Year 5 Monitoring Report Interim Remedial Action Log Pond Cleanup/Habitat Restoration

Log Pond
Bellingham, Washington

Prepared by:

The RETEC Group, Inc.
401 Harris Avenue, Suite 200
Bellingham, WA 98225

RETEC Project Number: PORTB-18876-230

Prepared for:

Port of Bellingham
1801 Roeder Avenue
Bellingham, WA 98225

August 3, 2006

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1801 Roeder Avenue
Bellingham, WA 98225

Prepared by:

____

Leslie McKee, Project Scientist

Reviewed by:

____

Dan Berlin, Project Manager

August 3, 2006

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1 Introduction

This report summarizes the results of monitoring activities conducted five years after a combined sediment cleanup/habitat restoration action at the Log Pond, located adjacent to the Whatcom Waterway Site in inner Bellingham Bay. A sediment cap was placed within the Log Pond by former land owner, Georgia-Pacific West, Inc. (GP) in 2000 as an Interim Remedial Action consistent with a Department of Ecology Agreed Order (00TCPNR-1418). The project was also authorized under Clean Water Act Permit No. 2002-2-00424 administered by the US Army Corps of Engineers (Corps). The sediment cap included containment measures to remediate sediment impacts while also enhancing and restoring inter-tidal and shallow sub-tidal aquatic habit.

In 2005, the Port of Bellingham (Port) assumed responsibility from GP for work carried out in the Log Pond under this Agreed Order. Consistent with the requirements of the Agreed Order, The RETEC Group, Inc. (RETEC) performed Year 5 monitoring of the cap as designated by the Operations, Maintenance, and Monitoring Plan (OMMP, Anchor, 2001a). the OMMP includes provisions for compliance monitoring at years 1, 2, 5, and 10 after construction. Implementation of the OMMP is required under Corps permit No. 2000-2-00424.

Previous monitoring efforts were conducted in May 2001 (Completion Report, Anchor, 2001a), Year 1 monitoring (Anchor, 2001b), and Year 2 monitoring (Anchor, 2002). These monitoring efforts were conducted consistent with the requirements of the Agreed Order and Corps permit. As described in the Completion Report, approximately 2.7 acres of shallow subtidal and 2.9 acres of low intertidal habitat was created from clean silt and sand. The goal of monitoring is to compare results and trend from all subsequent monitoring events to previous monitoring events.

1.1 Previous Monitoring

Year 1 and Year 2 monitoring presented data collected during the first and second year of post-construction monitoring. A summary of Year 1 and Year 2 monitoring results are provided below.

1.1.1 Surface Sediment Physical Monitoring

Year 1 bathymetric monitoring and other physical testing verified that the cap/habitat surface maintained its integrity following construction, and had developed suitable strength to generally resist further erosion. Year 2 monitoring showed that the majority of capping materials placed at the Log Pond had not been eroded significantly by vessel propeller wash or storm wave forces. No exceedances of chemical criteria were noted.

1.1.2 Sampling at the Cap Margins

Year 1 and Year 2 monitoring showed that surface water and sediment quality protection objectives had been attained within the nearshore seepage zone of the cap. These data also confirmed remedial design predictions of limited mobility of mercury within the Log Pond cap/habitat embankment.

1.1.3 Sediment Chemical Monitoring

Previous monitoring in the surface (Years 1 and 2) and subsurface (Year 1) zone of the cap/habitat layer were well below SMS Sediment Quality Standards (SQS) chemical criteria. Moreover, subsurface sampling from Year 1 showed that samples collected from 1.0 to 1.5 feet above the bottom of the cap were also below SQS criteria, indicating that the capping method successfully minimized mixing of underlying contaminated sediments into the bottom of the clean cap. These data also verify that chemicals are not migrating vertically into the cap/habitat layer.

1.1.4 Biological Monitoring

Epibenthic and benthic biomass, species richness, diversity, and evenness had recovered to Chuckanut Bay reference values within several months of construction, consistent with remedial design predictions of rapid re-colonization.

Bioaccumulation monitoring of juvenile Dungeness crab whole body tissue mercury concentrations demonstrated the protectiveness of the cap in controlling bioaccumulation exposures and restoration of aquatic habitat. Year 1 and 2 monitoring showed concentrations of mercury that were very low, and that were not significantly different from background sampling results.

Baseline and Year 2 fish seining in the Log Pond demonstrated use of the area by juvenile salmonids during their spring outmigration. These data and the healthy invertebrate community present in Log Pond benthic and epibenthic areas suggest a relatively high functioning habitat along the migration corridor of Bellingham Bay.

1.2 Year 5 Monitoring

Year 5 monitoring was performed by RETEC as part of the Whatcom Waterway RI/FS and to satisfy the Year 5 monitoring requirements of the OMMP. Any monitoring trends observed in recent and historic data are also discussed in this report. Figure 1-1 depicts Year 5 monitoring sampling locations in the Log Pond. Monitoring in the Log Pond during Year 5 consisted of the following activities:

- Well point water quality monitoring to evaluate whether surface water quality protection objectives continue to be met within the nearshore zone of the cap.

- Surface sediment chemical monitoring to ensure protection of habitat.

- Subsurface sediment chemical monitoring to ensure chemicals of concern are not migrating upward through the cap.

- Bioaccumulation sampling at the site and at a reference station to demonstrate the effectiveness of the cap in controlling bioaccumulation exposures.

- Biological monitoring within the Log Pond to document epibenthic and benthic colonization and juvenile salmonids utilization of the restored habitat.

The results of the Year 5 monitoring are presented in the following sections of this report.

2 Bathymetric Monitoring

Previous bathymetric monitoring events were conducted shortly after completion of in-water construction in February 2001, October 2001 (Year 1 survey), and October 2002 (Year 2 survey). Results of the Year 1 and Year 2 surveys identified that cap elevations were very similar to the initial constructed condition.

2.1 Year 5 Monitoring Results

Year 5 bathymetric monitoring was performed on October 12, 2005 by Blue Water Engineering using equivalent methods and transects used during previous surveys. Figure 1-1 includes bathymetric contours measured during Year 5 monitoring.

Changes in cap bathymetry since initial construction were estimated by comparing 2001 post-construction bathymetry to current (October 2005) contours. As shown on Figure 2-1, no significant changes in cap thickness were noted in most areas of the cap. Cap elevations in subtidal areas were generally within 0.5 feet of the post-construction survey elevations, indicating that the combined effects of erosion and consolidation were minimal in these areas since 2001. However, localized erosional areas were noted at the shoreline edges of the cap along the Central shoreline and in the Southern and Western Log Pond areas. Based on the observations from subtidal areas, these elevation changes are not attributable to consolidation. Areas of accretion were also noted in areas northeast and south of the Central shoreline, representing lateral movement and redeposition of capping material displaced from the Central and Southwestern shoreline areas.

Current minimum cap thickness was estimated by comparing 2000 pre-construction bathymetric data to existing contours. Based on estimated cap consolidation rates (Anchor 2000), the actual cap thicknesses in the areas where 3 feet of cap material was placed are likely 6 to 10 inches greater than the nominal thicknesses indicated by comparison of 2000 and 2005 surveys. This means that in areas where 3 feet of cap was placed, the final cap elevation (i.e., 2005 measurement) after consolidation will be 2.2 to 2.5 feet higher than the initial elevation (pre-construction 2000 survey) assuming 3 feet of cap placement and no erosion or accretion. As shown in Figure 2-2, the majority of the cap remains thicker than 3 feet (as conservatively estimated using the 2.5 foot nominal cap thickness contour). Thin cap areas are limited to the designed thin-layer cap areas and to the limited erosional areas noted above.

2.2 Supplemental Evaluations

Additional evaluation of current cap conditions was conducted to further understand the observed patterns of erosion and accretion. These evaluations include 1) identification and quantification of erosional forces (wave energies) acing upon the Log Pond shoreline and 2) estimates of sediment types that are expected to be stable under these energies. A third supplemental evaluation of surface sediment quality in shoreline areas with detected erosion or sediment redistribution is included in Section 4. The results of these evaluations will be used to evaluate potential shoreline enhancements or modifications that will improve long-term sediment stability of the cap. Potential shoreline enhancements or modifications are discussed in the Feasibility Study.

