S'Klallam Tribe, and other interested parties. Based on the historic and archaeological sensitivity of Port Gamble Bay, an Archaeological Monitoring Plan and Unanticipated Discovery Plan will be prepared for implementation during the remediation construction phase.

Indian Graves and Records –RCW Chapter 27.44 and Archaeological Sites and Resources – RCW Chapter 27.53

Triggering Activity: Construction project involving state funding.

Although remediation is subject to Section 106 requirements, Ecology will review project activities with the DAHP and the Port Gamble S'Klallam Tribe, in accordance with Governor's Executive Order 0505. The purpose of the review is to determine potential impacts to cultural resources.

Archeological and Historical Preservation Act – 16 USCA 469

Trigger Activity: Discovery of archaeological or historical materials during remediation activities.

Discovery of archaeological or historical materials requires notifications and actions similar to the above-listed federal and state-level archaeological regulations.

5.0 DELINEATION AND DESCRIPTION OF SEDIMENT MANAGEMENT AREAS

Section 4.0 summarized cleanup requirements for Port Gamble Bay sediment as determined by two primary factors:

- Benthic ecological impacts based on a suite of biological tests performed on surface sediment samples with potential for deleterious effects related to wood waste; and

- Results of the focused human health risk assessment performed to evaluate potential exposure risks from COPCs based on tribal shellfish ingestion and direct contact pathways.

Sediment cleanup levels were identified for the benthic ecological component using SMS criteria for biological testing results. Biological testing and other lines of evidence were further evaluated to develop suitable ecological SMAs for Port Gamble Bay, as described in this section. While there is no promulgated SMS criterion for wood waste, because of its potential toxicity to marine organisms, wood waste is considered a deleterious substance under the sediment management standards (Chapter 173-204 WAC). Samples submitted for toxicity testing were selected from locations deemed to have a high potential for deleterious effects and were based on evaluation of SPI photographs, presence of visible wood, Microtox screening results, and concentrations of wood waste indicators (TVS, bulk sulfide, and bulk ammonia).

To address the human health risk component, cleanup levels were developed for COCs presented in Appendix G of the RI report risk evaluation. However, human health risk conclusions could not be made for a few COCs due to elevated detection limits that limited comparisons between Port Gamble Bay and reference area background.

Bay-wide SMAs described in this section were first developed to address exceedances of the benthic ecological criteria. Then an overlay of areas that exceeded human health risk levels was used to come up with the final SMAs. These may be further refined when addressing a few COCs that were problematic due to detection limits.. The sample design for future bay-wide monitoring will assess data gaps related to potential human health risks as a key objective. Sample design will consider colocated sediment and tissue samples to help address the ingestion pathway question, especially in the intertidal areas targeted for shellfish harvest. Monitoring will also incorporate suitable analytical detection limits to allow adequate comparison to background. Bay-wide monitoring objectives and parameters will be further described in Cleanup Action Plan and Engineering Design Report documents to be prepared following this FS.

5.1 SMS Toxicity Testing Interpretation

Bioassay test interpretations under SMS consist of endpoint comparisons of test sediments to the measurements observed in reference sediments, including statistical comparisons between the test and reference endpoints. As discussed in the RI report (Hart Crowser 2009), the bioassay tests revealed that surface sediments collected from 24 of 51 locations tested throughout the bay exhibited varying degrees of toxicity in laboratory exposures to SMS test organisms (Figure 3). The highest toxicity was observed in samples collected from the northern portion of the FLA, southern portion of the FLTA, and the center of the bay east of the FLA and FLTA.

The delineation of sediment areas requiring remedial action under SMS and/or MTCA was initially based on point-by-point interpretations of bioassay data collected at the site during the RI. The point-by-point interpretations were based on comparisons of test results with matched reference samples meeting acceptance criteria that were collected during the same sampling event, as summarized in the RI report (Hart Crowser 2009). The reference sample associated with three of the larval tests did not meet performance criteria; however, an alternative reference sample, which met performance criteria and had acceptable grain size, was used for two of these larval tests. The third larval test was compared to test control results. The reference sample associated with five of the *Neanthes* growth tests did not meet performance criteria and results for these samples were compared to test controls. Summary interpretations of the point-by-point SMS bioassay data for the Microtox, amphipod, PSEP larval, and *Neanthes* bioassay tests are presented on Figure 3.

To apply a spatial component to sediment toxicity data, Thiessen polygons were drawn around each station exhibiting two-hit SQS and CSL failures. The use of Thiessen polygons is a spatial interpolation method by which a polygon is drawn around every data point. The boundaries of each polygon are drawn at the midpoint between the data point of interest and each surrounding data point thus, a spatial extent is assigned to empirical data at a given location. It should be noted that only Microtox testing was performed at a number of locations and Microtox results by themselves cannot be used to define a CSL failure. The Thiessen polygon spatial interpretation is presented on Figure 4.

5.2 Reference Envelope Toxicity Testing Interpretation

In addition to the conventional interpretation of the bioassay data provided under the SMS regulatory framework, an alternative interpretation was also included as part of the total weight-of-evidence approach. Significant variability has been observed in bioassay performance reference samples collected from both Carr Inlet and Sequim Bay. This variability can have a pronounced effect on overall bioassay interpretations, particularly for the Puget Sound Estuary Program (PSEP) larval test. This can be seen by comparing the range of normal survivorship of the Carr Inlet reference samples associated with the bay-wide bioassay data (Figure 5). Therefore, a reference envelope approach similar to that used on the Willamette River FS was employed as an additional line of evidence. This approach provides an additional assessment of biological effects, explicitly incorporating reference sample variability into the interpretations. The reference envelope interpretation was performed according to the following interpretation criteria:

- Bioassay test results were first compared to the lower 10th percentile of the range of reference sample results. If the test result was less than the lower 10th percentile of the reference, the test result was considered a bioassay hit or failure. For example, if the test sediment larval normal survivorship was less than the lower 10th percentile of reference samples (53 percent), the test result was considered a hit and additional evaluation was performed to determine if it was an SQS or CSL failure.

- Test sediment results were then compared to the average reference sample value, using SMS evaluation criteria to determine if the test result was an SQS or a CSL failure. For example, if the difference between the average reference (74 percent) and the test sediment larval normal survivorship was greater than 30 percent, results indicated a CSL failure. If the difference was between 15 and 30 percent, an SQS failure was indicated.

5.3 Wood Indicator Chemical Evaluation

While the bioassay data themselves were used as the primary basis to delineate potential SMAs for Port Gamble Bay, wood waste indicator parameters including surface sediment bulk sulfide and TVS concentrations were found to have a slight correlation ($P<0.01$; $r^2 \sim 0.2$) with toxicity test results and were also used in the overall weight-of-evidence delineation of bay-wide SMAs. Based on these correlations, the SQS and CSL concentrations for sulfide were 700 mg/kg and 1200 mg/kg, respectively. SQS and CSL concentrations for TVS were 12 percent and 21 percent, respectively.

5.4 Combined Weight-of-Evidence Approach

For the purpose of this FS, the following overall weight-of-evidence approach was used to delineate SMAs for Port Gamble Bay, resulting in a total of ten lines of evidence as follows:

- SMS point-by-point bioassay interpretations (four lines, one for each SMS bioassay; this was also the primary line of evidence used to determine SMA boundaries):

    1. Amphipod survival (no SQS effects noted in the Port Gamble Bay samples)

    2. PSEP normal larval survivorship (10 CSL and 9 SQS effects noted)

    3. *Neanthes* growth (5 SQS effects noted)

    4. Microtox luminescence (6 SQS effects noted)

- Average reference envelope interpretation (four lines, one for each SMS bioassay):

    5. Amphipod survival (no SQS effects noted)

    6. PSEP normal larval survivorship (5 CSL and 4 SQS effects noted)

7. *Neanthes* growth (No CSL or SQS effects noted)

8. Microtox luminescence (7 SQS effects noted)

Indicator parameter distributions (two lines)

9. Surface sediment bulk sulfide concentration (5 SQS effects noted)

10. Surface sediment TVS concentration (1 SQS effect noted)

Lines of evidence for items 1 through 8 received the following weighting relative to applicable SMS cleanup criteria:

- Less than SQS = 0
- Between SQS and CSL = 1
- Greater than CSL = 2

No SMS criteria are established for sulfide or TVS. Instead, weighting factors for these lines of evidence were based on the percentage of TVS present (less than 12 percent = 0, 12 percent to 21 percent = 1, and greater than 21 percent = 2), and concentration of sulfides present (less than 700 parts per million (ppm) = 0, 700 to 1,200 ppm = 1, and greater than 1,200 ppm = 2).

Using the data layers summarized above, a total score was calculated to determine the cumulative weight-of-evidence of adverse biological effects at the site. Sulfide and TVS were included as important indicator parameters, but the weighting is influenced most prominently by the SMS biological criteria. A summary of the overall weight-of-evidence scores at the site is presented in Table 1. The spatial distribution of the weight-of-evidence scores is shown on Figure 6.

5.5 Bay-Wide SMA Designations

SMA designations for affected areas of Port Gamble Bay were determined using a general hierarchical approach based on observed wood waste conditions at each sampling location, along with results of the weight-of-evidence assessment of biological indicators, sulfide, and TVS. Surface and near-surface sediment sampling locations commonly contained visible but often finely divided wood debris with sparse to more conspicuous abundance. Accumulation of bark or other wood debris in greater quantities was less common and appeared to have limited lateral continuity. For this reason, no areas of dense wood chip, sawdust, or bark accumulation were noted during the bay-wide investigation, as are present closer to the Port Gamble mill area. In comparison to the mill, field observations and wet sieving of sediment samples during the bay-wide field work revealed the presence of wood waste in very low to locally moderate quantities.

Cumulative weight-of-evidence scoring results for bay-wide sediment samples presented in Table 1 range from 0 to 5, with 0 being the most common score. For stations with data for all 10 lines of evidence, about half had scores of 0 to 1, one-third had scores of 3 and 4, and less than one-third had scores of 4 and 5. Stations with cumulative scores of 4 and 5 are considered to exhibit moderate weight-of-evidence effects, with lower-scoring stations considered to exhibit mixed or low weight-of-evidence effects. For comparative purposes only, many of the mill site stations had higher concentrations of wood waste and moderate to strong weight-of-evidence scores above 5.

Considering the general presence of wood waste, cumulative scoring, and SQS versus CSL exceedances, two general SMA areas, A and B, were designated for Port Gamble Bay (Figure 7). These areas are located in the west-central portion of Port Gamble Bay. SMA-A comprises approximately 140 acres to the north, east, and south of SMA-B. SMA-A is characterized by relatively low weight-of-evidence scores in the 2 to 3 range, i.e., exhibiting mixed to low weight-of-evidence effects. SMA-B comprises approximately 80 acres and includes stations with weight-of-evidence scores of 4 and 5, i.e., exhibiting moderate weight-of-evidence effects. Stations in other portions of the bay had scores of 0 and 1, with Station 69 scoring a 2 based (only) on an SMS Microtox failure. No SMA designations were assigned to these lower-scoring areas, given the apparent low impacts, or lack of conclusive evidence of impacts.

Although designation of SMAs is based on qualitative observations and weight-of-evidence data, this approach provides a consistent methodology for evaluating apparent impacts on sediment on a relative basis. Inherent to this approach are uncertainties associated with causal effects of biological testing failures and spatial data gaps. However, the SMA designation approach used for the bay-wide FS facilitates consistent screening of appropriate remedial technologies and selection of suitable alternatives for cleanup.

The designated SMAs also capture most locations where sediment concentrations for chemicals of concern (based on shellfish ingestion) exceed local background sediment concentrations. Figure 8 presents locations where sediment concentrations of cadmium and cPAH TEQs exceed local background.

6.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

Candidate remedial technologies were identified and screened to develop potential cleanup alternatives for further evaluation in the bay-wide feasibility study. This section presents results of the technology screening assessment, including No Action as a baseline or null comparison case. The remedial technologies considered included methodologies capable of achieving the remedial action objectives, including preliminary MTCA/SMS cleanup levels and other regulatory requirements.

Candidate technologies applicable to wood waste sites are identified in many sources, including the EPA's Assessment and Remediation of Contaminated Sediments Guidance Document (ARCS, EPA 1994), and Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (EPA 2005). Screening of technologies included consideration of available methodologies to address wood waste contaminants based on their expected feasibility, effectiveness, and relative cost. Screening was consistent with MTCA evaluation criteria described further below for the remedial alternatives evaluation. Screening also considered modifying criteria associated with avoiding impacts to potential historic and archaeological resources, habitat resources, and future aquatic land use.

The general technologies considered in addition to No Action included:

- Institutional Controls;
- Natural Recovery;
- Engineering Capping/Containment;
- Dredging/Removal; and
- Other Technologies.

Screening technologies are summarized in Table 2 along with the rationale for retaining or discarding for further alternatives evaluation.

6.1 No Action

Included as a baseline or null case for comparison, No Action does not achieve remedial action objectives, including protection of the environment. No Action does not address MTCA evaluation criteria or mitigate adverse wood waste impacts. The No Action case is, therefore, eliminated from further consideration.

6.2 Institutional Controls

Institutional controls (IC) represent non-engineering measures designed to prevent or limit exposure to hazardous substances left in place at a site, and/or assure the integrity, effectiveness, and long-term performance of the chosen remedy. Institutional controls are particularly effective if contaminants are not completely removed, as would be the case for the all candidate remedial technologies considered for the bay-wide FS, except dredging.

In this context, ICs can be evaluated based on four general categories previously identified by EPA (2004):

- Governmental Controls (e.g., zoning, local ordinances, and other governmental requirements restricting site uses). Controls using the regulatory authority of a governmental entity to impose restrictions on citizens or property under its jurisdiction.

- Proprietary Controls (e.g., easements, restrictive covenants). Proprietary controls are based on property law to restrict land use to maintain the protectiveness of the remedies. Proprietary controls prohibit activities that may compromise the effectiveness of a remedy (i.e., disturbing capped areas), or restrict future uses of resources that can result in risks to human health or the environment. Proprietary institutional controls are typically binding on subsequent purchasers of the property and run with the land.

- Enforcement and Permit Tools. Enforcement tools as an institutional control mechanism include administrative agreements such as Agreed Orders and Consent Decrees used to compel a party to engage in various site assessment and remediation activities, or to limit site activities that could impact the protectiveness of a remedy. Enforcement tools may include requirements to monitor and report on institutional control effectiveness at regular intervals (Information Tool), or require a party to establish a covenant (Proprietary Control) or post deed notices on a property (Information Tool), as necessary. Enforcement tools may have limited effectiveness if not coupled with Proprietary or Informational institutional controls.

- Informational Tools include notices filed in the land records, advisories, and listings on state and federal site registers. Informational Tools are common institutional controls providing information on the performance of a remedy, or notification that contamination remains on a site.

Applicable institutional controls for the Port Gamble bay-wide site in the Information Tools category may include placing notices of the remedial actions on state aquatic property records, or notices for future state leases, if applicable. Similar institutional controls include continued identification of the site on the Ecology hazardous site registry, and documenting completion of remedial actions for regulatory agency filing or permit purposes. Should site remediation or other actions be included as part of future Ecology administrative agreements, such actions would constitute institutional controls under the Enforcement or Permit Tools category. Permit review procedures, and related conditions and requirements for the remedial action are also included in this category. The need for restrictive environmental covenants as potential Proprietary Controls would need to be evaluated based on land use and the parties involved. Related institutional controls may also include planning documentation and reporting associated with long-term monitoring of the affected SMAs.

Similar institutional controls have been effectively applied to many other sediment cleanup projects at both the state and federal levels in Puget Sound and elsewhere. For the Port Gamble site, institutional controls are intrinsically coupled with other remedial actions and provide effective, feasible, and cost-beneficial measures to protect and maintain implemented alternative(s). Institutional controls are, therefore, retained for inclusion with the selected alternative(s).

6.3 Natural Recovery

Natural recovery of contaminated sediments can occur through sedimentation and mixing as physical processes, or through biological and chemical degradation. Chemical and biological processes are well documented at many sites for attenuation of various chemical constituents and commonly occur together with physical processes. For both the mill area and other areas of Port Gamble Bay, sedimentation is the most likely agent for potential natural recovery of wood waste-impacted areas.

As discussed above, lead radioisotope dating conducted at two locations for the bay-wide RI indicated sediment accumulation rates of up to 0.48 cm/year in Port Gamble Bay, or roughly 20 to 25 years to accumulate 10 cm of new sediment as a comparative index. In the mill area, radioisotope data reported in the Anchor FS indicated a sedimentation rate of about 1 cm/yr, or roughly 10 years to accumulate 10 cm (Anchor 2010b). Although it is unknown how much natural sediment deposition would be required to mitigate adverse effects of wood waste on bioassay toxicity, Anchor reported notable improvements in sediment quality in the mill area between 2002 and 2008 (Anchor 2010b). These sediment quality improvements were based on increased average amphipod survival rate from 35 to 86 percent over this time period. This approached the average reference area survival of 92 percent. Further, Puget Sound Estuary

Program (PSEP) normal larval survivorship in the mill area increased from 45 to 68 percent, comparable to the average reference area survivorship of 74 percent. Anchor further reported an approximate twofold reduction in surface sediment TVS in the southern mill embayment over the same time period.

6.3.1 Monitored Natural Recovery (MNR)

The above lines of evidence suggest that sedimentation and/or natural processes may be reducing biological toxicity from wood waste in the mill area over time. By extension, such processes may be promoting natural recovery in other areas of Port Gamble Bay as well. Improvements in mill area sediment quality between 2002 and 2008 correspond to an estimated 6 cm of accumulated sediment, based on the calculated 1 cm/yr accumulation rate from the Anchor data. Accumulations of 6 cm of sediment (or less) may, therefore, be sufficient to attenuate adverse biological effects. For the bay-wide case this could equate to a projected recovery time period on the order 12 years from the present, given that the sedimentation rate at the two bay-wide radioisotope study locations is roughly half of the rate in the mill area.

Additional lines of evidence support the overall viability of the MNR approach to remediation. The generally quiescent environment of Port Gamble Bay provides a stable environment for sedimentation and coverage of wood waste-affected areas. Sediment cores obtained during the bay-wide RI field investigation, including cores used for lead-isotope dating, typically show a continuous sediment profile with little indication of significant scour or evidence of obvious erosion in the uppermost profile representative of about the last 150 years. This provides a stable environment for continued sedimentation to diminish toxic effects from wood waste as a permanent solution. MNR has the further benefit of negligible disruptions to existing habitat features, biota, and possible cultural resources. On a bathymetric scale, changes to the seafloor from accumulated sediment are also minimal and occur over a relatively long time period as a natural process.