2.2.1 Wave Energy Estimates

A coastal engineering evaluation was performed to quantify the forces (i.e., wave energies) acting on shoreline areas of the Log Pond. The evaluations supplement previous evaluations conducted by Anchor Environmental as part of the Engineering Design report (Anchor, 2000). Additional narrative and calculation data are included as Attachment A.

Wave energies within the Log Pond vary with location, wind speed/direction and water depth. Based on available wind data and the calculations in Attachment A, the largest waves in the bay originate from the southwest, with significant (i.e., 33 percentile or typical design wave) wave heights of about 1.9 feet at low tide, and extreme storm waves of about 3.2 feet. But these waves cannot directly enter the Log Pond. Rather, they may enter the log pond only through diffraction (i.e., bending around the Port terminal). This diffraction process typically reduces the wave height by about half, and reduces potential erosive effects of these waves to a level consistent with wind-driven waves from the west (see below).

Given the geometry of the log pond, the greatest wave energies are caused by wind-generated waves from the west. Both typical and extreme storm waves from the west are fetch and depth limited. The wave period is estimated to be 2.3 seconds and the significant (i.e., 33 percentile) wave height is about 1.4 feet at low tide. These values are estimated at 2.4 seconds and 1.5 feet, respectively, at high tide. These calculations are consistent with those of Anchor from the Engineering Design Report (Anchor, 2000). The 1-percentile wave heights were estimated at 2.3 to 2.5 feet at low and high tides, respectively. These values do not change significantly under extreme storm events. The wave parameters for western wind-generated waves are relevant to shoreline stability calculations along the central and eastern portions of the Log Pond shoreline which are not shielded by the Port terminal from waves out of the west.

Portions of the log pond in the southern corner and western bulkheaded shoreline are shielded from direct wave action from the West. Along these sections of shoreline wave energies are lower. Waves affecting these shorelines include reflected and diffracted waves originating from the west/southwest, vessel wakes originating in the Whatcom Waterway, and waves driven by northerly winds. Waves reflected off a sloping beach are typically about one-third the height of the original waves (i.e., approximately 0.4 ft for a reflected 33-percentile westerly wave and 0.8 ft for a reflected 1-percentile westerly wave). These waves are similar in height to waves generated by northerly winds and/or vessel wakes. Vessel wakes were estimated at 0.4 feet. Waves generated by northerly winds were estimated at between 0.4 (33 percentile) and 0.7 feet (1 percentile) (see Attachment B). Winds and wakes from the north can encounter the southern and western shoreline directly, and at certain tidal elevations can reflect off of the Western bulkheaded shoreline and break on the Southern shoreline at wave-heights similar to those of the initial waves/wakes.

In summary, the more sheltered southern and western portions of the Log Pond are likely exposed to waves from storms and vessel wakes in the range of 0.4 ft (33 percentile) to 0.8 feet (1 percentile). The Central and Eastern sections of the Log Pond shoreline are likely exposed to waves from storms in the range of 1.4 feet (low tide 33-percentile) to 2.5 feet (high tide 1 percentile).

2.2.2 Sediment Stability Calculations

The initial stability of sediments subject to a given design wave varies with depth, sediment particle size and other factors. The water depth over the log pond will be controlled by the tides. Using MLLW as the controlling tide datum for the subtidal portion of the log pond, the minimum depth of water over the cap is assumed to vary from 12 feet to 0 feet. Storm waves will begin to feel the bottom at the outer edges of the log pond, in about 13 feet of water depth. Inshore of the edge, the waves begin to change from deepwater waves to transitional waves. The wavelength begins to shorten, the waves begin to steepen and increase in height and, as the water depth becomes shallower, the waves may break and reform. The waves eventually break against the shoreline (location determined by water level).

As described in the Environmental Design Report, the Phase 1 cap materials used within the Log Pond shoreline areas have a median particle size (d_{50}) of 1 mm. Using the wave calculations described above, the initial stability of these particles can be predicted using calculations defined by the Corps of Engineers *Shore Protection Manual*. The calculations (see Attachment A) indicate that the Phase 1 cap materials should be stable in water depths of between 4 and 6 feet in those areas receiving direct action of wind-driven waves from the west (i.e., Central Log Pond shoreline). At shallower depths in these areas, stability requires larger particle sizes, up to about 10 inches at a water depth of zero feet or in areas above MLLW.

In areas with lower wave energies (i.e., Southern and Western shorelines) the Phase 1 cap materials are expected to have higher stabilities in sub-tidal areas, but may be suspended by wave energies in inter-tidal areas that are periodically exposed by low tides. These wave energies are not expected to resuspend Phase 1 cap sediments in water deeper than about 1-2 feet (elevation varies with tide). In intertidal areas, the typical (33-percentile waves) design wave of 0.4 feet could disturb sediments of up to 20 mm in diameter, and the extreme (1-percentile) waves could disturb sediments of up to 75 mm in diameter (see Attachment A).

The observed patterns of erosion and accretion in the Log Pond are consistent with these calculations. The greatest erosion and lateral sediment redistribution has been observed in the highest energy areas of the central Log Pond shoreline. The cap that was initially placed along this shoreline edge has been eroded from elevations of approximately +2 to +3 feet above MLLW to current elevations of between 1 and 3 feet below MLLW. Sandy cap materials eroded from these areas have shifted laterally along the shoreline to areas north and south of the Central shoreline.

Erosion has also been observed in the area of the Southern and Western shorelines, with erosion focusing on the sloping inter-tidal beach areas, generally between elevations -2.0 feet MLLW and the top of the beach line. Reflected waves from the western bulkhead appear to have shifted some of these sediments in an easterly direction, from the southwestern corner toward the area of accretion near the former log ramp.

3 Well Point Water Quality Monitoring

Groundwater discharge areas adjacent to the Log Pond were identified in previous annual monitoring reports (e.g., Anchor, 2001 and 2002). These discharge areas were sampled to verify the seepage discharge compliance with State Surface Water Quality Standards (WAC-173-210A). The primary contaminant of concern for the seepage pathways is mercury. Applicable surface water quality standards for mercury are listed below:

- Acute criterion (1-hour average concentration) – 1.8 µg/L
- Chronic criterion (48-hour average concentration) – 0.025 µg/L.

This section describes the methods and the results of well point monitoring for Year 5.

3.1 Well Point Sampling Activities

Well point sampling occurred on July 21, 2005 and included samples taken from two locations (WP-1 and WP-2) within the Log Pond (Figure 1-1). Both of the locations were positioned at the margins of the cap as identified in the Year 1 Monitoring Report (Anchor, 2001). Water samples were collected with a 1-foot long temporary screen placed within the cap section immediately above the pre-cap sediment surface, in accordance with the OMMP. The sampling activities occurred at low tide for minimum tidal dilutions. Tide levels were 3.34 feet and 2.75 feet below mean lower low water (MLLW) at WP-1 and WP-2, respectively. Well point field logs are presented in Attachment B.

Samples were submitted to Brooks Rand LLC for low-level total and dissolved mercury and total suspended solids analyses in accordance with analytical methods outlined in the OMMP. One rinsate blank for dissolved mercury was submitted to the laboratory with the well point samples. The purpose of the rinsate blank was to assess the degree to which dissolved mercury was added or removed during field operations such as equipment decontamination procedures. Dissolved mercury concentrations were acceptably low in the rinsate blank.

3.2 Well Point Chemical Results

Well point chemical analyses included dissolved and total mercury and total suspended solids. Results are listed in Table 3-1 and the laboratory data report is included in Attachment C.

3.2.1 Mercury

Dissolved and total mercury concentrations detected at WP-1 and WP-2 each were well below both the chronic (0.025 µg/L) and acute (1.8 µg/L) water quality standards for mercury. Total Year 5 mercury concentrations were also lower than the Year 1 and 2 monitoring results summarized by Anchor (2001, 2002, respectively). Dissolved Year 5 mercury concentrations were lower than previous years for WP-1 and similar to previous concentrations from WP-2.

The results of the Year 5 water quality monitoring data indicate compliance of seepage discharges with state surface water quality standards and verify cap integrity with limited mobility of mercury within the cap. This finding is in agreement with monitoring conclusions from Year 1 and Year 2 monitoring events.