Long-term monitoring is an essential component of MNR to assess sedimentation rates and reductions in biological toxicity over time. Inclusion of the long-term monitoring component, coupled with the institutional controls noted above are key factors distinguishing MNR from No Action. Successful performance of MNR has been demonstrated at many other Puget Sound sediment cleanup sites, some of which have been monitored for more than 10 to 15 years. Costs for monitoring and documenting MNR process and performance in conjunction with institutional controls are favorable in comparison to other more intensive or invasive remedial approaches.

For the reasons outlined above, MNR is retained as an effective, feasible, and cost-effective technology for further evaluation as an FS alternative.

6.3.2 Enhanced Natural Recovery (ENR)

ENR or thin-layer capping (TLC) is often used at sediment remediation sites to augment natural physical, biological, and chemical processes promoting recovery. Placement of a nominal 3- to 12-inch layer of suitable sandy substrate is typically used to enhance natural sedimentation and other processes that are also occurring. Although TLC is not explicitly intended to isolate and stabilize underlying contaminated sediments, layers of only 5 to 15 cm will generally suffice to isolate the bulk of contaminants from the benthic macroinvertebrates that inhabit surface sediments (National Research Counsel 2003). This also shortens the time frame for restoration. As for MNR, ENR intrinsically includes long-term performance monitoring and application of appropriate institutional controls.

The effectiveness and feasibility of ENR using various application strategies has been demonstrated at numerous cleanup sites in Puget Sound and elsewhere. For the SMAs identified in this bay-wide FS, ENR represents a permanent, protective remediation method and is more cost-effective than engineered capping/containment and dredging/removal. ENR is also advantageous because it minimizes impacts to habitat/biota, potential cultural resources, and aquatic land use. While these effects may be slightly greater than MNR, environmental disruption is significantly less than for capping/containment and dredging/removal technologies. ENR is retained as an effective, feasible, and cost-effective technology for further evaluation as an FS alternative.

Considerations for ENR

Application of ENR technologies must consider several key factors including:

- Type and extent of contamination present;
- Nature of the mudline substrate (i.e., hard versus soft);
- Bottom slope angle;
- Biota present;
- Water depth and current conditions;
- Type and source of TLC material placed; and

- Placement methods and potential water quality impacts.

The overall objective of TLC placement would be to apply a layer of sandy capping material to reduce the influence and adverse effects of finely divided wood waste material in the upper 10 cm of the sediment profile. Affected sediments within the baywide SMAs are present on nearly level or very low-angle seafloor slopes at elevations varying from less than –10 feet to greater than –60 feet (Figure 7). Much of the SMA seafloor area lies between elevations –30 and –60 feet and would not pose significant challenges for TLC application.

Placement Over Soft Sediments and Ketchikan Pulp Company Site Example

Although much of the existing seafloor sediment within the bay-wide SMAs consists of soft, fine-grained material, experience at a number of sites with soft sediment has demonstrated that sandy capping material can by placed over soft sediment in a coherent layer without subsidence, sinking, or chaotic intermixing of capping materials. A pertinent example is placement of 6 to 12 inches of sandy TLC material over an approximate 27- to 28-acre area of the Ketchikan Pulp Company (KPC) site in Ketchikan, Alaska, in 2001 (Integral Consulting, Inc. 2009, and Becker and Others 2009). KPC is an EPA Superfund site with several remedial actions including TLC to enhance recovery of sediment with wood waste contaminants.

Related findings of TLC placement at the KPF Superfund site are as follows:

- TLC material was successfully placed on bottom slopes of varying angles and to elevations of about -100 feet.

- TLC material successfully bridged over very soft sediments in some places described as "black mayonnaise."

- Thin-layer placement was determined to be more effective than mounding capping materials on the bottom for current winnowing and smoothing.

- Post-construction monitoring demonstrated that environmental conditions improved substantially and most conditions showed continual improvement between monitoring events.

- TLC areas were successful in eliminating sediment toxicity and stimulating colonization of benthic macroinvertebrates, such that diverse communities comprising multiple taxa now inhabit most parts of the capped areas, and exhibit enhanced characteristics beyond those of the reference areas.

- EPA concluded in 2009 that multiple lines of evidence used to evaluate sediment quality indicated that project remedial action objectives had been achieved. Lines of evidence included quantitative and qualitative evaluations of temporal and spatial trends in biological toxicity response and benthic macroinvertebrate community characteristics, and supporting sediment chemistry.

Based on the above findings, the KPC site example provides valuable insight for potential application of ENR to the Port Gamble Bay SMAs.

Placement Methods

A variety of methods exist for placement of TLC material. From generally least technically complex to more complex these include:

- Washing or blowing capping material from a vessel deck;
- Overwater pneumatic placement through a flexible line with entrained air;
- Overwater placement using a clamshell or other bucket type swung from a crane-suspended cable;
- Overwater or underwater placement through a screen "sifter" or other device;
- Underwater placement using a tremie pipe, spreader, or diffuser system; or
- Underwater placement of a pre-slurried capping mixture using a tremie system or other methods.

Sandy cover material placed following an interim dredging action in the mill area of Port Gamble Bay in 2006 utilized the clamshell bucket and crane method (Hart Crowser 2008). The clamshell bucket was swung in regular arcs over the placement area, as controlled by the crane operator and recorded on an electronic log of the bucket arc swing areas. Good placement control was achieved for establishing a 6- to 12-inch cover thickness with limited water column turbidity impacts. Material was placed in two passes over an area of about 1.2 acres at rates typically in excess of 100 cubic yards per hour (cy/hr). Bottom elevations were in the range of -15 to -20 feet. A similar bucket and cable-arm crane placement method was used for the KPC project with good control and placement rates in excess of 100 cy/hr and 1,000 cy/day. Experience at the KPC site demonstrates that the bucket and crane method can be scaled up to cap larger areas with good consistency and economy.

Other placement methods may be feasible, but except for overwater pneumatic placement through an air line, such methods are not expected to provide comparable or greater value for additional cost. Washing or blowing TLC material from a vessel deck may be a lower cost option, but can be difficult to control and creates significant water column turbidity issues. Underwater methods involving tremie placement or similar systems are used at other sites to provide greater control or for other specific applications, but such methods are not expected to be needed or provide additional value. Underwater placement costs are also generally higher than the bucket and crane method. These technology options are, therefore, not retained for further evaluation.

Pneumatic placement of TLC material through an air line was successfully used for EPA Superfund remediation capping of an intertidal area of the Middle Waterway in Tacoma in 2005 (Hart Crowser 2005). Placement rates of about 50 cy/hr and up to about 200 cy per daily tidal work shift were achieved. Placement equipment was staged on temporary platforms on the tideflat with a land-based supply line and capping source material. The pneumatic placement option may be a viable consideration for the Port Gamble Bay SMAs but would require further pre-construction testing to demonstrate its scale-up feasibility and the cost-effectiveness of overwater placement from a vessel platform.

6.4 Engineered Capping/Containment

Permanent or long-term capping and containment of contaminated sediments is a common and proven remediation method at many aquatic cleanup sites. Engineered caps in excess of about 1 foot thickness are often placed when physical, chemical, and biological isolation are needed to mitigate potential toxic effects of the underlying sediments. Engineered caps are typically designed for several purposes:

- Provide a robust physical barrier to prevent contact with underlying contaminated sediments;
- Provide a chemical isolation barrier to attenuate concentrations of potentially mobile chemical constituents;
- Provide a biological barrier for burrowing benthic organisms; and
- Provide a surface armoring layer to prevent erosion of the cap by currents, wave action, and propeller wash.

Although engineered capping for containment of wood waste in the bay-wide SMAs involves feasible and effective technologies, capping would be expected to result in additional detrimental impacts to the environment. A major consideration is the loss of habitat associated with thick cap placement that would not occur with MNR or ENR, or at least not occur to the same degree. Habitat loss would have significant adverse impacts to the Port Gamble Bay ecosystem and likely require difficult and costly compensatory mitigation. Placement of thick caps can also create bathymetric changes affecting navigation and requiring additional institutional controls to protect the cap from anchor and vessel damage or address decreased draft clearance. Engineered capping and containment are also higher cost options than MNR and ENR that do not provide commensurate value for the additional cost. Despite these considerations, engineered capping/containment is retained from the screening process based on its overall effectiveness.

6.4.1 Considerations for Thick Capping

Like ENR thin-capping, the design, placement, and maintenance/monitoring of thicker caps depends on factors associated with the nature of the contamination, substrate bottom and aquatic conditions, biological considerations, material type, and construction methods. The capping thickness and materials used are determined by the type of contamination present and mobility, the need for armoring or physical protection from erosion or other disruption, and habitat requirements. Thick caps are often composed of a habitat-friendly mixture of sand with minor gravel and finer-grained materials. Capping remedies are frequently coupled with institutional controls to protect the cap structure by warning of its presence.

Key to placement of thicker cap sections is the ability for capping materials to successfully bridge the contaminated layer or otherwise form a protective barrier. Sites with soft bottom conditions typical of wood waste deposition often pose challenges for placing a continuous, intact cap without compromising the containment function of the cap from settling, buckling or shearing of the capping materials. In such cases, maintenance to augment or restore capping materials may be needed over time.

As noted above, placement of capping materials typically creates greater disruption to the benthic community compared to MNR and ENR, resulting in commensurately higher impacts to the aquatic food chain. Capped areas become biologically inactive and require more time to recover and recruit benthic organisms. Greater quantities of capping material placed in the aquatic environment can also have more adverse impacts on short-term water quality during placement.

6.4.2 Engineered Capping Placement Methods

Similar to MNR thin-capping methods, thick caps can be placed using a variety of methods depending on capping objectives and area, bottom and water conditions, and related factors. Conventional sand caps are routinely placed using clamshell, tremie, and hydraulic methods for environmental projects, with placement thickness monitored using acoustic or manual surveys, or grade stakes. Placement quantities may also be controlled using placement volume per unit area. Nearshore capping sections can be constructed using cranes staged from land or temporary platforms. The feasibility of capping using mechanical and hydraulic methods is well-proven at numerous sites in the northwest and worldwide. Placement using other methods is less common for environmental projects but may be necessary to address soft bottom conditions, composite caps, or armoring needs.

6.5 Dredging/Removal

Dredging is a frequently used technology for removing contaminated sediments from the aquatic environment. Many proven dredging technologies exist and are generally categorized as either mechanical or hydraulic methods. The different methods and modifications have advantages, disadvantages, and varying levels of environmental impact.

Dredging is retained as a feasible technology for further evaluation, although its effectiveness for removing finely divided wood waste associated with the bay-wide SMAs is questionable relative to MNR, ENR, or thick-capping options. Dredging also provides some degree of additional permanence relative to other remediation technology options, although the extent of potential additional protectiveness is uncertain. Significant environmental, habitat, and potential cultural resource impacts are also associated with dredging. On a comparative basis, dredging is also more expensive than the other screening technologies and may require off site disposal of dredged materials.

6.5.1 Considerations for Dredging

Dredging is often most effective for removing thicker sections of contaminated sediments over well-defined areas, such as was the case for interim dredging actions completed near the mill site in 2003 and 2006. These interim actions were successful in removing visible wood debris consisting of accumulated wood chips, sawdust, and larger debris near the former mill operations. Similarly, potential dredging areas currently being evaluated in the mill area FS address relatively coarse wood waste and a more-definable scale.

Unlike some wood waste accumulations targeted for dredging near the mill area, wood waste in the bay-wide SMAs consists predominantly of finely divided particles over large areas that are difficult to visually distinguish in terms of the extent and depth within fine-grained, mucky sediment. Such material poses significant challenges that may affect the effectiveness and feasibility of dredging. Adverse environmental, habitat, and potential cultural resources impacts are also associated with disruption of the Port Gamble Bay ecosystem as a result of dredging. In addition to habitat loss that would likely require extensive mitigation, a key contributing concern for dredging is control and containment of water column turbidity. The fine-grained nature of turbidity associated with dredging is more difficult to control through standard construction BMPs (silt curtains, etc.) than turbidity associated with placement of sandier TLC materials envisioned for the ENR option.

Resuspended particulate material (i.e., dredging residuals) also creates challenges for ensuring that finely divided wood waste does not settle out on the dredge surface and negate the intent of dredging to remove such material. Sandy cover material was needed to settle and contain residual wood material remaining after the 2006 interim dredging action near the mill (Hart Crowser 2008). Potential dredged areas associated with the bay-wide SMAs would require placement of similar cover material to promote benthic recovery, but the act of dredging in and of itself would cause considerable damage to existing habitat.

An additional consideration is the potential for dredging to encounter archaeological materials. Port Gamble Bay is an area with known archaeological sites, and nearshore and shallow-water areas are often associated with historical use patterns in archaeologically sensitive areas of Puget Sound. Shipwrecks may also be present in Port Gamble Bay, but specific locations remain somewhat uncertain. The likelihood of encountering such materials during dredging may be low, but additional research would be necessary to more conclusively determine potential impacts and develop appropriate response measures.

6.5.2 Dredging Methods

A variety of clamshell and other mechanical dredging methods have been well proven as successful technologies for many environmental projects in the northwest and worldwide. Hydraulic dredging has also been successfully employed but typically creates significant water handling, monitoring, and disposal challenges. Both mechanical and hydraulic dredging are feasible for the Port Gamble bay-wide SMAs, although the effectiveness for removing a relatively thin layer of wood-impacted material is questionable.

6.6 Other Technologies

Other sediment remediation technologies involve *in situ* treatment using admixtures to stabilize/immobilize toxic constituents, or chemical degradation methods such as electro-chemical remediation as noted in the mill area FS (Anchor 2010b). Although treating sediments *in situ* is advantageous and is less invasive than dredging and capping options, the feasibility and effectiveness of such methods is suspect for the nature of wood waste material in the bay-wide SMAs. In general, these methods have not been sufficiently tested to evaluate their applicability to the Port Gamble site and are not retained for further consideration. Potential side effects on sensitive habitat resources are also uncertain.

7.0 MTCA AND SMS EVALUATION CRITERIA

Key guiding requirements for evaluating FS alternatives and cleanup action selection are listed in the MTCA (WAC 173-340-360) and SMS (WAC 173-204-560) regulations. This section summarizes these requirements along with modifying criteria applied to technology screening and alternatives evaluation for the bay-wide FS.

7.1 MTCA Evaluation Criteria

MTCA criteria consist of threshold requirements and other criteria listed in WAC 173-340-360(2) Minimum Requirements for Cleanup Actions. Related criteria are also used for analysis of disproportionate costs.

7.1.1 MTCA Threshold Requirements – WAC 173-340-360(2)(a)

MTCA threshold requirements represent several basic compliance areas that cleanup alternatives must address to be considered as valid actions. Threshold requirements include:

- Protection of human health and the environment;
- Compliance with cleanup standards per WAC 173-340-700 through -760;
- Compliance with applicable state and federal laws per WAC 173-340-710; and
- Provision for compliance monitoring per WAC 173-340-720 through -760.

All MTCA cleanup actions must ensure protection of human health and the environment as fundamental requirements. As applied to the aquatic environment, compliance with cleanup standards must achieve a permanent remedy to the maximum extent practicable; be protective of human health; implement Institutional Controls; include compliance monitoring; and specify hazardous substances remaining on-site along with measures to prevent migration and contact. Compliance with state and federal laws addresses legally applicable requirements and other applicable, relevant and appropriate requirements (ARARs) determined by Ecology. Compliance monitoring must document remedy protectiveness, performance, and confirmation of long-term effectiveness.

7.1.2 Other MTCA Requirements – WAC 173-340-360(2)(b)

MTCA further specifies additional requirements when selecting from cleanup action alternatives that fulfill the threshold requirements. These other MTCA requirements include:

- Use of permanent solutions to the maximum extent practicable per WAC 173-340-360(3);
- Provide a reasonable restoration time frame per WAC 173-340-360(4); and
- Consider public concerns per WAC 173-340-600.

MTCA places preference on permanent solutions to the maximum extent practicable based on a disproportionate cost analysis (DCA). The benefits of the alternatives considered are balanced against relative costs for implementing each alternative. Preference is also placed on remedies that can be implemented in a shorter time period based on potential environmental risks and effects on current site use and associated site and surrounding area resources. The third criterion, public concerns, is addressed by Ecology during comment periods for the RI/FS documents, remedy selection decision, and subsequent Cleanup Action Plan (CAP) for remedy implementation.

7.1.3 MTCA DCA – WAC 173-340-360(3)(e) and (f)

As specified in WAC 173-340-360(3)(e), the DCA represents a test to determine if incremental costs of a given alternative over a lower-cost option exceed the incremental degree of benefit achieved by the higher cost alternative. The most practicable permanent solution is identified as the baseline cleanup action alternative for FS evaluation. The referenced section of MTCA further specifies that where alternatives are equal in benefits, Ecology shall select the less costly alternative provided the MTCA threshold and other requirements are met. Relative costs and benefits of the remedial alternatives are evaluated in the DCA based on specific criteria listed in WAC 173-340-360(3)(f):

- Protectiveness;
- Permanence;
- Cost;
- Effectiveness over the long term;
- Management of short-term risks;
- Technical and administrative implementability; and
- Consideration of public concerns.

Protectiveness considers the degree to which risks to human health and the environment are reduced; the time required for risk reduction and to attain cleanup standards; risks posed by implementing the alternative; and improvement of environmental quality. Costs include all items necessary to implement an alternative including construction, monitoring, operation and maintenance/repair, and agency oversight over the design life of the project.

Factors associated with the long-term effectiveness criterion include the level of certainty of remedy success and reliability, magnitude of residual risks, and effectiveness of controls needed to manage residual materials. DCA evaluation of short-term risks relates to human health and environmental risks that occur during construction and implementation, along with the effectiveness of risk management measures.

Alternatives are also evaluated in the DCA based on their technical feasibility, availability of supporting facilities and materials, administrative and regulatory requirements, scheduling, size, and complexity. Implementability considerations further include monitoring requirements, site access, and integration with facility operations and other remedial actions. Considerations for public concerns address the extent to which alternatives take such issues into account, including comments from individuals, community groups, local governments, tribes, state and federal agencies and other organizations. Public involvement includes comment periods during the RI/FS and remedy selection process.

7.2 SMS Evaluation Criteria

SMS lists cleanup alternatives evaluation requirements comparable to MTCA requirements under SMS section WAC 173-204-560(4). These requirements closely mirror MTCA in requiring evaluation of cleanup actions that protect human health and the environment by eliminating, reducing, or otherwise controlling risks posed through each exposure pathway and migration route. Additional SMS requirements listed in WAC 173-204-560(4)(f) through (k) for consideration include:

- The time period for sediment recovery;
- Confirmational monitoring;
- Current and potential future uses of affected areas or areas that may be affected by contaminant releases;
- Institutional controls;
- Phased approach for alternatives evaluation;
- Attainment of cleanup standards;
- Short-term and long-term effectiveness;
- Ability to be implemented;
- Cost;
- Community concerns;
- Degree to which recycling, reuse, and waste minimization are employed; and
- Environmental impacts pursuant to state SEPA requirements (not a MTCA requirement).

Requirements for SMS cleanup action decisions are further described in SMS section WAC 173-204-580(2) through (4). Similar to MTCA requirements, SMS cleanup actions require achieving protection of human health and the environment; compliance with cleanup standards and ARARs; source control; consideration of public concerns; and monitoring. SMS cleanup action decisions must also address cleanup time frames; current and future site/vicinity use and impacts; effectiveness and reliability; control of contamination; and natural recovery process. In addition, SMS allows authorization of cleanup time frames that exceed ten years where cleanup actions are not practicable in less time. Ecology must further consider net environmental effects of the alternatives, cost effectiveness, public participation and land access.

8.0 DESCRIPTION AND EVALUATION OF REMEDIAL ALTERNATIVES

Four general technologies were retained from the FS screening process for further evaluation in accordance with MTCA criteria and a disproportional cost analysis (DCA) per 173-340-360(2) and (3). These technologies include natural recovery options described for MNR and ENR as candidate technologies for SMA-A based on the nature and extent of wood waste, and the suitability of such technologies to address current biological impacts. MNR and ENR technologies would also be implemented with appropriate institutional controls. These technologies were also retained for alternatives analysis in SMA-B, along with engineered capping, and dredging and backfilling. In contrast to SMA-A, SMA-B is characterized by higher weight-of-evidence scoring results because of SMS CSL bioassay failures.

The engineered capping/containment and dredging technologies were carried forward from the screening process for further consideration in SMA-B, primarily because of their potential effectiveness to address biological impacts associated with the presence of wood waste. This assumes that the observed biological testing failures are in fact related to the presence of wood waste and related degradation products. Application of either technology would also result in considerable adverse environmental impacts to benthic fauna and potentially to short-term water quality, as discussed further below.

The following sections describe the application of MNR and ENR technologies as remedial alternatives, and provide an evaluation of benefits and concerns for each alternative based on MTCA evaluation criteria and DCA considerations. Tables 3 and 4 summarize evaluation criteria for alternative selection, and Tables 5 and 6 present a preliminary cost summary for comparison of MNR and ENR alternatives for each SMA. Tables 7 and 8 provide comparative cost summaries for engineered capping, and dredging and backfilling in SMA-B.

8.1 Alternative Descriptions

8.1.1 MNR (SMA-A and SMA-B)

Application of the MNR technology as a remedial alternative involves long-term monitoring over relatively large areas to document and evaluate the progress of sedimentation and biological response to natural recovery over time. A sampling plan would be prepared to confirm the number and locations of samples to be collected for further biological and chemical testing. Samples are assumed to consist of surface samples (upper 10 cm) to chart the progress of improved conditions in the biologically active zone and regulatory point of compliance. Summary reports would be prepared following each sampling event.

For planning purposes, it is estimated that long-term monitoring for MNR may be required for 10 to 15 years in SMA-A and for 10 to 20 years in SMA-B. This is based on a working assumption that approximately 6 cm of new accumulation may be adequate for benthic recovery, given comparable sediment quality improvements documented in the mill area since 2002. SMA-A is characterized by exceedances of SMS SQS criteria only, whereas SMA-B is characterized by SMS CSL exceedances. A slightly longer time frame of 10 to 20 years is, therefore, projected for SMA-B, assuming that additional sedimentation may be needed for recovery of the bottom substrate. Actual recovery times needed in SMA-A and SMA-B would depend on the conditions observed and monitoring result over time.

In contrast to the retained ENR alternative, as well as other technologies not retained, no construction or permitting are expected to be associated with MNR.

8.1.2 ENR (SMA-A and SMA-B)

ENR involves placement of a thin-layer cap (TLC) of clean imported sandy material to help speed the natural recovery process. Following engineering design, permitting, bidding, and contracting, TLC material would be placed over affected areas to achieve a nominal 6- to 12-inch layer, including a typical overplacement allowance. Using conventional bucket and cable application, placement rates of upwards of 1,000 cy per day may be achievable, resulting in construction durations of approximately 6 months for SMA-A and 4 months for SMA-B. Additional placement and equipment feasibility issues would be evaluated during the design phase.

Based on their size, ENR for SMA-A and SMA-B would require approximately 226,000 and 130,000 cy of clean TLC capping material, respectively. These quantities could pose challenges for locating a reliable source of consistent material with appropriate grain size gradation and other attributes. Clean dredge material from regional navigational dredging projects could be one potential source of material, but the viability of such sources would be subject to further stakeholder discussion as well as scheduling and permitting issues. The dredge material source option with barge transport to Port Gamble Bay likely represents the lowest cost option for consideration and costing. Alternatively, the ability of local sand and gravel pits to provide the needed quantities of TLC material would require further assessment. Shipment of TLC material from more distant upland sources would likely have a significant impact on project costs.

For planning purposes, it is further assumed that long-term monitoring would be required to document ENR performance for a minimum of 10 to 15 years following placement in either SMA. Long-term monitoring activities are, therefore, comparable to the MNR case described above.

8.1.3 Engineered Capping (SMA-B)

Engineered capping would involve placement of a nominal 2-foot-thick sand capping layer over SMA-B using a habitat/fish-friendly mix as for ENR, or other suitable blend based on availability of capping material. The conceptually simplest approach would be to obtain clean dredge material from a Puget Sound project and barge this material to Port Gamble Bay. Placement could be most simply accomplished using conventional clamshell or bucket techniques at the point of capping. The cost analysis for the capping alternative assumes the use of these methods, noting that other sources of material (i.e., upland), cap material blending, or more complex placement methods (tremie application, etc.) would likely increase the capping unit cost substantially.

Placement using clamshell or bucket methods further assumes that a reasonably intact capping layer can be formed along the bottom, with some acceptable degree of intermixing with bottom substrate, but not to the point where capping materials do not adequately cover and contain wood waste. A nominal 2-foot capping section was selected as the minimum expected thickness needed to address these issues, given the soft, muddy bottom conditions in SMA-B.

A related issue is the potential for generating turbidity from impact or clumping of capping material falling through the water column. These issues would require further engineering field analysis to support final design and to confirm the feasibility of the methods.

8.1.4 Dredging and Backfilling (SMA-B)

The SMA-B dredging alternative assumes a nominal 2-foot thick dredge cut. This cut thickness is based on an overall objective of removing wood waste to an approximate depth of 1 to 1-1/2 feet below the mudline, with a reasonable allowance for overdredging. Sediment coring data from SMA-B is limited to three locations as described in the bay-wide RI, but sediment removal to a target depth of 1 to 1-/2 feet is consistent with data showing significant wood waste in this depth interval. This depth interval is also consistent with radiometric coring data indicating sediment accumulation of about 1.6 to 1.8 feet since the beginning of mill operations in 1853.

Clamshell and bucket dredging were previously used in the mill area to remove accumulations of wood chips, sawdust, and other debris. Although effective at the mill from an operational perspective, dredging poses several challenges for potential application to other areas of Port Gamble Bay, including SMA-B:

- Dredging in SMA-B would result in a shallower dredge cut than generally accomplished in the mill area. While technically feasible for shallower cut, dredging could create resuspension of dredge material with woody debris that may be more difficult to control than in deeper cuts. Dredging residuals could, therefore, require even greater management than for the mill area.

- Placement of habitat-friendly backfill to match predredging grades is planned for settling dredging residuals and to help promote habitat restoration. A 2-foot backfill thickness is assumed for costing and analysis purposes, although a thinner section may be adequate given expected readjustment of bottom grades, sidewall sloughing, etc., during dredging.

- Dredging and backfilling could generate greater short-term turbidity and potential water column quality impacts than expected with ENR and engineered capping. Additional thin-capping outside the dredging area could be needed to settle dredging residuals. The additional TLC material needed could offset savings achieved by placing less than a 2-foot backfill thickness within the dredge cuts.

- The dredging approach for SMA-B assumes barge loading and transport of dredge materials to a non-dispersive PSDDA disposal site. This assumption is dependent on the availability of a PSDDA site and the suitability of the dredge material with regard to the wood waste and related TVS fraction. If upland disposal was required, the estimated transport and disposal cost of about $6 per cy could increase by an order of magnitude.

8.2 Evaluation of Remedial Alternatives

Remedial alternatives for SMA-A and SMA-B were evaluated based on MTCA regulatory criteria, modifying criteria, and DCA analysis. MTCA threshold criteria and other criteria were evaluated to assess the ability of each alternative to meet minimum regulatory requirements, including consistency with SMS and other ARARs. Modifying criteria are additional key factors for evaluating potential habitat, cultural resource, and land use impacts. DCA criteria were evaluated based on a relative numeric ranking system from 1 to 5, with 1 as the lowest (least favorable) ranking, and 5 as the highest (most favorable) ranking. The DCA ranking approach is consistent with the relative numeric ranking system used for the mill area FS and at other Puget Sound aquatic cleanup sites. The DCA scores were then totaled and compared to determine overall ranking and cost benefit. Table 3 presents results of the remedial alternatives evaluation and DCA for SMA-A, including MNR and ENR. Table 4 presents the remedial alternatives evaluation and DCA, as applied to SMA-B, including MNR, ENR, engineered capping, and dredging and capping alternatives.

8.2.1 SMA-A MNR and ENR Alternatives

MTCA Threshold Criteria – Protectiveness, Compliance with Standards and ARARs, and Provisions for Compliance Monitoring

Both MNR and ENR are expected to be protective of the environment by restoring benthic habitat and reducing biological toxicity over time. Methodologies and end points comply with MTCA/SMS cleanup levels (i.e., applicable SQS criteria) and other ARARs based on the project remedial objectives. In addition, compliance monitoring is a key element of both MNR and ENR alternatives.

Other MTCA Criteria – Permanence, Restoration Time Frame, and Public Concerns

Both MNR and ENR natural recovery options represent permanent remedial actions within the target restoration time frames. Measured sedimentation rates and testing data in the mill area since 2002 indicate that natural recovery may be possible with roughly 6 cm of accumulated sediment. In comparison, the MNR alternative could potentially provide recovery in roughly 10 to 15 years for other affected areas of Port Gamble Bay. ENR would help to speed recovery by providing fresh substrate, but would have greater impacts on existing biota. A restoration time frame of less than 10 years is projected for ENR, with understanding that biological recruitment of the TLC areas will be necessary to offset the short-term impacts of cap placement.

While MNR and ENR are intended to address public concerns responsibly, it is acknowledged that potential concerns may be raised that deleterious wood waste materials would not be removed from the environment. For SMA-A, SMS regulatory issues are associated with exceedances of SQS criteria, or the lowest threshold under the regulation. Based on this level of impact, a comparable concern is that engineered capping or dredging are invasive technologies resulting in more detrimental impacts that are not commensurate with their potential benefits.

Permanence, restoration time frame, and public concerns are further addressed as part of DCA ranking below.

Modifying Criteria – Prioritizing Habitat Resources, Avoiding Archeological Resources, and Facilitating Future Land Use

Key modifying criteria were considered at the FS screening level and during further evaluation of the retained MNR and ENR alternatives. The natural recovery options are distinguished from engineered capping/containment and dredging technologies (at the screening level) as having greater priority on preserving and enhancing sensitive habitat resources. MNR and ENR also avoid impacts to potential archaeological materials, where and if present. MNR and ENR further help to facilitate future land use with regard to potential navigational issues and future aquatic area uses yet to be determined. MNR and ENR address these criteria through minimal modifications of the existing sediment substrate of Port Gamble Bay.

Although recovery time for MNR may be longer than ENR with regard to prioritizing habitat recovery, ENR has more impacts on habitat resources over the short term following cap placement. For this reason MNR and ENR alternatives are viewed as somewhat comparable with regard to prioritizing habitat restoration. This is particularly true over time, as habitat restoration benefits should tend to be essentially the same for MNR and ENR alternatives. MNR and ENR also provide comparable levels of protection for archaeological resources and facilitation of future land use.

DCA Considerations

The relative rankings for each of the MTCA DCA criteria were generally comparable for MNR and ENR alternatives applied to SMA-A, with minor differences for some criteria (Table 3). Both alternatives are considered to be protective and permanent over the long-term and received rankings of 4 out of a possible 5 points. The permanence ranking of 4 for each alternative acknowledges that engineered caps or dredging provide more immediate elimination of the wood waste material (if applicable), and would receive a slightly higher ranking of 5. This ranking approach for permanence is also consistent with the mill area FS.

Similar considerations apply to long-term effectiveness and short-term risk management criteria. Long-term effectiveness was ranked as a 4 for MNR and ENR for consistency with the mill FS, where engineered capping or dredging were assigned rankings of 5. MNR short-term risk was ranked as a 3 based on the delayed time frame for recovery, and ENR short-term risks were ranked as a 3 given potential water quality and benthic habitat impacts during TLC placement.

Both MNR and ENR were also considered to be administratively implementable at a high level, but ENR was ranked as a 3 pending further engineering evaluation of the TLC placement methods over soft sediments throughout the large acreage of SMA-A. Both MNR and ENR were assigned rankings of 3 for consideration of public concerns for reasons noted above, and consistent with similar rankings for MNR and ENR alternatives where applied to the mill area SMAs.

Overall summary ranking results for DCA criteria resulted in a total of 23 points for MNR versus 21 points for ENR. Slight changes in the rankings of individual criteria for each alternative would have relatively limited influence on the total scores.

SMA-A DCA Evaluation and Alternatives Ranking

Preliminary cost analyses are presented for the SMA-A MNR alternative in Table 5, and for the ENR alternative if Table 6. Given the potential capping area of nearly 140 acres in SMA-A, a corresponding estimated quantity of up to 226,000 cy of TLC material would be required. This has a major influence on the DCA evaluation, with overall estimated MNR costs of $604,500 versus estimated costs in excess of $10,000,000 for the ENR alternative. By any means of comparison, the ENR alternative is highly disproportionate. For this reason the MNR was ranked as the overall preferred alternative for SMA-A, and ENR was ranked second.

8.2.2 SMA-B MNR, ENR, Engineered Capping, and Dredging and Capping Alternatives

MTCA Threshold Criteria, Other MTCA Criteria, and Modifying Criteria

MNR and ENR alternatives for SMA-B address and fulfill applicable MTCA requirements and modifying criteria based on essentially the same rationale as for SMA-A. Natural recovery technologies are favored over more intrusive capping, containment, or dredging to minimize or avoid impacts to habitat, potential archaeological resources, and future aquatic land use (i.e., modifying criteria). The time frame for recovery of SMS CSL biological toxicity exceedances associated with SMA-B may be slightly longer than for SQS exceedances in SMA-A, but the projected target recovery times discussed above and noted in Tables 3 and 4 remain applicable based on current data. As for SMA-A, compliance monitoring is a key element of both MNR and ENR alternatives as applied to SMA-B.

Engineered capping, and dredging and backfilling or capping also fulfill the MTCA criteria and provide more rapid reduction of wood waste exposure. However, a significant consideration is that these advantages are offset by the longer restoration time for habitat recovery. For both engineered capping and dredging and backfilling, the overall restoration time is estimated at 10 to 20 years, comparable to MNR.

DCA Considerations

Comparative MNR and ENR rankings for SMA-B listed in Table 4 are similar to those for SMA-A. The primary difference is that the MNR alternative ranked as a 3 for addressing protectiveness, permanence, and long-term effectiveness criteria associated with CSL exceedances in SMA-B. For comparison, MNR was ranked as potentially being slightly more effective (4) for these same criteria associated with lower-level SQS criteria in SMA-A. The remainder of the ranking scores for MNR and ENR are the same for SMA-B as they are for SMA-A.

Because of the slightly lower protectiveness, permanence, and long-term effectiveness criteria rankings for MNR in SMA-B, the total DCA score for MNR decreased from 23 in SMA-A to 20 in SMA-B. The ENR summary total of 21 was unchanged in the SMA-A to SMA-B rankings, indicating that MNR may be equally effective in both SMAs over time.

The engineered capping and dredging and capping alternatives scored slightly higher than the MNR baseline (24 and 26, respectively, versus 20). The engineered capping and dredging and capping alternatives could provide greater protectiveness, permanence (particularly with the dredging option), long-term effectiveness, and management of short-term risks. Engineered capping benefits are assessed to be possibly 20 percent greater compared to the MNR baseline, and dredging and backfilling are assessed to be possibly 30 percent greater (Table 4). The relative benefits of these alternatives are somewhat less when compared with the ENR alternative applied to SMA-B.

The potential benefits of engineered capping, and dredging and capping alternatives under the MTCA threshold criteria must be viewed cautiously because of the following:

- The weight-of-evidence scoring for stations in the SMA-B area indicates possible moderate adverse biological effects. Some degree of uncertainty about the causes of biological testing failures, and the consistency of such factors from sample to sample. A more conclusive link to wood waste-related impacts requires further monitoring over time to substantiate. Given their relative cost (see DCA analysis below) and impacts to natural resources, engineered capping, or dredging and capping are more frequently applied to areas with more tangibly demonstrated environmental impacts.

- Application of engineered capping, or dredging and capping in SMA-B would essentially eliminate biological resources over the remediation footprint for some time. If such losses were caused by a land use development action, substantial mitigation requirements would be triggered. Although not directly addressed in the DCA, costs for similar mitigation measures for the current project would likely run in the millions of dollars.

Potential habitat resource losses associated with engineered capping, or dredging and backfilling would require considerable further analysis to quantify and evaluate a realistic recovery time frame.

SMA-B DCA Evaluation and Alternatives Ranking

Preliminary cost analyses are presented for the SMA-B MNR alternative in Table 5, ENR in Table 6, engineered capping in Table 7, and dredging and backfilling in Table 8. The baseline MNR cost for SMA-B is $555,750. MNR costing assumptions for SMA-B are comparable to those for SMA-A. Estimated MNR costs for SMA-B are proportionally less than for SMA-A because of the smaller area, although monitoring is assumed over a longer time period because of greater relative impacts. MNR ranked as the preferred alternative for SMA-B.