3.2.2 Field Measurements

Total suspended solids values was similar to values reported previously for WP-1 and WP-2. Other measurements, including turbidity, conductivity, pH, redox, and dissolved oxygen are similar to previous results. Temperature was slightly higher than previous activities, potentially because sampling was conducted later in the year (July) than in previous sampling events (May).

3.3 Conclusions

The results of well point sampling indicate that there is no significant migration of mercury in groundwater through the cap, and that recontamination of the cap from dissolved mercury transport is not occurring. These results are consistent with the source control analysis contained in the Engineering Design Report (Anchor, 2000).

4 Surface Sediment Monitoring

Surface sediment sampling was used to determine compliance with SMS criteria to assess the integrity of the cap. This section describes the methods and the results of surface sediment sampling for Year 5 monitoring.

4.1 Surface Sediment Sampling Activities

Two rounds of surface sampling were conducted as part of Year 5 surface sediment monitoring. Sampling was conducted at each of the six stations visited during the Year 1 and Year 2 surveys, as required by the OMMP. Additional sampling was also conducted in shoreline areas in areas identified to exhibit erosion. Each of these studies are discussed below. Both studies were intended to meet monitoring requirements regulated by the Sediment Management Standards (SMS) administered by the Washington State Department of Ecology (Ecology). Sample collection logs are provided in Attachment B.

4.1.1 Grab Sampling

Year 5 surface sediment sampling occurred on August 30, 2005 and included samples taken from six (6) locations within the Log Pond (SS-40, SS-75, SS-76, SS-301, SS-WP-1, and SS-WP-2; Figure 1-1 and 4-1). Surface sediment was collected from the biologically active zone within the top 12 centimeters using a hydraulic VanVeen grab sampler. Samples were collected from sediment composited from a single grab and submitted for chemical and physical testing, consistent with Puget Sound Estuary Program (PSEP) protocols (PSEP, 1997). Sufficient sediment volume was collected from each location for potential bioassay testing if chemical concentrations were elevated. Reference sediment was collected from Samish Bay for bioassay test comparison.

One equipment rinsate blank was submitted to the laboratory with the surface sediment samples for chemical analyses. The rinsate blank was prepared by pouring distilled water over the decontaminated sampling and compositing equipment into an appropriate sample jar. The blank was analyzed for mercury and extractable organic compounds. No compounds or analytes were detected in the equipment rinsate blank.

4.1.2 Supplemental Shoreline Sampling

Additional surface sediment sampling was performed on October 21, 2005 to supplement the Year 5 Log Pond monitoring data and to define sediment quality in areas where erosion has been observed. These areas included the Central, Southern, and Western Log Pond shoreline areas. Sampling was performed at low tide (-1.5 feet MLLW) at twelve (12) locations along the Southern, Western, and Central shoreline areas (SS-W1 to SS-W8 and SS-E1 to SS-E4), as shown on Figure 4-2. Samples were located at mudline elevations equal to or above -2.0 feet MLLW. Surface sediment was collected from the top 12 centimeters using a 3-inch gravity core liner (push core). Dedicated core liners were used for each push core. Homogenized samples from each push core were submitted to ARI for mercury testing.

4.2 Surface Sediment Physical and Chemical Results

Six (6) surface sediment grab samples were submitted to ARI for physical and chemical analyses, as designated by the OMMP. The following section describes the physical results and analyses and chemical results for surface sediment grabs. Sampling observations from grab samples are provided in Table 4-1. Chemical concentrations are provided in Table 4-2. Supplemental sampling field observations and mercury concentrations are contained in Table 4-3. The overall data quality objectives for collection and chemical testing of sediment samples were met, as set forth in the OMMP.

4.2.1 Surface Sediment Physical Results

Surface sediment physical results included observations of vegetation, fauna, and anthropogenic debris found during surface grabs. All information was recorded on field logs at each sampling station. Physical analyses included surface sediment texture. Table 4-1 provides a summary of information contained on these field logs and from physical analyses. Sampling locations are illustrated on Figure 4-1.

Vegetation and Fauna

Biota were noted during field observations in all surface grab samples (Table 4-1). Clams, mussels, small and large worms, and tube worms were commonly observed in grab samples, along with less commonly observed algae. Eelgrass blades were observed in samples SS-40, SS-75, and SS-WP-2, but these blades were not rooted.

Debris

Anthropogenic debris was encountered in a number of surface grabs. Occasional wood debris was noted in half of the samples ranging in size from 0.1-1 feet. One piece of concrete debris was encountered at SS-WP-1.

Surface Sediment Texture

Sediment texture is described in Table 4-2 for grab samples. Samples SS-40, SS-75, WP-1, and WP-2 were mostly sand with smaller portions of fines. Gravel was highest in sample SS-WP-2 (6 percent). Samples SS-301 contained 88 percent fines (clay and silt fractions) and SS-76 contained 55 percent fines. This distribution of surface sediments is consistent with grain size analysis observed during Year 1 and 2 monitoring. Observations of sediment texture for supplemental sampling are provided in Table 4-3.

4.2.2 Surface Sediment Chemical Results

Chemical analyses were conducted for SMS constituents by Analytical Resources, Inc. Grab sample analytes included mercury, miscellaneous extractable semivolatile organic compounds (SVOCs), and conventional parameters (Table 4-2). Supplemental shoreline samples were tested only for mercury (Table 4-3). Mercury concentrations from grab samples are shown on Figure 4-1. Mercury results of both grab sampling and supplemental sampling are provided in Figure 4-2.

OMMP Sampling

Miscellaneous extractable SVOCs were either not detected or below SQS criteria for all compounds. The results of Year 5 monitoring are consistent with historic data from Years 1 and 2.

Conventional parameters analyzed included total solids and total organic carbon. Total solids ranged from 47 to 79 percent. These values are consistent with ranges of historic data from Year 1 (53.6-83.6 percent) and Year 2 (55-84.7 percent). Total organic carbon content ranged from 0.454 to 2.43 percent, with an average of 1.90 percent. These values are consistent with values typically found in Bellingham Bay (averaging 2.0 percent, Ecology, 1994). These values are also consistent with historic data collected from Year 1 (average 1.75 percent) and Year 2 (average 1.08 percent) (Anchor, 2001).

Mercury concentrations at most sampled locations were below Sediment Quality Standards (SQS) criteria. These samples included SS-301, SS-40, SS-75, and SS-WP-2, as shown in Figure 4-1. Mercury concentrations were intermediate between SQS and Cleanup Screening Level (CSL) concentrations at sample SS-76 (0.58 mg/kg), based on a mean of replicate measurements of 0.55 mg/kg and 0.60 mg/kg. This sample was submitted for confirmatory biological testing as described in Section 4.3 below.

Sample SS-WP-1 (2.65 mg/kg), located in the southern corner of the log pond, contained mercury above the CSL (0.59 mg/kg) and the site-specific bioaccumulation screening level (BSL; 1.2 mg/kg) based on a mean of replicate results of 2.6 and 2.7 mg/kg. The presence of a BSL exceedance in this area represents a change from earlier results. No mercury concentrations above SQS criteria (0.41 mg/kg) were detected in previous sampling in 2001 or 2002.

Supplemental Shoreline Samples

Supplemental testing was performed to document the lateral extent of impacts. Mercury concentrations at stations along the Central Log Pond shoreline (stations SS-E1 through SS-E4) were all below the SQS. In the Southern and Western areas of the Log Pond, elevated mercury concentrations were detected at four locations adjacent to station SS-WP-1 (grab sample with mercury above CSL). These samples included SS-W1, SS-W2, SS-W4, and SS-W6. One of these locations (SS-W4) was located outside the footprint of the original cap as described in the Engineering Design Report (Anchor, 2000). The remaining exceedances were located adjacent to this area. These exceedances were located both within the areas constructed as a thin-layer cap (along the Western bulkhead) and within the areas constructed as a thick cap (3-feet or greater cap thickness), immediately offshore of sample station SS-W4 (see Figure 4-2).

Samples collected further offshore of these stations did not exhibit exceedances of the SQS (SS-W3, SS-W5, SS-W7, SS-W8), confirming that areas of sediment impact are limited to the extreme southwest corner of the Log Pond shoreline, adjacent to an area not capped as part of the Interim Action.

4.3 Surface Sediment Biological Testing

Bioassay testing was conducted on sediment collected during grab sampling for sample SS-76 based on elevated mercury concentrations above SQS criteria. Bioassay testing was not conducted on sample SS-WP-1 because this sample also exceeded the BSL.