ENR costing assumptions for evaluating the SMA-B alternatives are essentially the same as for SMA-A. The ENR alternative cost for SMA-B is $6,259,000. The potential TLC area of about 80 acres in SMA-B and corresponding capping material requirement of up to an estimated 130,000 cy tends to drive the overall cost of ENR to a disproportionate level. The estimated ENR cost is more than an order of magnitude higher than the estimated MNR. The ENR alternative ranked second overall.

Engineered capping costs include relatively high costs for the acquisition and placement of capping materials. Although capping provides some additional benefit in comparison with the MNR baseline and ENR, the capping cost of nearly $12,000,000 is disproportionate in relation to MNR and ENR. Capping costs would be higher if an upland source of capping material was needed ,or if alternative placement methods became necessary. The engineered capping alternative ranked third overall.

Similar to capping, the dredging and backfilling alternative is disproportionate to MNR and ENR because of construction and materials costs. Dredging and backfilling is estimated to cost more than $19,000,000 and creates substantial resource impacts with commensurately limited additional benefit. The dredging and backfilling alternative ranked fourth overall.

9.0 CONCLUSIONS AND RECOMMENDATIONS

This section identifies the preferred remedial alternatives for SMA-A and SMA-B, and provides recommendations for implementation. Remedy selection is discussed in the context of MTCA and SMS cleanup decision requirements described in Section 7.0.

9.1 SMA-A and SMA-B Preferred Alternative

Based on the technology screening analysis presented in Section 6.0 and alternatives evaluation presented in Section 8.0, MNR is identified as the preferred remedial alternative for implementation in SMA-A and SMA-B. MNR adequately addresses MTCA and related SMS evaluation criteria for cleanup decisions, and is expected to promote biological recovery in a reasonable time frame. MNR would be implemented with appropriate institutional controls to be identified, and includes a periodic monitoring of biological and chemical conditions as a key component of the remedy.

For SMA-A, four nominal monitoring events are identified over a target duration of about 10 to 15 years. This time frame anticipates reasonably rapid recovery where biological impacts were limited to exceedances of lower-threshold SMS SQS criteria. A slightly longer recovery period of 10 to 20 years is projected for

SMA-B, where biological testing results exceeded SMS CSL criteria; therefore, a total of five monitoring events are identified. Scheduling of specific monitoring events will be further addressed in the Cleanup Action Plan (CAP) and related planning documents.

9.2 Considerations for Remedy Implementation

The success of the preferred MNR alternative in SMA-A and SMA-B will be closely measured by the progress of benthic recovery noted during monitoring. Results of biological testing of samples colocated with a portion of the bay-wide RI sampling locations will be a key metric for determining recovery progress. Should monitoring results indicate that natural recovery is not proceeding in a reasonable time frame, the need for conducting additional actions will be evaluated.

Potential additional actions would include reconsidering ENR or possibly other alternatives over identified areas of concern, and/or further delineation of problem areas through supplemental site characterization. In addition to better definition of problem areas, additional site characterization would also help confirm the viability of the ENR or other potential actions to be determined based on monitoring results and MTCA, SMS, and modifying criteria for remedy evaluation. Potential future site characterization costs above and beyond baseline costs assumed for MNR and ENR monitoring events are not currently included in the FS cost table summaries.

Estimated MNR implementation costs presented in Table 5 assume that MNR would be completed as a joint effort for SMA-A and SMA-B. The sampling and analysis program for MNR monitoring would be further outlined as part of the CAP and supporting sampling plan documents. Should ENR become necessary, costs presented in Table 6 assume that TLC remedy actions would be conducted separately for SMA-A and SMA-B, or portions thereof. Costs associated with ENR application over smaller portions of each SMA would be proportionally lower, but would require evaluation of future monitoring data (including possible supplemental site characterization data) to evaluate and refine.

Details of MNR implementation and monitoring costs will be further evaluated and modified as part of the CAP and supporting documents. Final selection of the cleanup action alternative will follow the stakeholder and public review process for the RI/FS, CAP, and related documents.

9.3 Additional Considerations for Modifying Criteria

9.3.1 Cultural Resources Overview Summary

A bay-wide Cultural Resources Overview (overview) was developed for Port Gamble Bay to identify and map areas of known or expected historical, archaeological, and cultural resources within the project area. This overview was developed by a professional archaeological consulting firm for Olympic Property Group, DNR, and the Port Gamble S'Klallam Tribe. The bay-wide overview also provides specific next steps and a plan to identify, evaluate, and protect cultural resources.

Information from this overview was considered in the selection of cleanup alternatives. The results of the overview did not indicate that any of the identified alternatives in this bay-wide FS should be eliminated. Prior to any proposed fieldwork, project proponents, in consultation with the Washington Department of Archaeology and Historic Preservation (DAHP) and the Port Gamble S'Klallam Tribe, must identify the area or areas to be affected by the project. These areas should include any locations where project-related disturbance may occur, including areas where woody debris will be removed, staging areas, dumping and upland sparging areas, transport routes, and anchor and mooring areas.

The forthcoming bay-wide Cleanup Action Plan needs to consider the results of the initial overview and provide for a site-specific assessment based on recommendations in the overview relative to the nature of the proposed cleanup. Cultural resources considerations will be integrated with studies for the engineering design phase of the project.

Identification of project boundaries will allow archaeologists to select appropriate and focused survey strategies. The regulatory context for the project, whether the project is subject to Section 106 of the National Historic Preservation Act (NHPA) or to Washington State laws, must also be determined, allowing archaeologists to plan appropriate compliance studies, consistent with recommendations put forth in the bay-wide overview. Cultural Resource review and the need for any on-site archaeologist will be determined by Ecology in communication with DAHP and the concerned tribal government. Appropriate cultural resource work plans including a cultural resources treatment plan, and an inadvertent discovery plan will be included in the bay-wide Cleanup Action Plan and Engineering Design Report, as required.

9.3.2 Preliminary Habitat Resource Analysis

The purpose of this Preliminary Habitat Resource Analysis is to summarize the importance of eelgrass and shellfish as resources, outline their occurrence in Port Gamble Bay, and evaluate potential effects of elevated sediment sulfide concentrations. The findings presented help inform the overall approach to remediation in Port Gamble Bay.

Information on the presence and distribution of eelgrass beds in Port Gamble Bay was obtained from Washington Department of Fish and Wildlife (WDFW) (unpublished results generated during herring spawn surveys) and Ecology, as well as Hart Crowser's observations during RI data gathering. Shellfish presence and distribution data were obtained from the Port Gamble S'Klallam Tribe and WDFW's geoduck commercial tract information, as provided to Hart Crowser. The distribution data obtained from the Port Gamble S'Klallam tribe spans harvest seasons between 2000 and 2009 but is not synoptic. Shellfish and eelgrass distribution data collected for this analysis should be considered indicative of resource conditions over a longer time frame.

This section describes eelgrass and shellfish importance and occurrence followed by the potential impacts of elevated sulfides on resource habitats. Summary findings and recommendations are presented at the end of the section, including identification of data gaps of value for further analysis.

Factors Affecting Habitat Resources

Effects of nearshore development and aquatic use on eelgrass and shellfish associated with coastal ecosystems are often hard to evaluate, but are an important consideration when examining overall ecosystem conditions and health. Historical activities can impact sediment chemistry and subsequently affect flora and fauna associated with these habitats. High organic particulate load, as is seen with log handling areas and wood processing facilities, can have drastic effects on sediment chemistry adjacent to these areas. Within sediments that are severely enriched with organics, increased sediment hypoxia, anoxia, and sulfide reduction are encountered (Mackin and Swider 1989; Swider and Macken 1989; Goodman et al. 1995). These shifts in sediment chemistry to a more reducing environment can have large negative effects on associated natural resources including eelgrass and shellfish beds, both of which are considered to have high ecological and commercial value in Port Gamble Bay.

Eelgrass Importance and Occurrence

Background. Eelgrass is a highly productive marine angiosperm that grows in shallow coastal marine waters at temperate latitudes, often in sheltered bays and lagoons which are poorly flushed and sensitive to nutrient loading from adjacent human population growth (Harlin 1993; Williams and Ruckelshaus 1993). Eelgrass, like other seagrass species, provides critical habitat and a nutritional base for finfish, shellfish, and waterfowl (Phillips 1984; Thayer et al. 1984). The presence of seagrasses may increase the abundance of organisms by increasing:

- The amount of physical structure usable as living space;
- The number of microhabitats;
- Sediment deposition and stabilization;
- Food resources; and
- Protection from predators (Lewis 1984).

In the past few decades, major declines in seagrass meadows including temperate eelgrass meadows have been reported worldwide, attributed either directly or indirectly to human alteration of watersheds or nearshore environments (Harlin 1993; Morris and Tomasko 1993; Williams and Ruckelshaus 1993).

Port Gamble Bay Eelgrass Occurrence and Distribution. Within Port Gamble Bay, eelgrass (*Zostera marina*) forms a narrow band around the perimeter of the bay in what is typically called a fringe habitat (Washington Department of Natural Resources Annual Report 2005). This fringe habitat is often limited by light penetration at it lower limit and desiccation/exposure at its upper limit. As is shown on Figure 8, eelgrass occurrence compiled opportunistically from herring survey data from 2005-2009 and RI data from 2009 shows this fringe habitat extends over most of the boundary of the bay with the exception of a few bare areas along the eastern and western boundary, most of the southern boundary of the bay, and the Pope mill site. Typical eelgrass beds are either patchy or dense, with the denser beds providing significant value to Port Gamble Bay resources.

Shellfish Importance and Occurrence

Background. Shellfish beds including clams, oysters, and cockles are of both economic and environmental importance in shallow coastal ecosystems. Commercial and domestic shellfish harvesting provides necessary income to state, local, and individual entities. The contribution of tribal entities to overall commercial shellfish harvest has been increasing as other fisheries, such as salmon, have experienced reduced runs or increased farming (Tiller and Chase

1998). Shellfish, mainly oysters, are also habitat architects, providing high quality habitat for many different marine organisms. Shellfish also play an important ecological role by filtering large volumes of suspended particles from the water column (Dethier 2006), thus helping to control plankton blooms (Newell 2004).

Shellfish at many locations in Puget Sound have long been subjected to pollution, overfishing, and habitat loss/alteration that can adversely affect shellfish populations over both the short and long term. Impacts are commonly promoted by human activities near coastal areas that can alter sediment characteristics (size, composition, or supply), and reduce shellfish settlement, growth, survival, or species diversification (Dethier 2006). In nature, each shellfish species is found most abundantly, or grows and reproduces most efficiently, in relatively specific types of substrates. For Dungeness crabs, geoducks, oysters and cockles, preferred sediments are fairly fine sand or mud, often associated with eelgrass in shallower habitats. In contrast, clams are most abundant in substrates with a gravel-sand sediment mixture indicative of the subtidal/intertidal interface where wave energy actively re-sorts the sediments.

Newly recruited shellfish are very sensitive to their physical and chemical environment. Their early survival can be impacted by alterations in the conditions of interstitial water associated with their preferred settling habitats such as changes in redox potential, organic load, pollutants, and concomitant changes that go hand in hand with these primary modifiers. These sorts of impacts can be caused by changes in upland development practices or nearshore development (Dethier 2006). Dependence on physical and chemical sediment composition and toxicity are of paramount importance when considering Port Gamble Bay shellfish populations.

Port Gamble Bay Shellfish Occurrence and Distribution. Commercial and subsistence harvest shellfish beds are prevalent on both the eastern and western shores of Port Gamble Bay, with larger densities present on the western shore (Figure 9). The WDFW commercial geoduck bed is located at the northern end of Port Gamble Bay where water depth is shallower than the rest of the bay. It is presumed that geoducks inhabit deeper waters of the bay as well. Data obtained from the Port Gamble S'Klallam Tribe indicates that cockles, oysters, and littlenecks are present on the southwestern shore adjacent to the former DNR lease area. The eastern shore of Port Gamble Bay has beds of oysters, manila clams, and cockles, according to tribal data. Table 1 provides additional supporting shellfish density information reported by the Port Gamble S'Klallam Tribe.

Eelgrass and Potential Sulfide Impacts

Background. High sulfide concentrations negatively affect seagrass photosynthesis, metabolism, and growth (Goodman et al. 1995; Erskine and Koch, 2000; Holmer and Bondgaard, 2001). In *Z. marina*, moderate sulfide levels (N400 micromolar (µM)) were related to depressed maximum rates of photosynthesis (Pmax), increased requirements for light, and decreased slope of the photosynthesis versus irradiance curve, which led to a 55% decrease in shoot-to-root ratios from shoot senescence/mortality within 6 days of exposure (Goodman et al. 1995; Holmer and Bondgaard, 2001). The authors reported that eutrophication effects through reduced light and increased sediment sulfide on Pmax were additive, and suggested that elevated sulfide could contribute to *Z. marina* loss under low-light stress. Interactive effects of high salinity (55–60 parts per thousand) and/or relatively high temperature (35° C) with high sulfide (6 millimolar (mM)), sometimes characteristic of its natural habitat, were linked to mortality of the tropical seagrass, *T. testudinum* (Koch and Erskine, 2001).

Declines have been hypothesized to occur after long-term accumulation of dead seagrass and mats of drift algae form a relatively thick (10–15 cm) layer of organic detritus and ooze in which the poorly rooted plants are stressed by high sulfide concentrations (Zimmerman and Montgomery, 1984).

Port Gamble Bay Sulfide Concentrations. In general, elevated sulfide was not detected in eelgrass beds, whereas areas of high sulfide concentration were inhabited by little or no eelgrass. No eelgrass was found at the former mill site where the highest sulfide concentrations were documented. The aquatic areas near the mill have been highly modified by historical activities. While eelgrass beds are prevalent around the fringe of Port Gamble Bay, high sulfide concentrations are most often found in the deeper parts of the bay (Figure 8). Bulk sulfide samples obtained on the western nearshore range from non-detect to 200 mg/kg in or near eelgrass beds.

One sulfide sample obtained on the western nearshore ranged from 200-500 mg/kg sulfide, however no eelgrass was found near this station. Similarly, on the eastern nearshore, sulfide concentrations up to 100 mg/kg were found in or near eelgrass beds. However, there is one instance of sulfide concentrations near 500 mg/kg in an eelgrass bed on the eastern nearshore. No eelgrass was found at the former mill site and data collected by Anchor Environmental shows porewater sulfide concentrations ranging from non-detects to 60 mg/L. It is necessary to note that Anchor collected sediment porewater samples for sulfide analysis while Hart Crowser collected bulk sediment sulfide samples, so the two methods cannot be directly compared. In general, the presence of wood waste in areas that could potentially support eelgrass may limit natural recruitment through indirect elevation of sediment sulfide concentrations.

Shellfish and Potential Sulfide Impacts

Generally, the presence of elevated sulfide concentrations is indicative of high organic matter and low dissolved oxygen in this system. High organic matter may be the result of the degradation of wood waste over time, based on the known uses of the bay. High organic matter, low dissolved oxygen and elevated sulfide concentrations may have deleterious effects on shellfish beds in this area. Elevated bulk sulfide concentrations were found in several areas of the bay and almost always in waters deeper than 30 feet MLLW (Figure 9) except where noted in the eelgrass analysis.

High bulk sulfide concentrations coincide with some of the shellfish beds and the former DNR lease area. Bulk sulfide concentrations in the southwest corner of the WDFW commercial geoduck bed range from non-detect to 500 mg/kg (Figure 9). Porewater sediment sulfide concentrations collected by Anchor Environmental range from 0 to 60 mg/L within the commercial geoduck beds. Similarly, high sulfide concentrations are also found in the northern half of the former DNR lease area, with values between 200-1000 mg/kg. One sample obtained on the edge of the DNR lease area showed sulfide concentrations greater than 1000 mg/kg. Cockles, oysters, and littlenecks are present on the southwestern shore adjacent to the former DNR lease area and are just outside of areas where elevated sulfide concentrations were found. The eastern shore of Port Gamble Bay has beds of oysters, manila clams, and cockles. Elevated sulfide concentrations were found near the southernmost manila clam beds only, and these values were in waters deeper than the identified shellfish beds. It is presumed that geoducks inhabit deeper waters of the bay as well; however, these are areas with documented high sulfide concentrations. It is unlikely that these would represent areas of high recruitment.

Preliminary Habitat Resource Analysis Findings and Recommendations

Background documentation cited in this section provides information on how elevated sulfide concentrations negatively impacts both eelgrass and shellfish. Eelgrasses typically respond with decreased photosynthesis, metabolism, and growth. Shellfish typically respond with increased mortality, reduced size, and lower densities. Sulfide, along with low dissolved oxygen concentrations and high organic matter, can be associated with wood presence and decomposition. In addition, the presence of analytes such as elevated TOC and TVS, ammonia, fatty and resin acids, and phenols are also indicators of the presence of wood waste. These constituents are known to affect eelgrass and shellfish growth and metabolism either directly or indirectly.

Elevated concentrations of sulfides and other wood waste-related constituents in Port Gamble Bay were primarily detected in SMA-B. The majority of SMA-B does not appear to be associated with shellfish beds, and only a small amount of eelgrass at its relatively shallow northwest periphery, although it is assumed by local resource managers that there may be a geoduck seed stock population in this area. In contrast, some spatial correlation may exist between elevated analytes found in SMA-A, and documented eelgrass and shellfish resources. There may be other mitigating circumstances/conditions that may provide suitable habitat for these resources despite elevated analyte concentrations.

Conversely, despite the mechanistic relationship detailed previously, areas of elevated analytes of concern may not be directly linked to the absence of shellfish or eelgrass habitat:

- Sediment in both SMA-A and SMA-B may be of too fine a grain size and/or naturally organically enriched to support shellfish/eelgrass colonization or growth.

- Specifically for eelgrass, SMA-A is characterized by water depths greater than the limits where light penetration is insufficient for eelgrass to photosynthesize.

- Recommendations for remedial actions in SMA-A and SMA-B include monitored natural recovery, with continued evaluation of remedy effectiveness and consideration of potential additional actions, if necessary. Enhanced natural recovery by future thin-layer capping could potentially be a viable option for addressing MTCA threshold criteria for remediation. Particularly in SMA-B, thin-capping could also provide additional habitat substrate, although, thicker capping on the order of 3 to 4 feet thick would be necessary to accommodate normal geoduck growth, habitat requirements, and expand resource utilization.

Except for the northernmost corner, SMA-B is generally not a suitable area for eelgrass growth because of inadequate light at depth. Potential eelgrass enhancement would be problematic. In SMA-A, portions of this area are on the outskirts of documented shellfish beds and eelgrass beds; however, elevated sulfide concentrations are documented near shellfish and eelgrass resources (Figures 8 and 9). Capping is not currently recommended as a remedial alternative in either SMA, and smothering of existing eelgrass in SMA-A is a likely outcome if capping material was applied, particularly with a thicker cap.

Capping is, therefore, not recommended within existing SMA-A eelgrass beds, and the presence of existing eelgrass suggests a healthy or recovering system without the need for further enhancement.

Areas without eelgrass could potentially benefit from capping to increase substrate thickness above the sulfide-affected sediment, and to raise elevations to increase light levels and promote eelgrass colonization and growth. Further, capping of sediments could be coupled with targeted eelgrass plantings to initiate/promote eelgrass colonization and spreading. A thicker cap beyond the typical ENR thin-layer approach would likely be needed to achieve these benefits, however, and the additional cost is disproportionate to the remediation benefit achieved over other options.

Data Gaps

This preliminary habitat assessment summarizes available data to inform the remediation selection process and evaluate potential enhancement options for eelgrass and shellfish resources in Port Gamble Bay. Additional survey information is needed to more fully evaluate potential historical impacts and potential future impacts from remediation actions other than MNR.

Focused eelgrass surveys in the nearshore area are necessary to accurately delineate the areal coverage and density of eelgrass in Port Gamble Bay. Areas that do contain eelgrass beds should be targeted for monitored recovery as feasible, without further disturbance or enhancement. Eelgrass communities, in general, are excellent indicators of system health because they tend to integrate both water column and sediment quality (Dowty, et al 2010). The presence of eelgrass suggests a healthy or recovering community. Documenting areas of eelgrass expansion would provide an excellent indicator of recovery for areas that are known to have been associated with mill or log-handling activities.

Current available data on shellfish beds in port Gamble Bay provide information for a preliminary level of analysis. Shellfish density surveys are done relatively infrequently, making more complete assessment of shellfish occurrence and density difficult. As a consequence, changes to the extent of shellfish populations and distribution over time in Port Gamble Bay are not well understood. While recent published harvest rates are known, these data cannot be used to estimate natural population levels or trends. Therefore, it is difficult to discern if sulfide is having a negative effect on shellfish or to document post-remediation recovery relative to historical conditions. Updated shellfish surveys at representative locations are, therefore, needed to provide a more accurate understanding of shellfish dynamics and possible recovery of this resource in Port Gamble Bay.

9.3.3 Future Land Use Considerations

The preferred MNR alternative has negligible, if any, impact on current and future land use. Long-term monitoring results in minimal disturbance during anticipated sampling and surveying work As an alternative remedial action, ENR thin-layer capping would create sea floor elevation increases of less than one foot, with limited institutional controls expected for cap protection.

The current dredging alternative evaluated for SMA-B assumes backfilling to match the approximate existing seafloor grade, resulting in limited bathymetric change and negating the general need for institutional controls. Dredging without backfilling would deepen seafloor elevations by up to several feet, with limited effects on land use other than habitat impacts.

Aquatic or upland disposal of dredged material also creates further land use impacts at the point of disposal. This includes short-term impacts for potential dewatering and/or sparging of dredge materials slated for upland disposal or reuse. Dredging and backfilling also have progressively greater habitat and marine resource impacts in comparison with MNR and ENR, as noted in previous FS sections.

The engineered capping alternative would raise the seafloor up to several feet, resulting in proportionally greater bathymetric modifications and habitat resource impacts. Maintaining the cap integrity would likely require additional site institutional controls to restrict vessel anchoring, and other activities that could disrupt the physical integrity of the cap. Much of the capping area envisioned for SMA-B is in relatively deep water, but capping in shallower areas near the northern corner of SMA-B could locally affect navigation and vessel draft.

10.0 REFERENCES

Anchor 2006a. Existing Data Compilation Report, Former Mill Site Sediments, Port Gamble, Washington. Prepared for Pope & Talbot, Inc. by Anchor Environmental, LLC. April 2006.

Anchor 2006b. Biological Evaluation, Former Port Gamble Mill Site, Interim Sediment Cleanup Action. Prepared for Washington Department of Ecology and Pope & Talbot, Inc. by Anchor Environmental, LLC. July 2006.

Anchor QEA, LLC 2010a. Remedial Investigation Report: Former Pope & Talbot Sawmill Site, Port Gamble, Washington. Prepared for Pope Resources LP, Olympic Property Group, LLC, and the Washington State Department of Ecology by Anchor Environmental LLC and Environmental Partners, Inc. January 2010.

Anchor QEA, LLC 2010b (in preparation). Draft Feasibility Study, Former Pope & Talbot Sawmill Site, Port Gamble, Washington. Prepared for Pope Resources LP, Olympic Property Group, LLC, and the Washington State Department of Ecology.

Becker, D. Scott, and J. Sexton, L. Jacobs, B. Hogarty, and K. Keeley 2009. Biological Responses to Sediment Remediation Based on Thin Layer Placement Near a Former Pulp Mill in Ward Cove, AK (USA). Environ. Monit. Assess. (2009) 154:427-438, DOI 10.1007/s10661-008-0409-0. August 2, 2009.

Dethier, Dr. Megan 2006. Native Shellfish in Nearshore Ecosystems of Puget Sound. Puget Sound Nearshore Partnership Technical Report 2006-04.

Dethier, M., 2006. Native Shellfish in Nearshore Ecosystems of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-04. Published by Seattle District, US Army Corps of Engineers, Seattle, Washington.

Dowty, P., Berry, H., Gaeckle, J., 2010. Draft: Developing indicators and targets for eelgrass in Puget Sound: A science assessment. Washington Department of Natural Resources, Nearshore Habitat Program, pp. 78.

EPA 1994. Assessment and Remediation of Contaminated Sediments (ARCS) Guidance Document. EPA 905-B94-003. Great Lakes National Program Office, Chicago, Illinois.

EPA 2004. Strategy to Ensure Institutional Control Implementation at Superfund Sites. OSWER No. 9355.0-106. September 2004.

EPA 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. EPA-540-R-5-012. Office of Solid Waste and Emergency Response.

Erskine, J.M., Koch, M.S., 2000. Sulfide effects on *Thalassia testudinum* carbon balance and adenylate energy charge. Aquat. Bot. 67, 275–285.

Goodman, J.L., Moore, K.A., Dennison, W.C., 1995. Photosynthetic responses of eelgrass (*Zostera marina* L.) to light and sediment sulfide in a shallow barrier island lagoon. Aquat. Bot. 50, 37–47.

Harlin, M.M., 1993. Changes in major plant groups following nutrient enrichment. In: McComb, A.J. (Ed.), Eutrophic Shallow Estuaries and Lagoons. CRC Press, Boca Raton, FL, pp. 173–187.

Hart Crowser 2005. Remedial Action Construction Report, Middle Waterway Problem Area C, Sediment Management Units 51a and 51b, Commencement Bay Nearshore/Tideflats Superfund Site, Tacoma, Washington. Prepared for the Washington Department of Natural Resources, Contract No. AE 099, 7946-01. April 7, 2005.

Hart Crowser 2008. Construction Completion Report, Port Gamble Interim Remedial Action Wood Waste Removal Project, Port Gamble, Washington. Prepared for the Washington State Department of Natural Resources. June 13, 2008.

Hart Crowser 2010 (in preparation). Remedial Investigation, Port Gamble Bay, Port Gamble, Washington. Prepared for the Washington State Department of Ecology. Job No. 17330-14.

Holmer, M., Bondagaard, E.J., 2001. Photosynthetic and growth response of eelgrass to low oxygen and high sulfide concentrations during hypoxic events. Aquat. Bot. 70, 29–38.

Integral 2009. Final Remedial Action Report, Sediment Remediation in Ward Cove Marine Operable Unit, Ketchikan Pulp Company Site, Ketchikan, Alaska, AKD009252230. Prepared by Integral Consulting, Inc. for Ketchikan Pulp Company. September 30, 2009.

Koch, M.S., Erskine, J.M., 2001. Sulfide as a phytotoxin to the tropical seagrass *Thalassia testudinum*: interactions with light, salinity, and temperature. J. Exp. Mar. Biol. Ecol. 266, 81–95.

Lewis III, F.G., 1984. Distribution of macrobenthic crustaceans associated with *Thalassia*, *Halodule* and bare sand substrata. Mar. Ecol.: Prog. Ser. 19, 101–113.

Mackin, J.E., Swider, K.T., 1989. Organic matter decomposition pathways and oxygen consumption in coastal marine sediments. J. Mar. Res. 47, 681–716.

Morris, L.J., Tomasko, D.A. (Eds.), 1993. Proceedings and conclusions of workshops on submerged aquatic vegetation initiative and photosynthetically active radiation. St. Johns River Water Management District, Palatka, FL, Special Publication SJ93-SP13.

National Research Counsel 2003. Environmental Cleanup at Navy Facilities: Adaptive Site Management. Washington DC: The National Academies Press.

Newell, R.I.E., 2004. Ecosystem influences of natural and cultivated populations of suspension-feeding bivalve molluscs: a review. J. Shellfish Res. 23, 51–62.

NewFields Northwest 2007. Port Gamble Baseline Investigations: Marine Natural Resources. Prepared for Olympic Property Group by NewFields Northwest, Port Gamble, Washington. February 2007.

Parametrix 2002. Sediment Data Summary and Cleanup Study Plan, Former Pope & Talbot, Inc. Site, Port Gamble Bay, Washington, DRAFT. April 2002.

Parametrix 2003. Sediment Characterization Report, Former Pope & Talbot, Inc., Department of Natural Resources Aquatic Land Lease No. 20-012795. April 2003.

Phillips, R.C., 1984. Ecology of eelgrass meadows in the Pacific northwest: A community profile.

Swider, K. T., Mackin, J. E., 1989. Transformations of sulfur compounds in marsh-flat sediments. Geochim. cosmochim. Acta 53: 231 1-2323

Thayer, G.W., Bjorndal, K.A., Ogden, J.C., Williams, S.L., Zieman, J.C., 1984. Role of larger herbivores in seagrass communities. Faunal relationships in seagrass and marsh ecosystems. Estuaries, vol. 7, 351-376

Tiller, V., Chase, R., 1998. Economic contributions of indian tribes to the economy of Washington state. Tiller Research, Inc. and Chase Economics

Washington Department of Natural Resources, 2005. Puget Sound submerged vegetation monitoring project 2003-2004 monitoring report. Washington Department of Natural Resources, Nearshore Habitat Program, pp. 101.

Williams, S.L., Ruckelshaus, M.H., 1993. Effects of nitrogen availability and herbivory on eelgrass (*Zostera marina*) and epiphytes. Ecology 74, 904-918.

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Table 1 - Port Gamble Sediment Impact Weight-of-Evidence Scoring

	Location		**8**	**14A**	**15**	**16**	**18**	**20**	**21A**	**21B**	**22**	**29**	**29A**	**30**	**31**	**33**	**35**	**38**	**38A**	**39**	**40**	**42**	**44**	**45**	**46**	**47**	**47A**	**51**	**53**
Layer	**Parameter**	**Score**																											
1	**Microtox (SMS)**		0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
	Pass	0																											
	Fail	1																											
2	**Amphipods (SMS)**		0		0	0	0	0		0	0		0	0	0	0	0		0	0	0	0	0	0		0		0	0
	Pass	0																											
	SQS Failure	1																											
	CSL Failure	2																											
3	**Mytilus (SMS)**		0		0	0	**1**	0		**2** ▨	**2**		**2** ▨	**1**	**1**	**1**	**1**		**2** ▨	**2**	**2**	**2**	**1**	0		**1**		**1**	**1**
	Pass	0																											
	SQS Failure	1																											
	CSL Failure	2																											
4	**Polychaete (SMS)**		0		0	0	**1** ▨	0		0	0		0	**1** ▨	0	**1** ▨	0		0	**1** ▨	**1** ▨	0	0	0		0		0	0
	Pass	0																											
	SQS Failure	1																											
	CSL Failure	2																											
5	**Microtox (10%tile ref)**		0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	**1**	0
	Pass	0																											
	Fail	1																											
6	**Amphipods (10%tile ref)**		0		0	0	0	0		0	0		0	0	0	0	0		0	0	0	0	0	0		0		0	0
	Pass	0																											
	SQS Failure	1																											
	CSL Failure	2																											
7	**Mytilus (10%tile ref)**		0		0	0	0	0		**1**	**2**		0	0	0	0	0		**1**	**1**	**1**	**2**	0	0		0		0	0
	Pass	0																											
	SQS Failure	1																											
	CSL Failure	2																											
8	**Polychaete (10%tile ref)**		0		0	0	0	0		0	0		0	0	0	0	0		0	0	0	0	0	0		0		0	0
	Pass	0																											
	SQS Failure	1																											
	CSL Failure	2																											
9	**TVS**		0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	<12%	0																											
	12-21%	1																											
	≥21%	2																											
10	**Sulfide (ppm)**		0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	0	0	**1**	**1**
	<700	0																											
	700-1200	1																											
	>1200	2																											
	Total Score		**0**	**0**	**0**	**3**	**2**	**0**	**0**	**3**	**4**	**0**	**3**	**2**	**1**	**2**	**1**	**0**	**3**	**4**	**5**	**5**	**1**	**1**	**0**	**1**	**0**	**4**	**2**

▨ Reference sample did not meet performance criteria. Results compared to alternate reference sample or control.

Table 1 - Port Gamble Sediment Impact Weight-of-Evidence Scoring

Location		**54**	**55**	**56**	**58**	**61**	**62**	**62A**	**62B**	**63**	**64**	**67**	**68**	**69**	**70**	**71**	**73**	**75**	**77**	**77A**	**78**	**80**	**82**	**83**	**92**	**Geo 03**
Parameter	**Score**																									
Microtox (SMS)		0	0	0	**1**	0	0	0	**1**	**1**	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0
Pass	0																									
Fail	1																									
Amphipods (SMS)		0		0	0		0			0	0	0					0	0		0					0	
Pass	0																									
SQS Failure	1																									
CSL Failure	2																									
Mytilus (SMS)		**2**		**2**	0		0			0	**2**	0					0	0		0					0	
Pass	0																									
SQS Failure	1																									
CSL Failure	2																									
Polychaete (SMS)		0		0	0		0			0	0	0					0	0		0					0	
Pass	0																									
SQS Failure	1																									
CSL Failure	2																									
Microtox (10%tile ref)		0	0	0	**1**	0	0	0	**1**	**1**	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0
Pass	0																									
Fail	1																									
Amphipods (10%tile ref)		0		0	0		0			0	0	0					0	0		0					0	
Pass	0																									
SQS Failure	1																									
CSL Failure	2																									
Mytilus (10%tile ref)		**2**		**2**	0		0			0	**2**	0					0	0		0					0	
Pass	0																									
SQS Failure	1																									
CSL Failure	2																									
Polychaete (10%tile ref)		0		0	0		0			0	0	0					0	0		0					0	
Pass	0																									
SQS Failure	1																									
CSL Failure	2																									
TVS		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<12%	0																									
12-21%	1																									
≥21%	2																									
Sulfide (ppm)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<700	0																									
700-1200	1																									
>1200	2																									
Total Score		**4**	**0**	**4**	**2**	**0**	**0**	**0**	**2**	**2**	**4**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

▨ Reference sample did not meet performance criteria. Results compared to alternate reference sample or control.

Table 2 - Remedial Technologies Screening Summary

Candidate Technology	Retained or Discarded	Rationale and Comments
No Action	Discarded	Baseline/null case for comparison. Does not achieve remedial action objectives, including protection of the environment.
Institutional Controls	**Retained**	Includes site regulatory listings/notifications and other potentially appropriate actions.
Natural Recovery Monitored Natural Recovery (MNR)	**Retained**	Mill area RI bioassay data indicates that natural recovery may be occuring at that location. Bay-wide and mill area RI radiometric data indicate that sedimentation rates may support natural recovery.
Enhanced Natural Recovery (ENR)	**Retained**	Potential enhancing measure using thin-layer capping to shorten remediation/restoration time frame for natural recovery for bay-wide SMAs.
Engineered Capping/Containment Thick Capping	Discarded	Significant adverse habitat and potential land use impacts (i.e., navigation) with limited benefit of additional environmental protection and permanence relative to natural recovery. Compensatory mitigation required.
Dredging/Removal	Discarded	Includes dredging or dredge and cap. Significant adverse habitat and water quality impacts with limited benefit of additional environmental protection and permanence relative to natural recovery. Compensatory mitigation required.
Other Technologies *In Situ* Treatment	Discarded	Includes physical stabilization, chemical stabilization, and electrochemical methodologies. Not proven to be effective, feasible, or cost effective for wood waste or at bay-wide SMA scale in marine environment.