Surface sediment samples were originally collected in August 2005. Bioassay testing was conducted on sample SS-76 and reference sample RR-02 for comparison purposes by Vizon Scitec of Vancouver, BC. Sample RR-02 contained similar grain size and physical properties as sample SS-76. Testing was initiated within the maximum 8-week hold time. The following marine bioassay tests were conducted on each sediment sample within the maximum 8-week hold time:

- Acute
  - 10-day amphipod mortality test using *Eohaustorius estuaries*
  - Larval normal development test using *Mytilus galloprovincialis*
- Chronic
  - 20-day juvenile polychaete growth test using *Neanthes arenaceodentata.*

Bioassay testing was initiated in October 2005, however, performance standards were not met for the larval development and juvenile polychaete tests. Retesting within the maximum 8-week hold time was not possible.

Results for the marine amphipod test met reference and control test acceptability criteria, as presented in Table 4-4. Sample SS-76 passed SQS criteria.

Surface sediment was recollected from station SS-76 and the reference station on March 13 and 14, 2006. Sampling methods and locations were identical to those used during the 2005 round of sampling. Testing was initiated within the maximum 8-week holding time by Northwestern Aquatic Sciences of Newport, OR. Results of the juvenile polychaete test and larval development test are summarized in Tables 4-5 and 4-6, respectively. Table 4-7 provides reference and control bioassay performance standards, and Table 4-8 provides SQS and CSL biological effects criteria. Bioassay endpoint evaluations are presented in Table 4-9.

Juvenile polychaete and larval development tests met test acceptability requirements for reference and control sediment (See Tables 4-5 and 4-6). Sample SS-76 passed SQS criteria for the juvenile polychaete and larval development tests, as shown in Table 4-8.

4.4 Conclusions

The majority of OMMP-specified surface sediment stations contained mercury concentrations below SQS criteria (SS-40, SS-301, SS-75, and SS-WP-2). Sample SS-76 contained mercury concentrations slightly above the numeric SQS criteria for mercury; however, this sample passed all three conformational bioassay tests, indicating that this station complies with SMS criteria.

Erosional areas sampled along the Central Log Pond shoreline showed mercury concentrations below SQS criteria. This area is subjected to the highest wave energies and has exhibited cap edge erosion. However, the cap thickness to date remains sufficient to have maintained containment over the sediments capped in this area.

In the Southwest corner of the Log Pond, results indicate that the surface detections of mercury at SS-WP-1 were caused by the resuspension of impacted sediments in the extreme southwestern corner of the Log Pond. The current distribution of mercury exceedances is very limited in extent. Additional actions are warranted to correct conditions in this area as part of the final cleanup of the Whatcom Waterway site. Such actions have been incorporated into the site Feasibility Study.

5 Subsurface Sediment Monitoring

Subsurface sediment sampling was used to verify the cap's effectiveness at blocking the upward migration of mercury through the cap. This section describes the methods and the results of sediment coring for Year 5.

5.1 Subsurface Sediment Sampling Activities

Subsurface sediment cores were collected from the Log Pond on August 31, 2005. Samples were taken from four (4) locations within the Log Pond (SC-40, SC-75, SC-76, and SC-301), as shown in Figure 1-1. Subsurface cores were collected using a vibracore sampler and processed at ARI. Sediment sampling logs are provided in Attachment B.

Sample intervals are designated in the OMMP based on physical observations of the Phase I and II capping layers. The Phase I cap consisted of fine to medium sand while the Phase II cap consisted of very sandy silt to very silty sand (Anchor, 2001). A summary of target sampling intervals for each sediment core is specified below:

- **Interval A –** 0.4 to 1.0 feet below mudline
- **Interval B –** 1.0 to 1.5 feet below mudline
- **Interval C –** 1.0 to 1.5 feet above the Phase I/II cap interface
- **Interval D –** 1.0 to 1.5 feet above the bottom of the Phase I cap
- **Interval E –** 1.0 to 1.5 feet below the bottom of the Phase I cap (original material).

As with Year 1 and Year 2 monitoring, the total number of intervals collected in each core varied with designed cap thickness. Due to the variation in cap thickness, it was not possible to collect all intervals in each core. However, more samples were collected from Log Pond cores from Year 5 monitoring than from Year 1 monitoring in depositional areas (SC-301, SC-40, and SC-75). A summary of the material present in each core is listed below:

- **Core SC-40:** The Phase I cap was identified at 0.4 feet below mudline and extends to the interface with original material at 2.0 feet below mudline. Interval A was collected at 0.4-1.0 feet below mudline (SC-40A). Interval B was collected 1.0-1.5 feet below mudline (SC-40B). Interval E was collected at 3.0-3.5 feet below mudline (SC-40E).

- **Core SC-75:** The Phase I cap was identified at the mudline and extends to the interface with original material at 5.2 feet below mudline. Interval A was collected at 0.4-1.0 feet below mudline (SC-75A). Interval B was collected 1.0-1.5 feet below mudline (SC-75B). Interval D was collected at 3.7-4.2 feet below mudline

(SC-75D). Interval E was collected at 5.7-6.2 feet below mudline (SC-75E).

- **Core SC-76:** The Phase I cap was identified at 0.4 feet below mudline and extends to the interface with original material at 4.8 feet below mudline. Interval A was collected at 0.4-1.0 feet below mudline (SC-76A). Interval B was collected 1.0-1.5 feet below mudline (SC-76B). Interval D was collected at 3.4-3.9 feet below mudline (SC-76D). Interval E was collected at 5.8-6.4 feet below mudline (SC-76E).

- **Core SC-301:** The Phase I/II cap interface was identified at 3.9 feet below mudline. Interval A was collected at 0.4-1.0 feet below mudline and (SC-301A). Interval B was collected 1.0-1.5 feet below mudline (SC-301B). Interval C was collected at 2.4-2.9 feet below mudline (SC-301C). Interval D was collected at 5.5-6.0 feet below mudline (SC-301D). Interval E was collected at 7.0-7.4 feet below mudline (SC-301E).

5.2 Subsurface Sediment Physical and Chemical Results

Sixteen (16) subsurface sediment samples were submitted to ARI for chemical analyses in accordance with PSEP protocols as designated by the OMMP. The purpose of subsurface sampling was to examine the vertical distribution of chemicals of concern in order to assess cap integrity. Physical analyses included grain size, and chemical analyses included mercury, miscellaneous extractable compounds, and conventional parameters. Results are presented in Table 5-1.

5.2.1 Subsurface Sediment Physical Results

Subsurface Sediment Texture

The sediment texture in Intervals A-D was consistent with typical cap material, including very sandy silt to very silty sand. Grain size in Interval E was silty sand and was consistent with previous descriptions of original material (e.g., Anchor, 2000). Cap material at locations SC-40, SC-75, and SC-76 was predominantly sand. Cap material in intervals A through C at location SC-301 was slightly sandy silt. Interval E at this location was sand.

5.2.2 Subsurface Sediment Chemistry Results

Mercury

Mercury concentrations in the shallow subsurface (Intervals A-D) at stations SC-301, SC-40, and SC-75 were very low and were consistently below the mercury SQS (0.41 mg/kg). Mercury concentrations in these samples ranged from 0.07-0.12 mg/kg. These shallow subsurface sediments represent Phase I and II cap samples. Mercury was below method reporting limits at station SC-76.

The deeper subsurface sediments, representing sediments underlying the cap (Interval E), had mercury exceedances at each station. Concentrations were 9.6 mg/kg at SC-301, 151 mg/kg and 153 mg/kg (reanalysis) at SC-40, 1.6 mg/kg at SC-75, and 1.5 mg/kg at SC-76. These values are similar to Year 1 mercury reported results (Anchor, 2001).

The lack of elevated mercury concentrations in cap sediments confirm that the sediments underlying the cap are being successfully contained and that no recontamination through vertical migration of mercury is occurring.

Miscellaneous Extractable Compounds

Of the miscellaneous extractable compounds analyzed only phenol and 4-methylphenol were detected. Sample SC-75E, measured from the underlying sediments, had a phenol concentration of 0.021 mg/kg and 4-methylphenol concentration of 0.05 mg/kg, each of which is well below SQS criteria.

Conventional Parameters

Conventional parameters analyzed included total solids and total organic carbon. Total solids were higher in cap material (57.3 to 92.7 percent) than in underlying cap material (41.6 to 51.3 percent). Total organic carbon was in ranges typical of Puget Sound sediment in cap material (0.097 to 2.08 percdent). Underlying cap material had higher organic carbon content (3.29 to 12.5 percent), consistent with previous sampling results for the Log Pond area prior to capping.

5.3 Conclusions

Subsurface chemical results confirm that mercury and other chemicals are not migrating upward through the capping sediments. The impacted sediments remain stable beneath the capping sediment, consistent with the project engineering design. The cap continues to isolate the underlying impacted sediment, consistent with the Engineering Design Report (Anchor, 2000).

6 Biological Monitoring

Three types of biological monitoring were performed, consistent with the OMMP. These included crab tissue mercury-bioaccumulation to investigate the cap's effectiveness in controlling bioaccumulation exposures. Juvenile Dungeness crab (*Cancer magister*) samples were collected at three stations in the Log Pond and whole tissue crab analysis was performed for mercury by BrooksRand, LLC.

6.1 Crab Tissue Monitoring

6.1.1 Juvenile Crab Sampling Activities

Juvenile Dungeness crab tissue sampling was conducted on August 30, 2005 at stations SS-74, SS-75, and SS-76 in the Log Pond. Crabs were collected in crab pots baited with crab bait purchased at a local fisheries supply shop. Attempts at collecting reference area crabs were made in west Bellingham Bay near Portage Island on September 1 and 2, 2005 and in Chuckanut Bay and off Post Point on October 20 and 21, 2005. No juvenile Dungeness crabs were captured during these four attempts, though large numbers of Red Rock crabs and Graceful crabs were present at these locations. As such, crab tissue data was compared against Year 2 reference samples.

Three juvenile crab replicate samples from each of the Log Pond stations were comprised of two to three juvenile crabs. The tissue samples were analyzed by the lab according to the OMMP. The results are listed in Table 6-1 and depicted in Figure 6-1. Laboratory data reports are contained in Attachment C.

6.1.2 Juvenile Crab Results

Juvenile Dungeness crabs ranged in carapace length from 62 to 108 mm. Whole body total mercury concentrations in crabs ranged from 0.0194 to 0.0375 mg/kg wet weight (Table 6-1). The arithmetic mean value was 0.028 mg/kg wet weight; this value was the same as the arithmetic mean of the reference sample. By comparison, the Year 5 arithmetic mean was similar to data from Years 1 (0.023 mg/kg ww) and 2 (0.020 mg/kg ww). Figure 6-1 shows that whole body total mercury concentrations were not significantly different from reference crabs collected in 2002 (Year 2). The whole-body mercury concentrations were 10 times lower than conservative benchmark concentrations created for human and wildlife consumption (Anchor and Hart Crowser, 2000).

The relatively low concentrations of mercury detected in the Year 5 juvenile crab tissue samples are not significantly different from natural background levels. These results demonstrate the effectiveness of the cap in controlling bioaccumulation exposures. This conclusion is consistent with previous findings based on data collected in Years 1 and 2 (i.e., Anchor, 2001 and 2002).

6.2 Fish Utilization

Juvenile salmonids utilization of the Log Pond was evaluated during the baseline survey (July 2000) and Year 2 monitoring during the spring outmigration period using beach seining. Available beach seine data from the Log Pond is provided in this section. Year 5 monitoring results are based on data collected by the Lummi Nation. The methods differed from those employed during baseline and Year 2 monitoring.

6.2.1 Fish Sampling Activities

The OMMP includes beach seine sampling to investigate fish utilization of the Log Pond. Previous seining was conducted as part of the baseline and Year 2 monitoring events. The Year 5 monitoring event was conducted using seining data collected by the Lummi Nation in the Log Pond under scientific collection permits. Based on discussions with the US Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and Washington Department of Fish and Wildlife (WDFW), additional beach seining was not conducted because the data would be redundant with the Lummi Nation data, and the additional disturbance to the juvenile salmonids was considered unwarranted by the agencies.

Beach seine data presented in Table 6-2 are summaries of organisms collected by Alan Chapman of the Lummi Nation in the Log Pond under separate scientific collection permits. Beach seine sampling was conducted in December 2004 and January, March, April, May, June, and July 2005. Data collected in May, June, and July overlap with juvenile salmonid outmigration periods monitored during Year 2.

6.2.2 Fish Sampling Results

Beach seine catches were identified to species and enumerated. All fish were released back into the water at their point of capture. Three Chinook salmon and five chum salmon were identified during the monitoring events. Salmonids were observed in March, April, May, and June 2005. Results confirm that the restored Log Pond area continues to be utilized by juvenile salmonids as observed during baseline and Year 2 monitoring.

6.3 Benthic and Epibenthic Recolonization

Benthic and epibenthic recolonization was evaluated in the Log Pond by Western Washington University's Huxley College of Environmental Studies using methods described in the OMMP. The benthic and epibenthic community report is included in Attachment E.

7 Recommendations

Year-5 monitoring of the Log Pond has been completed consistent with the OMMP. The results are generally favorable and demonstrate that the principal features of the cap are performing within project design limits. Key observations from the Year-5 monitoring include the following:

- Submerged cap areas are functioning as designed, with stability of the cap surface and continued compliance with SMS standards.

- Core sampling results confirm that the cap is successfully containing subsurface impacted sediments, with no upward migration of constituents into the bottom cap layers

- Well point sampling demonstrates that groundwater discharges to the cap are below applicable water quality limits, and are below the source control levels established in the Engineering Design Report (Anchor 2000).

- Biological sampling continues to show that the restored Log Pond area is utilized by juvenile salmonids and other fish, and that recolonization by benthic and epibenthic invertebrates occurred and has been maintained.

- Monitoring of mercury concentrations in crab tissue confirms that mercury bioaccumulation is being prevented, and that crab tissue levels are not significantly different from those in crabs collected from clean reference sites.

While overall monitoring data are favorable, the Year-5 monitoring did, however, show that wave energies are sufficient in some shoreline cap areas to resuspend some of the capping sediments. Limited areas of erosion have been noted along the Central and Southwest shoreline edges of the Log Pond cap. In the Central shoreline area, the erosion has not been sufficient to expose underlying sediment or to trigger cap recontamination. In the southwest corner of the Log Pond, the cap erosion has been minimal, but impacted sediments from an adjacent non-capped area have been resuspended, and this material has impacted surface conditions in the immediately-adjacent area.

Consistent with Ecology expectations and with the contingency measures defined in the Engineering Design Report and OMMP, enhancements to the shoreline edges of the Log Pond cap are to be implemented as part of the final Remedial Action for the Whatcom Waterway site. These enhancements are discussed as part of the site Feasibility Study. These measures will minimize the potential for future erosion of the cap edges, and will correct surface conditions in the southwest corner of the Log Pond.

The next scheduled full monitoring event for the Log Pond is the Year-10 monitoring event, scheduled for 2010. Based on the OMMP, and after review of the findings from the Year 1, 2 and 5 monitoring events, the Year-10 monitoring event should include the following parameters:

- Bathymetric monitoring to verify continued stability of the submerged cap areas and to monitor the performance of the cap enhancements to be implemented in shoreline cap areas.

- Surface chemical testing for mercury and phenolic compounds to verify compliance with performance standards for surface sediments.

- Well point testing of mercury concentrations to verify that upland groundwater discharges are consistent with surface water quality criteria and are protective of cap sediment quality.

- Biological monitoring, including juvenile crab tissue measurements to verify that mercury bioaccumulation is not occurring, and review of beach seining data collected by others. Consistent with discussions with USFWS, NMFS, and DFW, additional project-specific beach seining is not recommended, in order to minimize unnecessary disturbance of juvenile salmonids.

- We recommend that a diver survey be used in place of benthic, epibenthic testing to monitor cap recolonization. Results of benthic/epibenthic testing have demonstrated successful recolonization of the cap with sediment invertebrates. Full recolonization occurred during the first year following cap placement and has been consistently similar to reference stations in subsequent monitoring events. A diver survey would be more useful in monitoring potential eel grass colonization within the project area.

- Subsurface core sampling from Year 1 and Year 5 have demonstrated that no vertical migration of underlying sediments is occurring. Additional core sampling as part of the Year-10 monitoring event is not recommended. This will avoid the potential for the invasive core sampling to cause cap recontamination.