Table 3 - Summary of MTCA Evaluation Criteria and Modifying Criteria for Remedy Selection - SMA-A

Criteria	Alternative	
	Monitored Natural Recovery (Baseline Case)	**Enhanced Natural Recovery**
MTCA Evaluation Criteria		
MTCA Threshold Criteria WAC 173-340-360(2)(a)		
Protection of Human Health and the Environment	Yes	Yes
Compliance with Cleanup Standards	Yes	Yes
Compliance with ARARs	Yes	Yes
Provision for Compliance Monitoring	Yes	Yes
Other MTCA Evaluation Criteria WAC 173-340-360(2)(b)		
Permanence	Yes	Yes
Restoration Time Frame	< 10 to 15 Years?	< 10 Years
Consideration of Public Concerns	Yes	Yes
Modifying Criteria		
Avoid Impacts to Cultural and Archaeological Resources	Yes	Yes
Prioritize Consideration of Resource and Habitat Restoration	Yes	Yes
Facilitate Land Use Redevelopment as Practicable	Yes	Yes
MTCA Disproportionate Cost Analysis DCA - WAC 173-340-360(3)(f)*		
Protectiveness	4	4
Permanence	4	4
Long-Term Effectiveness	4	4
Management of Short-Term Risks	3	3
Technical and Administrative Implementability	5	3
Consideration of Public Concerns	3	3
Total Scores	23	21
Estimated Cost (+30% contingency)	**$604,500**	**$10,425,413**
Cost Disproportionate?		Yes
Overall Alternative Ranking	1	2
% Benefit Increase Over Baseline		-9%
% Cost Increase Over Baseline		1725%

Notes:

* DCA cost estimated separately below

Table 4 - Summary of MTCA Evaluation Criteria and Modifying Criteria for Remedy Selection - SMA-B

Criteria	**Alternative**			
	Monitored Natural Recovery (Baseline Case)	**Enhanced Natural Recovery**	**Engineered Capping**	**Dredging and Backfilling**
MTCA Evaluation Criteria				
MTCA Threshold Criteria WAC 173-340-360(2)(a)				
Protection of Human Health and the Environment	Yes	Yes	Yes	Yes
Compliance with Cleanup Standards	Yes	Yes	Yes	Yes
Compliance with ARARs	Yes	Yes	Yes	Yes
Provision for Compliance Monitoring	Yes	Yes	Yes	Yes
Other MTCA Evaluation Criteria WAC 173-340-360(2)(b)				
Permanence	Yes	Yes	Yes	Yes
Restoration Time Frame	10 to 20 Years?	< 10 Years	5 to 10 Years?	5 to 10 Years?
Consideration of Public Concerns	Yes	Yes	Yes	Yes
Modifying Criteria				
Avoid Impacts to Cultural and Archaeological Resources	Yes	Yes	Yes	Presence of potential cultural resources could inhibit extent of dredging and require alternate remediation measures
Prioritize Consideration of Resource and Habitat Restoration	Yes	Yes	Capping impacts would adversely affect existing resources	Dredging impacts would adversely affect existing resources
Facilitate Land Use Redevelopment as Practicable	Yes	Yes	Capping would alter navigational draft	Assume dredging and backfilling to match approximate current bottom elevations
MTCA Disproportionate Cost Analysis DCA - WAC 173-340-360(3)(f)				
Protectiveness	3	4	5	5
Permanence	3	4	4	5
Long-Term Effectiveness	3	4	4	5
Management of Short-Term Risks	3	3	5	5
Technical and Administrative Implementability	5	3	3	3
Consideration of Public Concerns	3	3	3	3
Total Scores	20	21	24	26
Estimated Cost (+30% contingency)	**$555,750**	**$6,259,000**	**$11,755,750**	**$19,466,013**
Cost Disproportionate?		Yes	Yes	Yes
Overall Alternative Ranking	1	2	3	4
% Benefit Increase Over Baseline		105%	120%	130%
% Cost Increase Over Baseline		1126%	2115%	3503%

Table 5 - Cost Estimates for SMA-A and SMA-B MNR Remedial Action Alternatives

Item	Amount	Units	Unit Cost	Total Cost	Notes and Assumptions
Monitored Natural Recovery (MNR) - SMA-A					
Prepare Sampling Plan	1	LS	$15,000	$15,000	Completed in conjunction with MNR sampling plan for SMA-B.
Per Sampling Event Cost					
Collect Site and Reference Samples	1	LS	$30,000	$30,000	Up to 15 samples including reference.
Analyze Samples	1	LS	$70,000	$70,000	Samples analyzed for SMS constituents, bioassays, wood-related compounds, and dioxins.
Prepare Summary Report	1	LS	$12,500	$12,500	Report prepared in conjunction with report for SMA-B. Includes anticipated related interaction with Ecology, stakeholders, etc.
Total Cost per Event				$112,500	
Total Assumed Sampling Events	4	ea	$112,500	$450,000	Over assumed 10 to 15 year duration.
Total MNR Sampling and Reporting Cost				$465,000	
Contingency	+30	%		$139,500	
Total Estimated SMA-A MNR Remedial Cost				**$604,500**	
Monitored Natural Recovery (MNR) - SMA-B					
Prepare Sampling Plan	1	LS	$15,000	$15,000	Completed in conjunction with MNR sampling plan for SMA-A.
Per Sampling Event Cost					
Collect Site and Reference Samples	1	LS	$20,000	$20,000	Up to 10 samples including reference.
Analyze Samples	1	LS	$50,000	$50,000	Samples analyzed for SMS constituents, bioassays, wood-related compounds, and dioxins.
Prepare Summary Report			$12,500	$12,500	Report prepared in conjunction with report for SMA-A. Includes anticipated related interaction with Ecology, stakeholders, etc.
Total Cost per Event				$82,500	
Total Assumed Sampling Events	5	ea	$82,500	$412,500	Over assumed 10 to 20 year duration.
Total MNR Sampling and Reporting Cost				$427,500	
Contingency	+30	%		$128,250	
Total Estimated SMA-B MNR Remedial Cost				**$555,750**	

Table 6 - Cost Estimates for SMA-A and SMA-B ENR Remedial Action Alternatives

Item	Amount	Units	Unit Cost	Total Cost	Notes and Assumptions
Enhanced Natural Recovery (ENR) - SMA-A					
Mobilization and Demobilization					
Mobilization	1	LS	$100,000	**$100,000**	SMA-A ENR completed independently from SMA-B ENR.
Demobilization	1	LS	$50,000	**$50,000**	
Thin-Layer Capping (TLC) Placement					Nominal 12-inch cap including overplacement allowance.
Purchase and Transport TLC Material	226,000	CY	$10	$2,260,000	Reuse of clean dredged materials, if available, practicable, and permittable.
Place TLC Material	226,000	CY	$20	$4,520,000	Overwater bucket and crane operation. Includes routine QA.
Environmental Controls	1	LS	$75,000	$75,000	Water quality controls.
Bathymetric Surveys	2	EA	$25,000	$50,000	Pre- and post-capping record surveys.
Subtotal TLC Placement Costs				$6,905,000	
Contingency	30	%		$2,071,500	
Subtotal Construction with Contingency				**$8,976,500**	
Non-Construction Costs					
Project Management	6	Month	$25,000	$150,000	Nominal 6-month duration.
Engineering and Design	2.5	%		$224,413	
Permitting	1	LS	$50,000	$50,000	
Construction Management and Reporting	6	Month	$25,000	$180,000	Nominal 6-month duration plus nominal $30,000 reporting.
Environmental Monitoring During Construction	6	Month	$10,000	$90,000	
Total Non-Construction Costs				**$694,413**	
Long-Term Monitoring				**$604,500**	Based on Table 5 estimate for SMA-A monitoring over 10- to 15-year duration.
Total Estimated SMA-A ENR Remedial Cost				**$10,425,413**	

Item	Amount	Units	Unit Cost	Total Cost	Notes and Assumptions
Enhanced Natural Recovery (ENR) - SMA-B					
Mobilization and Demobilization					
Mobilization	1	LS	$100,000	**$100,000**	SMA-B ENR completed independently from SMA-A ENR.
Demobilization	1	LS	$50,000	**$50,000**	
Thin-Layer Capping (TLC) Placement					Nominal 12-inch cap including overplacement allowance.
Purchase and Transport TLC Material	130,000	CY	$10	$1,300,000	Reuse of clean dredged materials, if available, practicable, and permittable.
Place TLC Material	130,000	CY	$20	$2,600,000	Overwater bucket and crane operation. Includes routine QA.
Environmental Controls	1	LS	$50,000	$50,000	Water quality controls.
Bathymetric Surveys	2	EA	$25,000	$50,000	Pre- and post-capping record surveys.
Subtotal TLC Placement Costs				$4,000,000	
Contingency	30	%		$1,200,000	
Subtotal Construction with Contingency				**$5,200,000**	
Non-Construction Costs					
Project Management	4	Month	$25,000	$100,000	Nominal 4-month duration.
Engineering and Design	2.5	%		$130,000	
Permitting	1	LS	$50,000	$50,000	
Construction Management and Reporting	4	Month	$25,000	$130,000	Nominal 4-month duration plus nominal $30,000 reporting.
Environmental Monitoring During Construction	4	Month	$10,000	$70,000	
Total Non-Construction Costs				**$480,000**	
Long-Term Monitoring				**$429,000**	Based on Table 5 estimate for SMA-B monitoring: $82,500 per event for 4 total sampling events over 10- to 15-year duration of monitoring, and +30% contingency.
Total Estimated SMA-B ENR Remedial Cost				**$6,259,000**	

Table 7 - Cost Estimates for SMA-B Engineered Capping Remedial Action Alternative

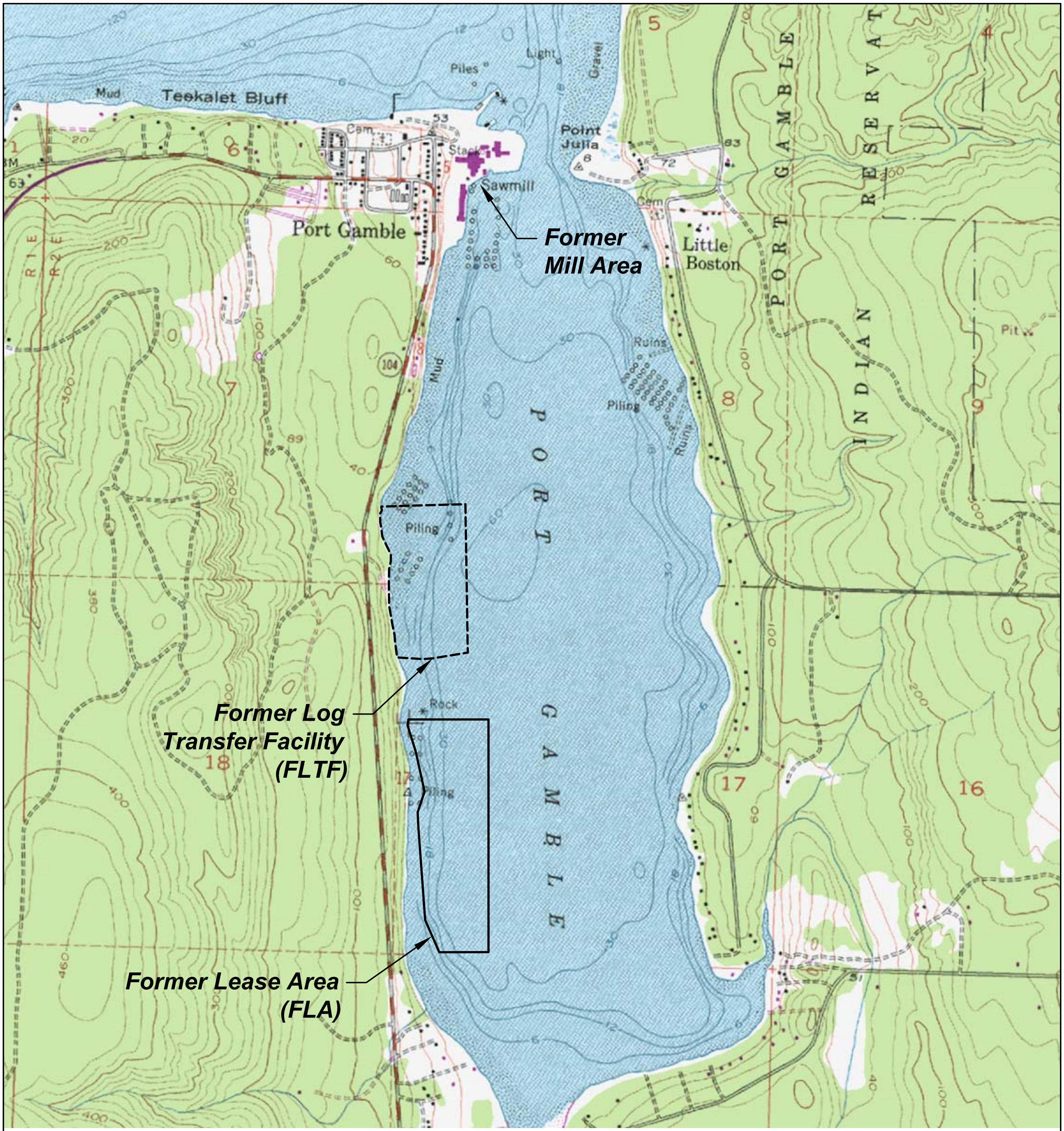
Engineered Capping - SMA-B					
Mobilization and Demobilization					
Mobilization	1	LS	$100,000	**$100,000**	SMA-B remedial actions completed independently from SMA-A actions.
Demobilization	1	LS	$50,000	**$50,000**	
Capping Placement					Nominal 2-foot thick cap including overplacement allowance.
Purchase and Transport Capping Material	260,000	CY	$10	$2,600,000	Reuse of clean dredged materials, if available, practicable, and
Place Capping Material	260,000	CY	$20	$5,200,000	Overwater bucket and crane operation. Includes routine QA.
Environmental Controls	1	LS	$50,000	$50,000	Water quality controls.
Bathymetric Surveys	2	EA	$25,000	$50,000	Pre- and post-capping record surveys.
Subtotal Capping Placement Costs				$7,900,000	
Contingency	30	%		$2,370,000	
Subtotal Construction with Contingency				**$10,270,000**	
Non-Construction Costs					
Project Management	9	Month	$25,000	$225,000	Nominal 9-month duration.
Engineering and Design	2.5	%		$256,750	
Permitting	1	LS	$50,000	$50,000	
Construction Management and Reporting	9	Month	$25,000	$255,000	Nominal 9-month duration plus nominal $30,000 reporting.
Environmental Monitoring During Construction	9	Month	$10,000	$120,000	
Total Non-Construction Costs				**$906,750**	
Long-Term Monitoring				**$429,000**	Based on Table 5 estimate for SMA-B monitoring: $82,500 per event for 4 total sampling events over 10- to 15-year duration of monitoring, and +30% contingency.
Total Estimated SMA-B Engineered Capping Remedial Cost				**$11,755,750**	

Table 8 - Cost Estimates for SMA-B Dredging and Backfilling Remedial Action Alternative

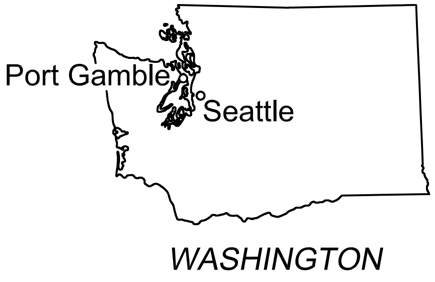
Dredging and Backcapping - SMA-B					
Mobilization and Demobilization					
Mobilization	1	LS	$100,000	**$100,000**	SMA-B remedial actions completed independently from SMA-A actions.
Demobilization	1	LS	$50,000	**$50,000**	
Dredging					
Dredge Prism Material/Chemical Characterization	1	LS	$75,000	$75,000	Assumes PSDDA disposal.
Dredging	260,000	CY	$15	$3,900,000	Assumes 2-foot dredge cut including 0.5 to 1-foot overdredge. Assumes conventional clamshell and barge management methods.
Transport and Disposal	260,000	CY	$6	$1,560,000	PSDDA disposal site assumed, if available. Cost dependent on material acceptability, disposal site location, and barging distance.
Environmental Controls	1	LS	$100,000	$100,000	Water quality controls for duration of dredging and backfilling.
Bathymetric Surveys	2	EA	$25,000	$50,000	Pre- and post-dredging record surveys.
Subtotal Dredging Costs				$5,685,000	
Dredge Backfilling					Nominal 12-inch cap including overplacement allowance.
Purchase and Transport Backfill Material	260,000	CY	$10	$2,600,000	Reuse of clean dredged materials, if available, practicable, and permittable.
Place Backfill Material	260,000	CY	$20	$5,200,000	Overwater bucket and crane operation. Includes routine QA.
Environmental Controls					Included with dredging costs.
Bathymetric Surveys	2	EA	$25,000	$50,000	Pre- and post-capping record surveys.
Subtotal Backfill Placement Costs				$7,850,000	
Subtotal Construction (Dredging and Backfilling)				**$13,535,000**	
Contingency	30	%		**$4,060,500**	
Non-Construction Costs					
Project Management	18	Month	$25,000	$450,000	Assumes scale of dredging and backfilling will require 2 construction seasons over 18 months.
Engineering and Design	2.5	%		$101,513	
Permitting	1	LS	$50,000	$50,000	
Construction Management and Reporting	18	Month	$25,000	$480,000	Nominal 18-month duration plus nominal $30,000 reporting.
Environmental Monitoring During Construction	18	Month	$10,000	$210,000	
Total Non-Construction Costs				**$1,291,513**	
Long-Term Monitoring				**$429,000**	Based on Table 5 estimate for SMA-B monitoring: $82,500 per event for 4 total sampling events over 10- to 15-year duration of monitoring, and +30% contingency.
Total Estimated SMA-B Dredging and Backcapping Remedial Cost				**$19,466,013**	

Table 9 - Port Gamble Shellfish Densities Reported By The Port Gamble S'Klallam Tribe

Shellfish Type	Density per bed	Location	Average Density per species
Littleneck	0.10 lb/sq ft	West	0.109
Littleneck	0.12 lb/sq ft	West	
Littleneck	0.02 lb/sq ft	East	0.065
Littleneck	0.08 lb/sq ft	East	
Littleneck	0.10 lb/sq ft	East	
Oysters	6.90 sq ft	West	8.200
Oysters	9.50 sq ft	West	
Oysters	7.04 sq ft	East	6.210
Oysters	5.38 sq ft	East	
Manila	0.07 lb/sq ft	West	0.082
Manila	0.10 lb/sq ft	West	
Manila	0.07 lb/sq ft	East	0.052
Manila	0.05 lb/sq ft	East	
Manila	0.03 lb/sq ft	East	
Cockles	0.03 lb/sq ft	East	0.024
Cockles	0.02 lb/sq ft	East	
WDFW Geoducks	0.11 sq ft	Total	



Note: Base map prepared from USGS 7.5 minute quadrangle map of Port Gamble, WA.