As specified in the OMMP, the Year-10 monitoring data will be summarized in a monitoring report and will be reviewed by Ecology (in consultation with the Corps and other agencies, consistent with the Bellingham Bay cooperative agreement) as part of the 5 year MTCA remedial action review.

8 References

Anchor, 2000. *Interim Remedial Action: Log Pond Cleanup/Habitat Restoration-Engineering Design Report*. Prepared for Georgia Pacific West Inc., Bellingham, Washington. Prepared by Anchor Environmental, L.L.C., Seattle, Washington. July 2000.

Anchor, 2001. *Year 1 Monitoring Report – Interim Remedial Action Log Pond Cleanup/Habitat Restoration Project*. Prepared for Georgia Pacific West Inc., Bellingham, Washington. Prepared by Anchor Environmental, L.L.C., Seattle, Washington. December 2001.

Anchor, 2002. *Year 2 Monitoring Report – Interim Remedial Action Log Pond Cleanup/Habitat Restoration Project*. Prepared for Georgia Pacific West Inc., Bellingham, Washington. Prepared by Anchor Environmental, L.L.C., Seattle, Washington. December 2002.

Anchor and Hart Crowser, 2000. *Remedial Investigation/Feasibility Study, Whatcom Waterway Site, Bellingham, Washington*. Prepared for Georgia Pacific West Inc., Bellingham, Washington. Prepared by Anchor Environmental, L.L.C. and Hart Crowser. July 2000.

RETEC, 2005. *Log Pond Technical Memorandum*. Prepared for the Port of Bellingham, Bellingham, Washington. Prepared by The RETEC Group, Inc. November 2005.

Tables

Table 3-1 Summary of Well-Point Monitoring Data at the Log Pond

Parameter	Units	Chemical Criteria (173-201A WAC)		WP-1			WP-2		
				Year 1	Year 2	Year 5	Year 1	Year 2	Year 5
		Chronic	Acute	2001	2002	2005	2001	2002	2005
Field Measurements									
Turbidity	NTU	NA	NA	5	3	1	2	4	0
Conductivity	µS/cm @ 25C	NA	NA	46,300	41,800	34,000	23,800	20,400	26,000
Temperature	Deg C	NA	NA	11.9	15.9	18.7	12.4	15.1	19.8
pH	pH units	NA	NA	7.1	7.1	7.3	7.6	7.5	7.5
Redox	mV	NA	NA	-146	-138	-304	-151	-95.0	-227
Dissolved oxygen	mg/L	NA	NA	0.2	0.4	3.3	0.4	3.3	1.7
Laboratory Measurements									
Total susp. Solids	mg/L	NA	NA	—	14.5 J	23.1	-	18.2 J	0.50 B
Mercury – dissolved	µg/L	0.025	1.8	0.0059	**0.0721**	0.00118	0.0074	< 0.0026	0.00277
Mercury – total	µg/L	0.025	1.8	**0.0579**	**0.1550**	0.0223	**0.0304**	**0.0313**	0.00285

Notes:
NA - not applicable
J indicates an estimated concentration
B indicates the reported value is less than the reporting detection limit but greater than the method detection limit.
— indicates no sample taken

Table 4-1 Year 5 Surface Sediment Testing Observations at the Log Pond

Sample ID	Date Collected	Coordinates (WA State Plane NAD27 North)		Field Observations of Sample							Sample Recovery Details			
		Easting	Northing	Color	Soil Type	Biological	Odor	Sheen	Attempt	Comments	Recovery Depth (cm)	Depth of Sample (cm)	Mudline Elevation (MLLW, ft)	Water Depth-Leadline (ft)
SS-40	8/30/2005	1600145.656	641472.8978	dark grey	silty fine to medium sand	worm tubes to 3.5", abundant oligochates, 17 bitium snails, algae, clam and mussel shells, 1 eel grass blade	slight sulfide-like odor	none	first	none	20	0-12	-7.1	11.8
SS-75	8/30/2005	1600371.811	641608.518	brownish grey	silty fine to medium sand	worm tubes to 3", trace shell fragments, dead mussel shells, eel grass blades	none	none	first	none	19	0-12	-7.0	9.9
SS-76	8/30/2005	1600704.392	641923.7035	dark grey to black	silty fine to medium sand	2.5" living clam	none	strong sulfide-like odor	first	abundant wood fragments up to 2"	22	0-12	-7.7	9.3
SS-301	8/30/2005	1600402.304	641492.9087	black	silt with trace fine sand grading to slightly sandy silt	common oligochates	none	none	first	wood 1.6" diameter, 2' long in jaws of grab	20	0-12	-4.4	10.1
SS-WP-1	8/30/2005	1600327.213	641237.2539	black	slightly sandy clayey silt	abundant polychaetes, trace shell fragments, 1 cm hemigrappsis crab, trace 1/2" mussel shells, juvenile fish 1", algae	none	none	second: jaws were open on first attempt due to large rock	refused first grab-jaws were open on a rock- accepted second grab	20	0-12	1.9	5.9
SS-WP-2	8/30/2005	1600628.498	641574.4003	grey	sand trace gravel up to 2" diameter	trace worms and shell fragments, several blades eel grass	none	none	first	1' long wood piece with 1 cm diameter, 1 3" long 1"diameter wood piece	22	0-12	-0.7	7.7

Notes:
All samples collected using hydraulic Vivien grab sampler.
Mudline elevations were calculated using leadline and height of tide elevations on the collection date
* Height of tide was determined using the XTide program provided online by the Biological Sciences Department, University of South Carolina, Columbia, South Carolina (http://tbone.biol.sc.edu/tide/sitesel.html)

Table 4-2 Summary of Surface Sediment Grain Size and Chemistry Results at the Log Pond