0 2000 4000
Scale in Feet

N

Port Gamble Bay
Port Gamble, Washington

Vicinity Map

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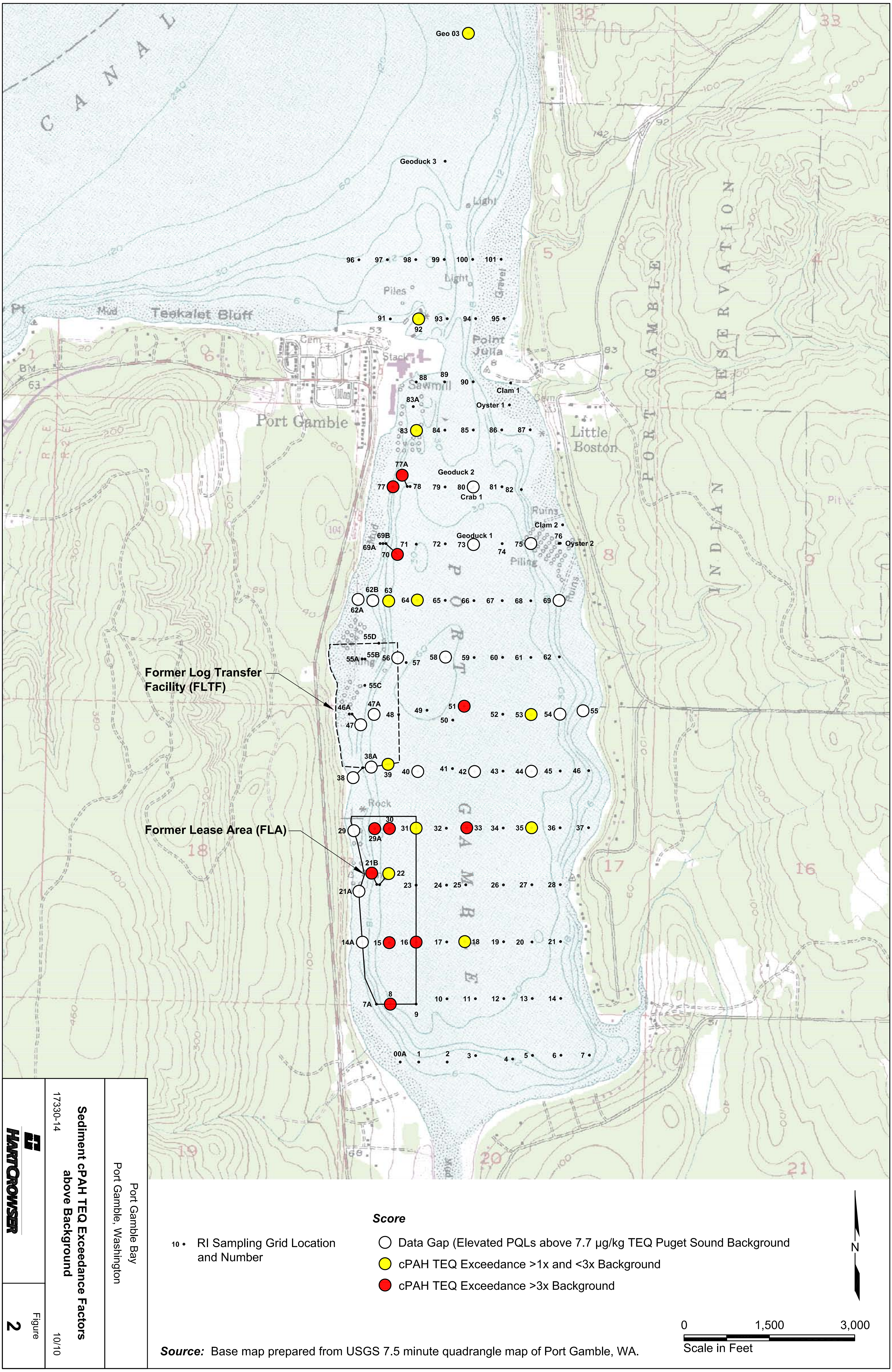
Figure
1

JAB 10/18/10 1733014-031.dwg



Source: Base map prepared from USGS 7.5 minute quadrangle map of Port Gamble, WA.

Port Gamble Bay
Port Gamble, Washington

Sediment cPAH TEQ Exceedance Factors above Background

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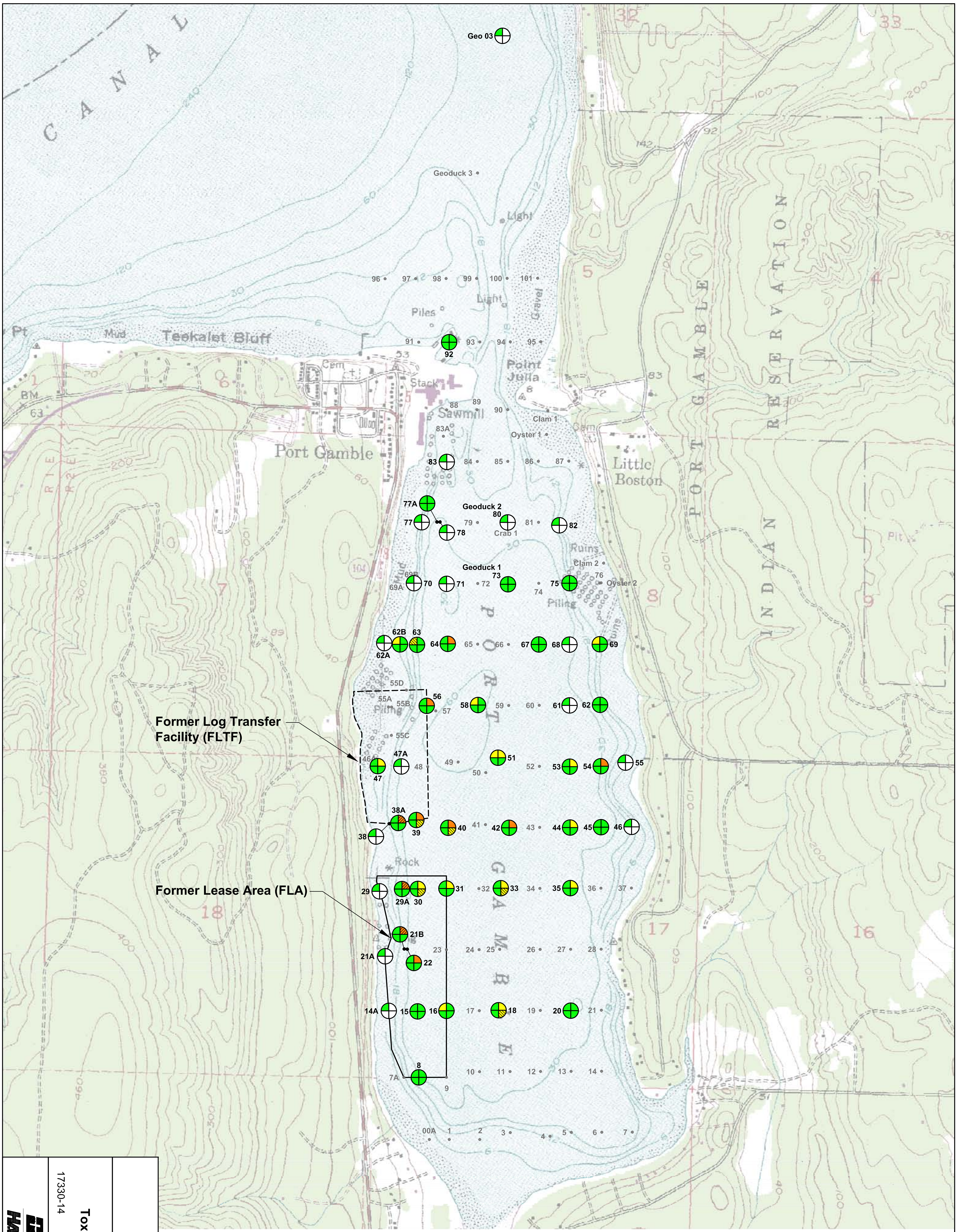
Figure
2



10 • Grid Location and Number

▨	Test Sediment Compared to Alternate Reference or Control
🟩	Pass
🟨	Fail SQS*
🟧	Fail CSL (Excluding 2-Hit SQS Failures)

MT | LD
AM | PG

MT: Microtox
LD: Larval Development
AM: Amphipod
PG: Juvenile Polychaete Growth

N

***Note:** Two-Hit SQS failures also fail CSL.

***Source:** Base map prepared from USGS 7.5 minute quadrangle map of Port Gamble, WA.

0 1,500 3,000
Scale in Feet

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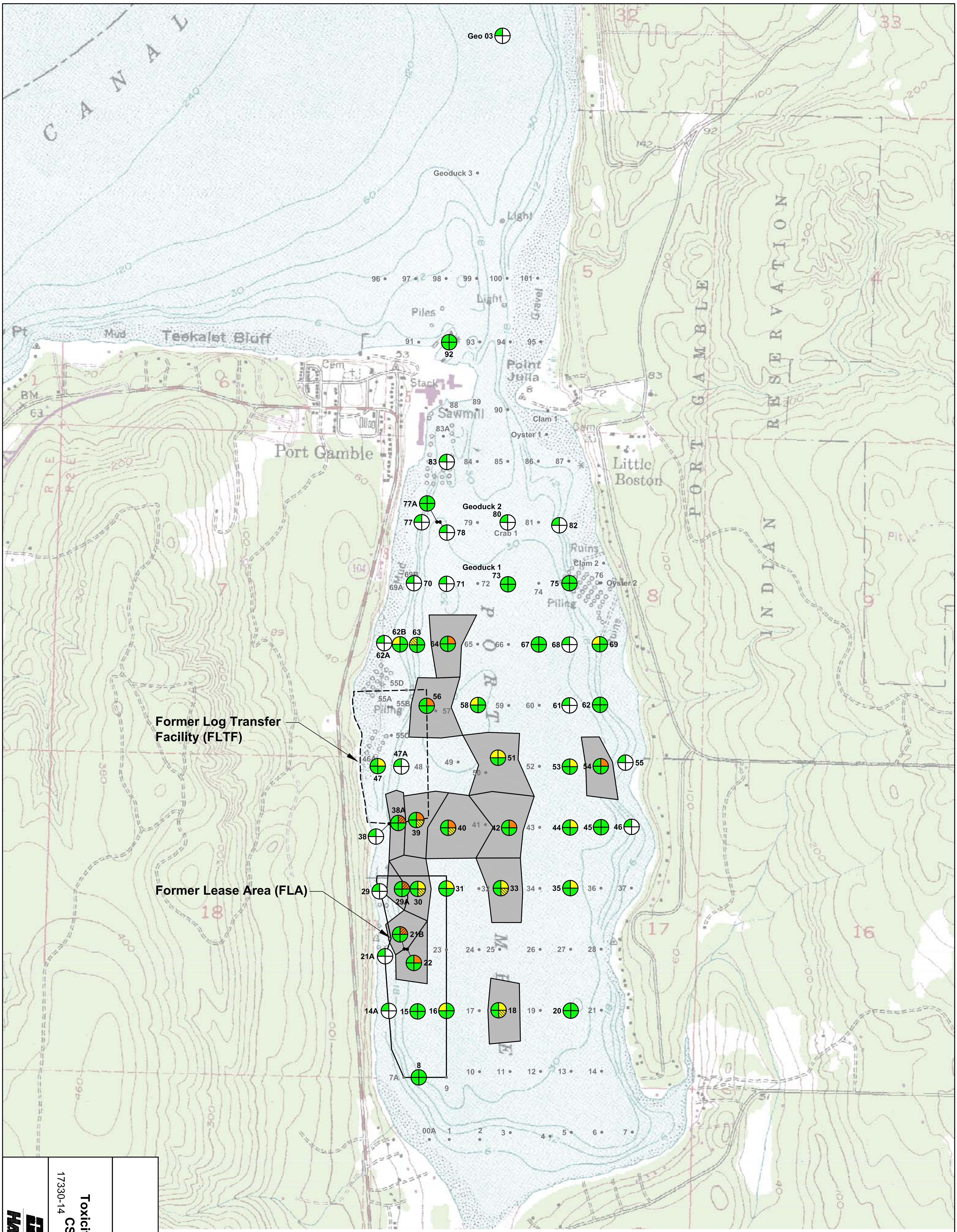
Toxicity Testing Summary Results

Port Gamble Bay
Port Gamble, Washington

10/10

Figure
3



10 • Grid Location and Number

MT	LD
AM	PG

MT: Microtox

LD: Larval Development

AM: Amphipod

PG: Juvenile Polychaete Growth

▨ Test Sediment Compared to Alternate Reference or Control

🟩 Pass

🟨 Fail SQS*

🟧 Fail CSL (Excluding 2-Hit SQS Failures)

Note: Two-Hit SQS failures also fail CSL.

Source: Base map prepared from USGS 7.5 minute quadrangle map of Port Gamble, WA.

0 1,500 3,000
Scale in Feet

Port Gamble Bay
Port Gamble, Washington

Toxicity Testing Summary Results with CSL Failure Thiessen Polygons

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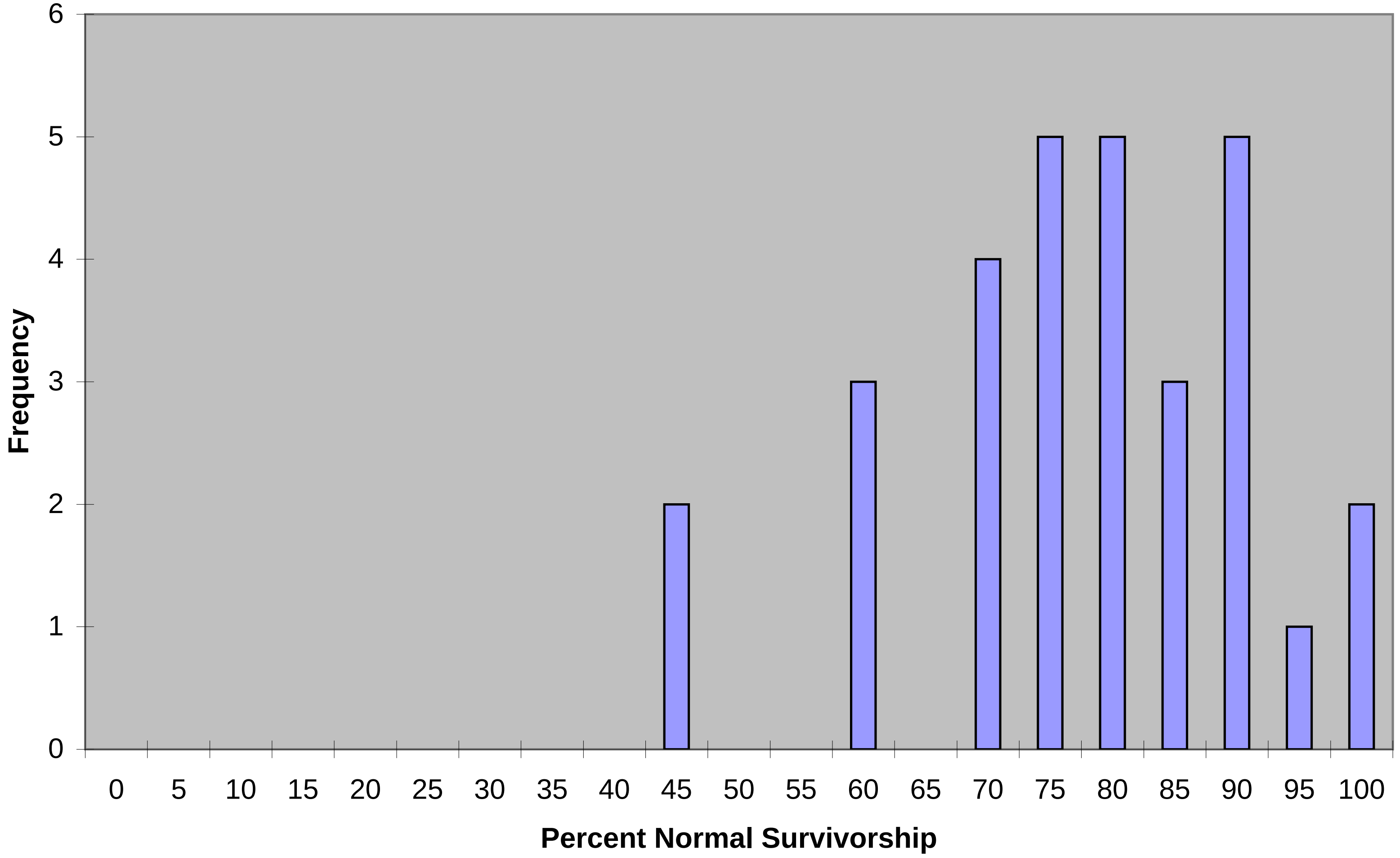
Figure 4

Port Gamble Baywide Reference Sample
Larval Percent Normal Survivorship Histogram



Port Gamble Bay
Port Gamble, Washington

Port Gamble Baywide Reference Sample
Larval Percent Normal Survivorship Histogram

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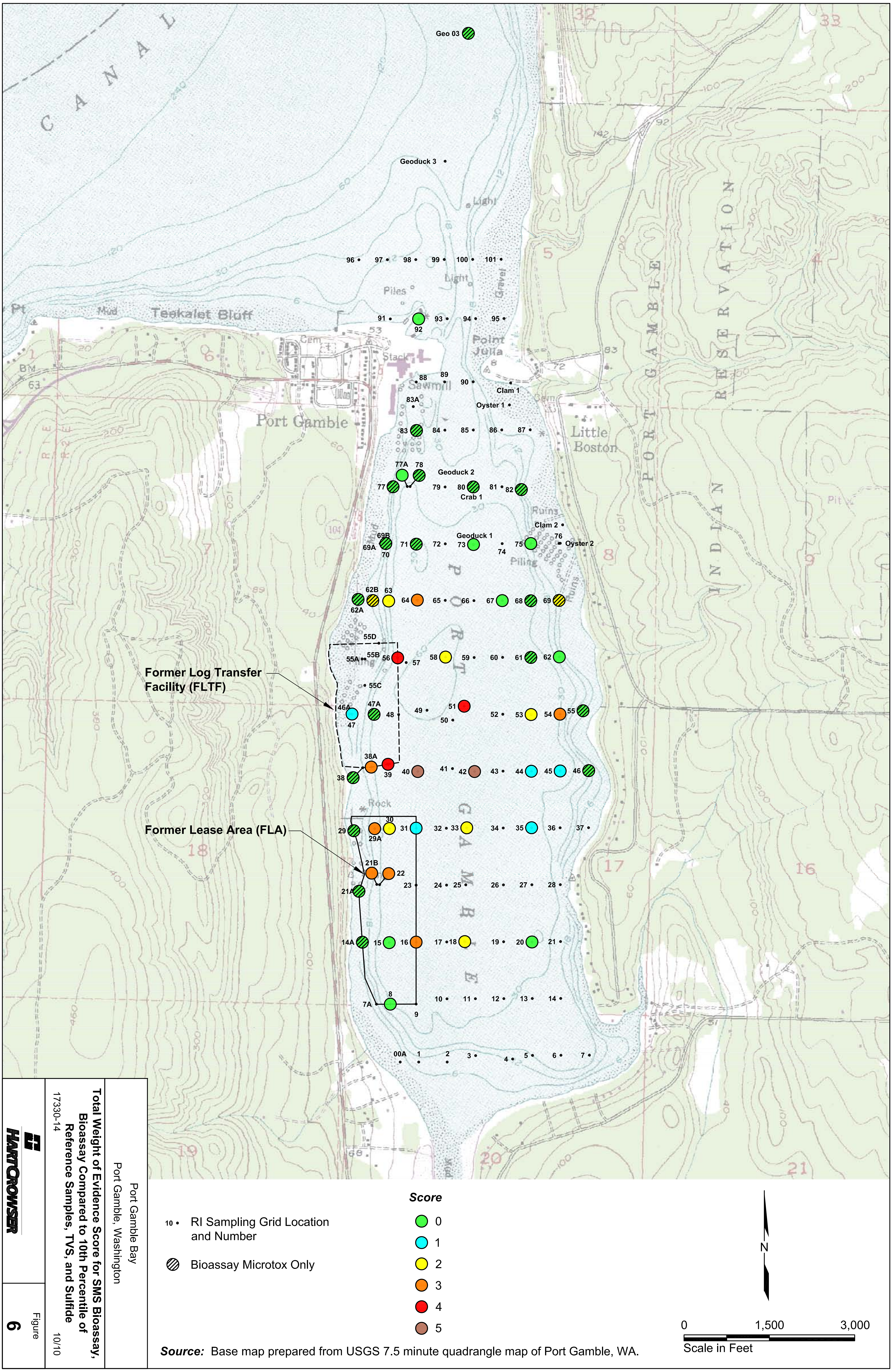
Figure
5



Source: Base map prepared from USGS 7.5 minute quadrangle map of Port Gamble, WA.

Port Gamble Bay
Port Gamble, Washington

Total Weight of Evidence Score for SMS Bioassay, Bioassay Compared to 10th Percentile of Reference Samples, TVS, and Sulfide

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Figure
6

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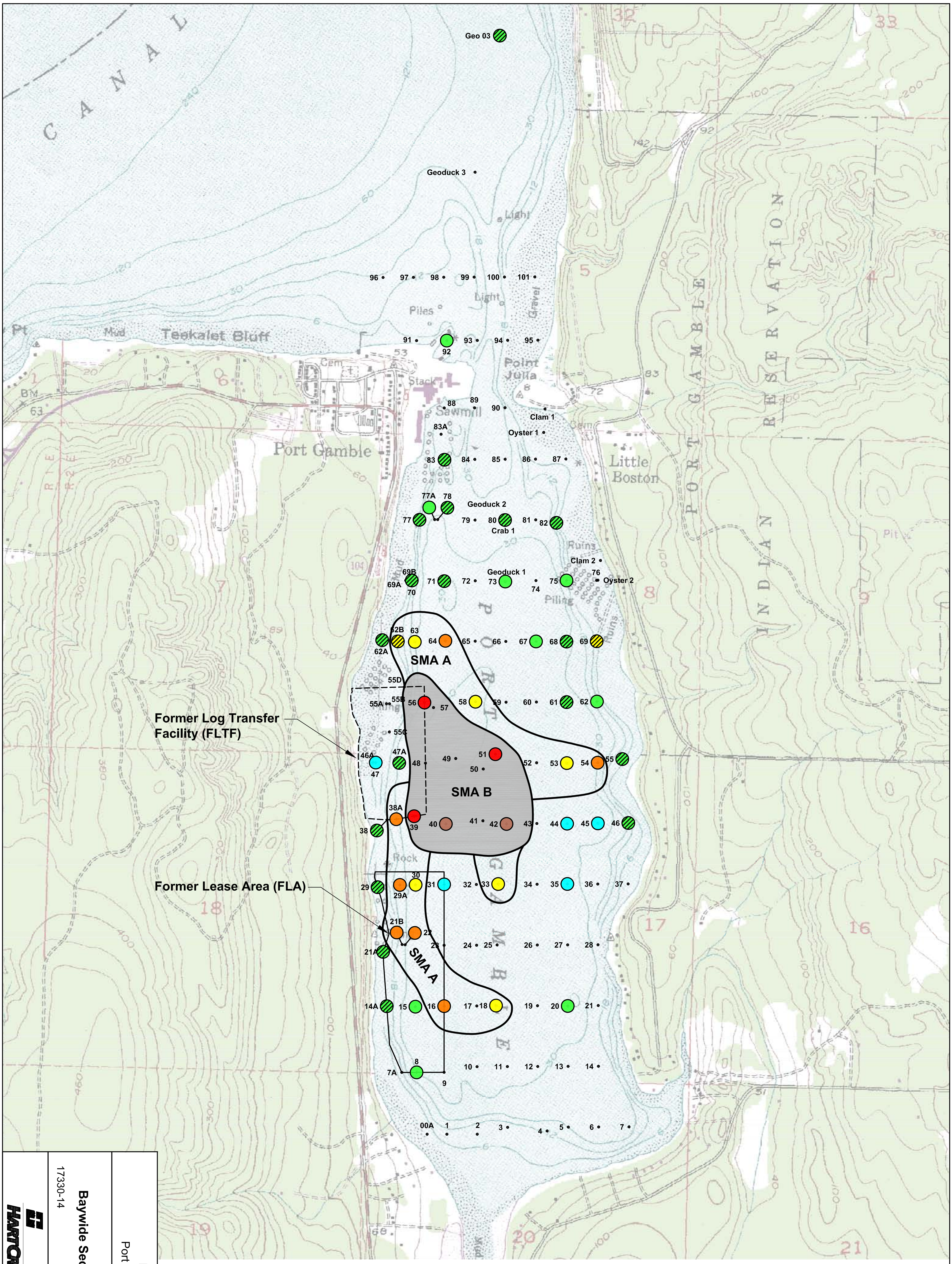

Score

10 •	RI Sampling Grid Location and Number
▨	Bioassay Microtox Only

🟢	0
🔵	1
🟡	2
🟠	3
🔴	4
🟤	5

Source: Base map prepared from USGS 7.5 minute quadrangle map of Port Gamble, WA.

Port Gamble Bay
Port Gamble, Washington

Baywide Sediment Management Areas

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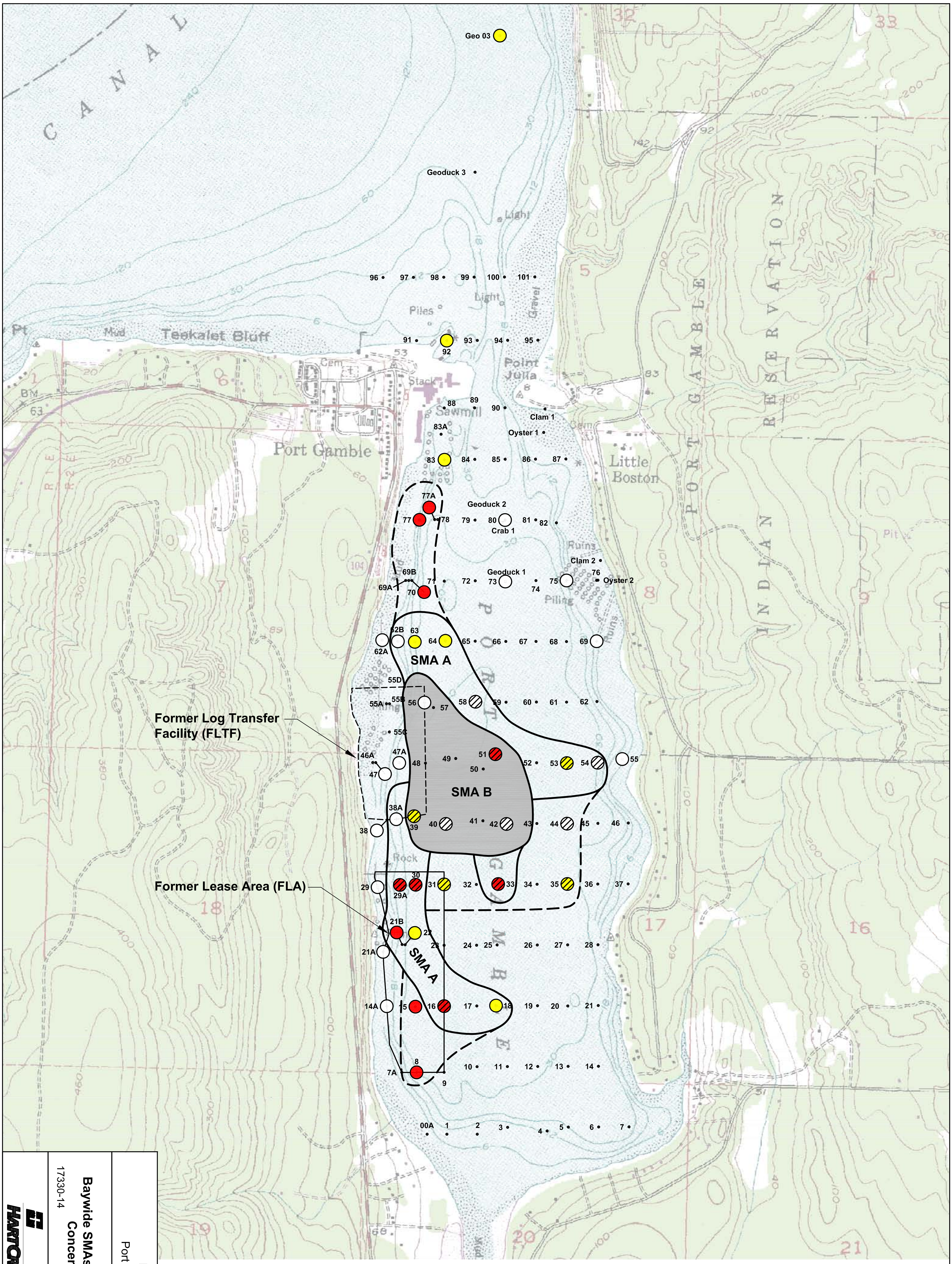
Figure
7



- 10 • RI Sampling Grid Location and Number
- — — SMA Boundary Incorporating Human Health Risks Based on Shellfish Ingestion
- ○ cPAH Data Gap (Elevated PQLs above 6.0 µg/kg TEQ Puget Sound Background
- 🟡 cPAH TEQ Exceedance >1x and <3x Background
- 🔴 cPAH TEQ Exceedance >3x Background
- ▨ Cadmium Concentration Exceeds Background

N

0 1,500 3,000

Scale in Feet

Source: Base map prepared from USGS 7.5 minute quadrangle map of Port Gamble, WA.

Port Gamble Bay
Port Gamble, Washington

Baywide SMAs Incorporating Chemicals of Concern Above Background

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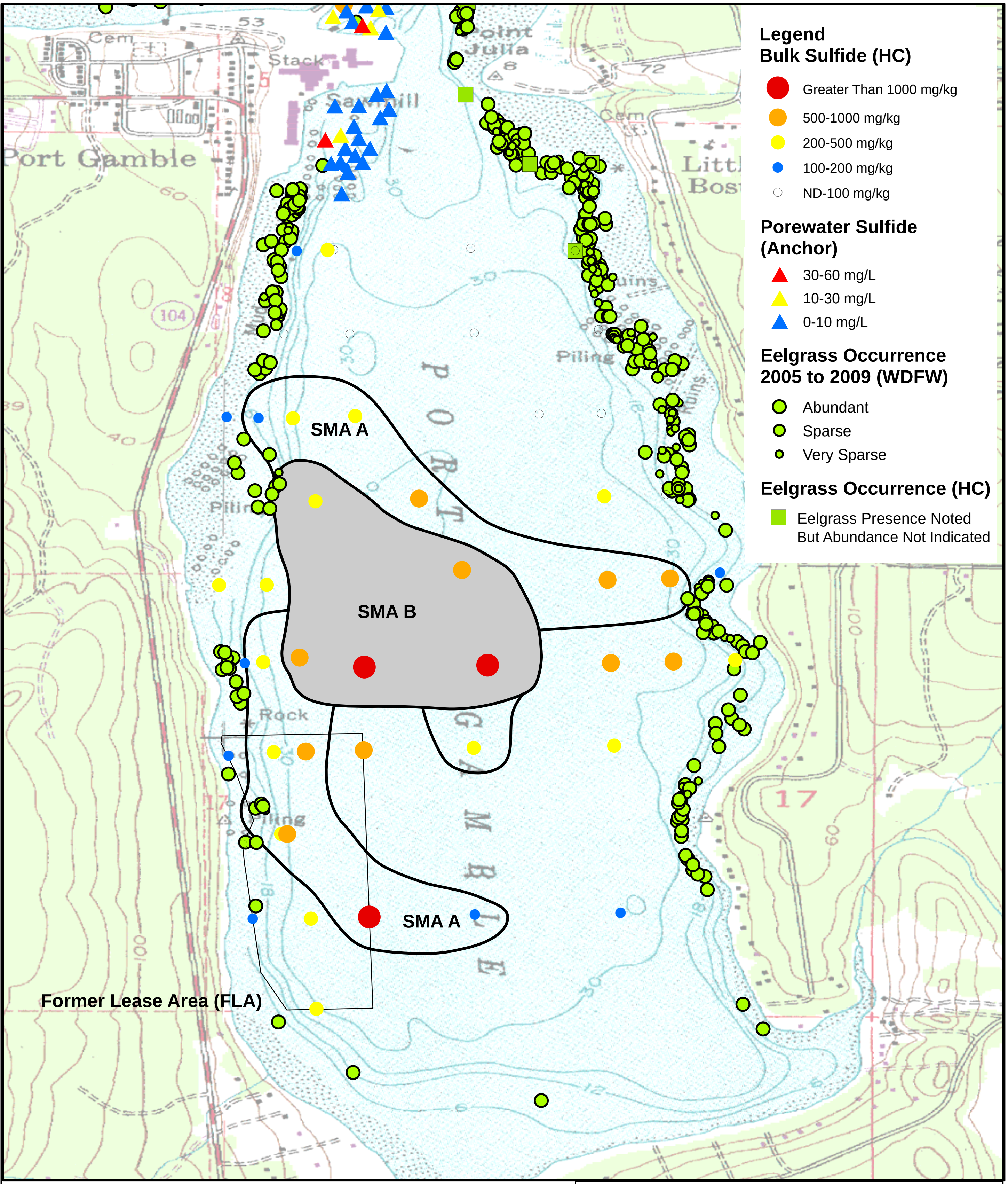
Figure

8



Notes: Map prepared from USGS 7.5 minute series quadrangle map of Port Gamble, WA and eelgrass data provided by Ecology.

0 1,000 2,000 4,000 Feet

N

Port Gamble Bay
Port Gamble, Washington

Eelgrass Occurrence and Sulfide Concentrations

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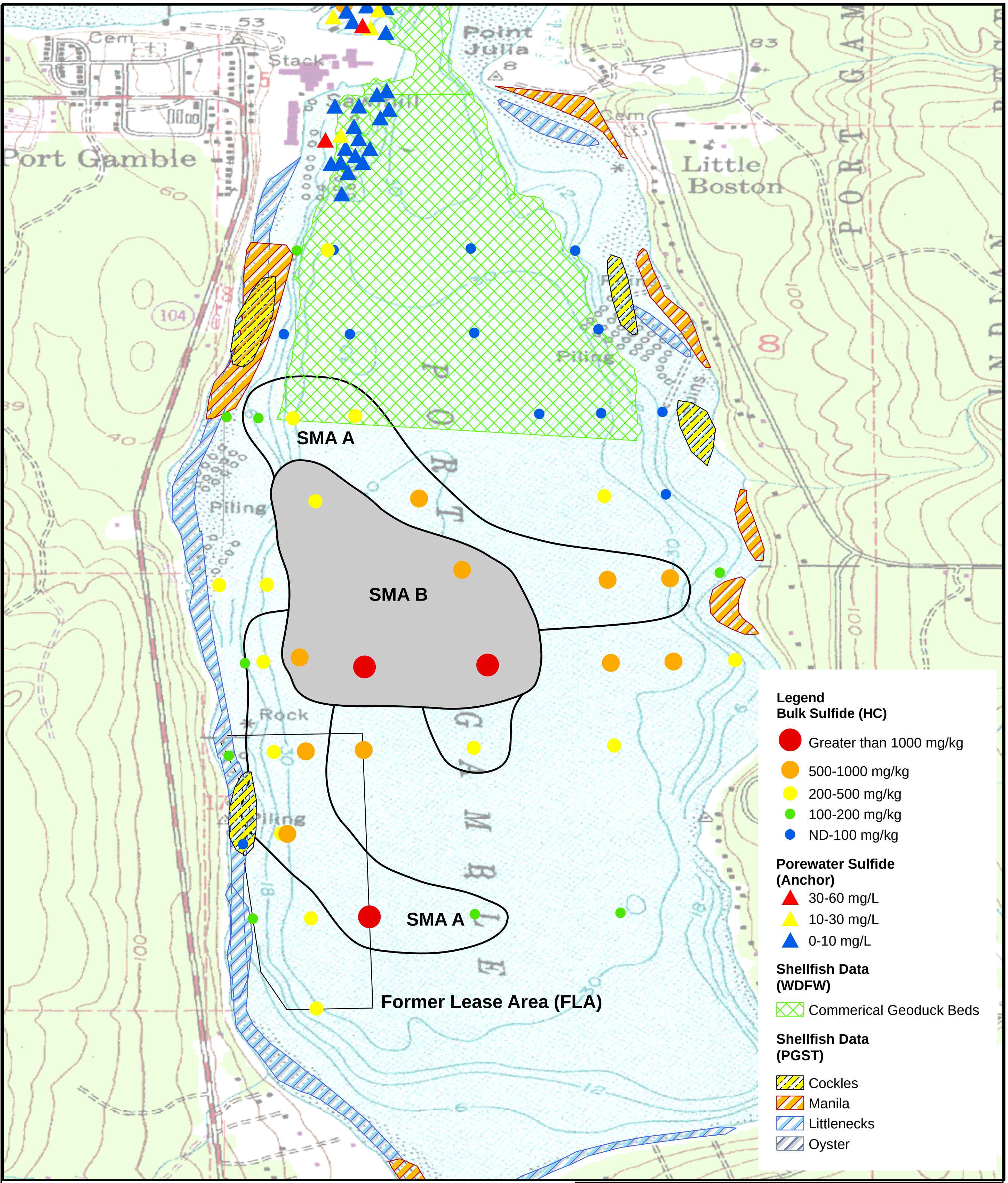
Figure

9

R:\17330 Ecology\Port Gamble\GIS\Eelgrass_map.mxd



Notes: Map prepared from USGS 7.5 minute series quadrangle map of Port Gamble, WA and eelgrass data provided by Ecology. Geoduck data provided by WDFW and all other shellfish data provided by the Port Gamble S'Klallam tribe.

0 750 1,500 3,000 Feet

N

Port Gamble Bay
Port Gamble, Washington

Shellfish Occurrence and Sulfide Concentrations

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Figure

10

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