Compound / Sample ID	SMS Criteria		SS-301			SS-40			SS-75			SS-76			SS-WP-1			SS-WP-2		
Sample Depth			0-0.4'			0-0.4'			0-0.4'			0-0.4'			0-0.4'			0-0.4'		
Sample Date	SQS	CSL	2001	2002	2005	2001	2002	2005	2001	2002	2005	2001	2002	2005	2001	2002	2005	2001	2002	2005
Sample Year			Year 1	Year 2	Year 5	Year 1	Year 2	Year 5	Year 1	Year 2	Year 5	Year 1	Year 2	Year 5	Year 1	Year 2	Year 5	Year 1	Year 2	Year 5
Conventionals - %																				
Total Organic Carbon	—	—	**1.9**	**1.5**	**1.89**	**1.6**	**1.6**	**1.91**	**1**	**2.1**	**1.06**	**3.1**	**0.65**	**2.43**	**0.13**	**0.24**	**2.17**	**1.9**	**0.2**	**0.454**
Total Solids	—	—	**53.6**	**55**	**46.7**	**68.4**	**69.6**	**68.2**	**72.4**	**63.5**	**73.8**	**56.6**	**75.3**	**49**	**83.6**	**77.3**	**61.3**	**66.1**	**84.7**	**79.9**
Grain Size - %																				
Gravel	—	—	**0**	**1.3**	**0.2**	**0.3**	**2.9**	**0.3**	**0.4**	**0.4**	**0.1**	**1.6**	**0.2**	**1.0**	**5.1**	**2.1**	**1.8**	**1.2**	**6.8**	**6.3**
Sand	—	—	**8.5**	**13.4**	**11.7**	**84.1**	**49.1**	**74.4**	**92.8**	**55.9**	**85.2**	**61.4**	**92.9**	**43.8**	**94.2**	**94.9**	**62.7**	**55.7**	**91.6**	**92.5**
Silt	—	—	**76**	**70.7**	**69.5**	**11.1**	**27.2**	**13.9**	**4.4**	**27**	**9.1**	**29.1**	**4.6**	**39.3**	**0.7**	**2.0**	**18.9**	**35.7**	**1.4**	**0.6**
Clay	—	—	**15.5**	**14.6**	**18.7**	**3.8**	**20.7**	**11.5**	**2.4**	**16.7**	**5.6**	**7.9**	**2.1**	**15.9**	**0**	**1.0**	**16.5**	**7.4**	**0.2**	**0.6**
Fines (total silt and clay)	—	—	**91.5**	**85.3**	**88.2**	**14.9**	**47.9**	**25.4**	**6.8**	**43.7**	**14.7**	**37.0**	**6.7**	**55.2**	**0.7**	**3.0**	**35.4**	**43.1**	**1.6**	**1.2**
Metals - mg/kg																				
Mercury	**0.41**	**0.59**	**0.11**	**0.25**	**0.41**	**0.12**	**0.26**	**0.35**	< 0.07	**0.15**	**0.09**	**0.13**	< 0.05	***<u>0.58</u>*** [3]	< 0.05	**0.08**	***<u>2.65</u>*** [4]	< 0.07	**0.15**	**0.09**
Miscellaneous Extractables - mg/kg																				
2,4-Dimethylphenol	**0.029**	**0.029**	< 0.019	< 0.02	< 0.059 [2]	< 0.019	< 0.02	< 0.059 [2]	< 0.019	< 0.02	< 0.019	< 0.019	< 0.02	< 0.059 [2]	< 0.019	< 0.02	< 0.059 [2]	< 0.019	< 0.019	< 0.019
2-Methylphenol	**0.063**	**0.063**	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	< 0.019	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	< 0.059	< 0.019	< 0.019	< 0.019
4-Methylphenol	**0.67**	**0.67**	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	< 0.019	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	< 0.059	< 0.019	< 0.019	< 0.019
Benzoic Acid	**0.65**	**0.65**	< 0.19	< 0.2	< 0.59	< 0.19	< 0.2	< 0.59	< 0.19	< 0.2	< 0.19	< 0.19	< 0.2	< 0.59	< 0.19	< 0.2	< 0.59	< 0.19	< 0.19	< 0.19
Benzyl Alcohol	**0.057**	**0.073**	< 0.019	< 0.02	< 0.059 [1]	< 0.019	< 0.02	< 0.059 [1]	< 0.019	< 0.02	< 0.019	< 0.019	< 0.02	< 0.059 [1]	< 0.019	< 0.02	< 0.059 [1]	< 0.019	< 0.019	< 0.019
Pentachlorophenol	**0.36**	**0.69**	< 0.095	< 0.099	< 0.3	< 0.097	< 0.098	< 0.29	< 0.094	< 0.098	< 0.097	< 0.096	< 0.098	< 0.3	< 0.096	< 0.098	< 0.29	< 0.095	< 0.096	< 0.096
Phenol	**0.42**	**1.00**	< 0.019	< 0.020	< 0.059	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	**0.052**	< 0.019	< 0.02	< 0.059	< 0.019	< 0.02	< 0.059	< 0.019	< 0.019	< 0.019

Notes:
[1] = Value is non-detect. RDL exceeds SQS Criteria. MDL passes criteria.
[2] = Value is non-detect. RDL exceeds both SQS and CSL Criteria. MDL passes criteria.
[3] = Mean results of duplicate analyses. Individual sample results were 0.55 and 0.60 mg/kg. This sample was subsequently analyzed by confirmatory bioassays and passed all SMS criteria.
[4] = Mean results of duplicate analyses. Individual sample results were 2.7 and 2.6 mg/kg.
* = Duplicate measurement after reextraction and reanalysis
— = No criteria value established
< = Below laboratory instrument detection limit
Y = Reporting limit is raised due to instrument activity. Compound not detected.
B = Analyte was detected in the blank as well as the sample.
Bold = value exceeds laboratory detection limit
<u>Bold and underline</u> = value exceeds numeric SQS Criteria

Table 4-3 Summary Description and Mercury Results of Log Pond Compliance Monitoring Supplemental Sampling

Sample ID	Date Collected	Method	Coordinates (WA State Plane NAD27 North) Easting	Northing	Color	Soil Type	Odor	Sheen	Depth of Sample (cm)	Estimated Elevation (ft MLLW)	Mercury (mg/kg)
Compliance Monitoing Supplemental Sampling											
SS-E1	10/21/2005	Push Core	1600553.9	641672.7	Brownish Gray	wet, slightly silty SAND, medium grains	none	none	0-12	-2.0	0.05
SS-E2	10/21/2005	Push Core	1600606.2	641763.9	Gray	wet to moist slightly silty SAND, medium grains	none	none	0-12	-2.1	0.04
SS-E3	10/21/2005	Push Core	1600670.9	641841.2	Grayish Brown	slightly silty SAND, med grains	slight sulfide	none	0-12	-2.1	0.06
SS-E4	10/21/2005	Push Core	1600739.2	641911.4	Dark Gray	wet SANDY SILT	none	none	0-12	-2.0	0.15
SS-W1	10/21/2005	Push Core	1600322.9	641300.3	Black	very wet SILT	moderate sulfide	none	0-12	-1.9	***2.00***
SS-W2	10/21/2005	Push Core	1600272.3	641257.0	Dark Olive Gray	wet SAND, medium to coarse grains	slight sulfide	none	0-12	1.3	**0.43**
SS-W3	10/21/2005	Push Core	1600370.7	641252.9	Grayish Brown	moist SAND, medium to coarse multicolored grains	none	none	0-12	3.6	0.13
SS-W4	10/21/2005	Push Core	1600314.9	641198.3	Gray	wet SAND, medium to coarse grains	none	none	0-12	4.0	***2.08***
SS-W5	10/21/2005	Push Core	1600366.6	641388.7	Dark Gray	very wet CLAYEY SILT	slight sulfide	none	0-12	-1.7	0.30
SS-W6	10/21/2005	Push Core	1600211.7	641319.6	Dark Olive Gray	wet SILTY SAND, fine to medium grains	slight sulfide	none	0-12	0.0	***0.52***
SS-W7	10/21/2005	Push Core	1600226.4	641333.3	Dark Gray	wet slightly silty SAND, fine to medium grains	none	none	0-12	-2.5	0.12
SS-W8	10/21/2005	Push Core	1600418.0	641340.6	Dark Gray	very wet CLAYEY SILT	slight sulfide	none	0-12	1.2	0.18

Notes:
Mudline elevations for push core samples were estimated from bathymetry data mapped on October 12, 2005. Elevations for Van Veen grab samples were estimated based on wate depth and tide measurements.
* = Mean results of duplicate analyses. Individual sample results were 2.70 and 1.45 mg/kg.

Table 4-4 Summary of Bioassay 10- Day Amphipod Testing (*Eohaustorius estuarius*)

Sample Location	Replicate	Initial Count	Final Count	Percent Mortality
Control-1	A	20	20	0
	B	20	19	5
	C	20	20	0
	D	20	17	15
	E	20	18	10
	Mean			**6**
Control-2	A	20	19	5
	B	20	20	0
	C	20	19	5
	D	20	20	0
	E	20	20	0
	Mean			**2**
IJW-RR-02	A	20	16	20
	B	20	13	35
	C	20	14	30
	D	20	15	25
	E	20	18	10
	Mean			**24**
SS-76	A	20	19	5
	B	20	19	5
	C	20	20	0
	D	20	20	0
	E	20	17	15
	Mean			**5**

Table 4-5 Summary of Bioassay 20-Day Growth Juvenile Polychaete Testing *(Neanthes arenaceodentata)*

Sample Location	Replicate	Initial Count	Final Count	Percent Survival	Total Worm Weight (mg)	Average Weight Per Worm (mg)	Mean Individual Growth Rate (mg/ind/day)
Control-1	A	5	5	100	18.50	3.70	0.87
	B	5	5	100	23.80	4.76	1.14
	C	6	6	100	22.20	3.70	1.06
	D	5	4	80	18.80	4.70	0.88
	E	5	5	100	25.90	5.18	1.24
	Mean			**96**	**21.84**	**4.41**	**1.04**
IJW-RR-02	A	5	5	100	23.4	4.68	1.12
	B	5	5	100	19.8	3.96	0.93
	C	5	5	100	24.6	4.92	1.18
	D	5	5	100	22.1	4.42	1.05
	E	5	5	100	23.7	4.74	1.13
	Mean			**100**	**22.72**	**4.54**	**1.08**
SS-76	A	5	5	100	23.8	4.76	1.14
	B	5	5	100	21.6	4.32	1.02
	C	5	5	100	26.3	5.26	1.26
	D	5	5	100	17	3.40	0.8
	E	5	5	100	14.6	2.92	0.67
	Mean			**100**	**20.66**	**4.13**	**0.98**

Table 4-6 Summary of Bioassay Larval Mortality Testing (*Mytilis*

Site	Replicate	Initial Number of Embryos, T=0	Number Normal	Number Abnormal	Total Number	N_C/Mean Initial
Sea Water Control	A	259	248	9	257	1.02
	B	233	217	16	233	0.89
	C	235	236	8	244	0.97
	D	253	243	7	250	1.00
	E	241	207	5	212	0.85
	Mean	244	230	9	239	**0.94**

Site	Replicate	Number Normal	Number Abnormal	Total Number	N_{R2}/N_C
Reference (RR-02)	A	183	4	187	0.75
	B	128	3	131	0.52
	C	166	4	170	0.68
	D	126	5	131	0.52
	E	208	3	211	0.85
	Mean	162	4	166	**0.66**

Site	Replicate	Number Normal	Number Abnormal	Total Number	Mean Normal Survival (N_T/N_{R2})
SS-76	A	165	22	187	1.02
	B	176	30	206	1.09
	C	159	15	174	0.98
	D	93	27	120	0.57
	E	100	36	136	0.62
	Mean	139	26	165	**0.855**

Notes:
Replicates were run using standard method
N = normal counts
Subscripts: R2 = reference sediment RR-02, C = negative control

Table 4-7 Reference and Control Bioassay Performance Standards

Biological Test	Control		Reference	
	Criteria	Pass or Fail?	Criteria	Pass or Fail?
Amphipod	The control has a mortality of less than 10 percent ($M_C < 10\%$)	*Pass*	The reference has a mortality of less than 25 percent ($M_R < 25\%$)	*Pass*
Juvenile Polychaete	The control has a mortality of less than 10 percent and a target mean individual growth rate of 0.72 mg per individual per day. Control growth rates below 0.38 mg per individual per day will be considered a QA/QC failure (PSDDA, 1996) ($M_C > 10\%$ and MIG ≥ 0.38 mg)	*Pass*	The reference has a mean individual growth rate greater than or equal to 80 percent of the growth rate measured in the control ($MIG_R/MIG_C < 0.80$)	*Pass*
Larval	The control has a mean normal survivorship of greater than 70 percent of the initial count ($N_C/I \geq 0.70$)	*Pass*	The reference has a mean normal survivorship of greater than or equal to 65 percent of the mean normal survivorship measured in the control ($N_R/N_C \geq 0.65$)	*Pass*

Source: (Ecology, 1998b)

M = mortality, MIG = mean individual growth rate, N = normal counts, I = initial count

Subscripts: C = negative control, R = reference sediment

Table 4-8 Biological Effects Criteria[1]

Biological Test	SQS Biological Criteria	CSL Biological Criteria
Amphipod	The test sediment has a significantly higher (t-test, p = 0.05) mean mortality than the reference sediment, and the test sediment mean mortality exceeds 25 percent (M_T>25%)	The test sediment has a significantly higher (t-test, p = 0.05) mean mortality than the reference sediment, and the test sediment mean mortality is more than 30 percent greater (M_R-M_T > 30%) than the reference sediment mean mortality
Juvenile Polychaete	The mean individual growth rate in the test sediment is less than 70 percent of the mean individual growth rate in the reference sediment (MIG_T/MIG_R < 0.70), and the test sediment biomass is significantly different (t-test, p = 0.05) from the reference sediment biomass	The mean individual growth rate in the test sediment is less than 50 percent of the mean individual growth rate in the reference sediment (MIG_T/MIG_R < 0.50), and the test sediment biomass is significantly different (t-test, p = 0.05) from the reference sediment biomass
Larval	The test sediment has a mean survivorship of normal larvae that is significantly less (t-test, p = 0.05) than the mean normal survivorship in the reference sediment, and the mean normal survivorship as a percentage of the negative control is less than 85% than the mean normal survivorship in the reference sediment as a percentage of the negative control [(N_T/N_R)<0.85]	The test sediment has a mean survivorship of normal larvae that is significantly less (t-test, p = 0.05) than the mean normal survivorship in the reference sediment, and the mean normal survivorship as a percentage of the negative control is less than 70% than the mean normal survivorship in the reference sediment as a percentage of the negative control [(N_T/N_R)<0.70]

[1] SMS Bioassay Evaluation Endpoints - Ecology, 1998b

M = mortality, MIG = mean individual growth rate, N = normal counts, I = initial count

Subscripts: C = negative control, R = reference sediment

Table 4-9 Bioassay Endpoint Evaluation

Bioassay Test	Site	Statistical Difference Present (Yes/No) [1] t-test, p=0.05	Exceeds SQS Effect Criteria (Yes/No)	Exceeds CSL Effect Criteria (Yes/No)	SQS/CSL Bioligical Criteria (Pass/Fail) [2]
Amphipod			*M_T > 25%, Absolute*	*M_R-M_T>30%*	
	SS-76	No	No	No	Pass
Juvenile Polychaete			*MIG_T/MIG_R<0.70*	*MIG_T/MIG_R<0.50*	
	SS-76	No	No	No	Pass
Larval			*(N_T/N_R)<0.85*	*(N_T/N_R)<0.70*	
	SS-76	No	No	No	Pass

[1] Statistical analyses conducted to determine if test sediment performance is significantly lower than reference sediment (p=0.05) using DMMP/SMS Bioassay Statistics Program Beta v2.0c developed by the Corps of Engineers, Seattle District.
[2] SQS and CSL Biological Criteria for each bioassay are stated in Table 6.
M = mortality, N = normal counts, MIG = mean individual growth rate
Subscripts: R = reference sediment, T = test sediment, C = negative control
The test sample was compared to Reference 2 (RR-02) due to similarities in percent fines

Table 5-1 Year 5 Subsurface Sediment Data

Compound	SQS (SMS Criteria)	CSL (SMS Criteria)	SC-301A	SC-301B	SC-301C	SC-301D	SC-40A	SC-40B	SC-75A	SC-75B	SC-75D	SC-76A	SC-76B	SC-76D	SC-301E	SC-40E	SC-75E	SC-76E
Sample ID			Phase I and Phase II Cap Samples: SC-301	SC-301	SC-301	SC-301	SC-40	SC-40	SC-75	SC-75	SC-75	SC-76	SC-76	SC-76	Underlying Sediment Samples: SC-301	SC-40	SC-75	SC-76
Sample Date			8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005	8/31/2005
Conventionals - %																		
Total Organic Carbon	—	—	**2.08**	**1.83**	**1.59**	**0.132**	**0.15**	**0.345**	**1.55**	**0.121**	**0.097**	**0.06**	**0.108**	**0.163**	**7.25**	**6.29**	**3.29**	**12.5**
Total Solids	—	—	**57.3**	**61.7**	**60.1**	**84.1**	**79.2**	**76.7**	**78.8**	**92.7**	**89.5**	**91.2**	**90.9**	**79.9**	**51.3**	**41.6**	**47.3**	**43.5**
Grain Size - %																		
Gravel	—	—	< 0.01	**0.4**	< 0.01	**7.5**	**0.4**	**0.5**	**0.2**	**0.2**	**0.6**	**0.6**	**0.3**	**1.1**	**12.3**	**0.2**	**5.3**	**7**
Sand	—	—	**8.2**	**9.9**	**7.8**	**91**	**97.5**	**96.6**	**85.6**	**98.6**	**98.1**	**98.5**	**96.1**	**95.7**	**44.4**	**26.4**	**21.8**	**53.5**
Silt	—	—	**79.9**	**76.4**	**83.3**	**0.7**	**0.8**	**1.2**	**11.1**	**0.4**	**0.4**	**0.6**	**3.2**	**2.5**	**24.1**	**39.9**	**35.5**	**24.9**
Clay	—	—	**11.8**	**13.2**	**8.9**	**0.7**	**1.5**	**1.7**	**3.3**	**0.7**	**0.8**	**0.3**	**0.4**	**0.6**	**19.2**	**33.5**	**37.5**	**14.5**
Metals - mg/kg																		
Mercury	**0.41**	**0.59**	**0.12**	**0.12**	**0.11**	< 0.05 U	< 0.05 U	**0.07**	**0.09**	< 0.04 U	< 0.04 U	< 0.04 U	< 0.05 U	< 0.04 U	***9.6***	***152*** [3]	***1.6***	***1.5***
Miscellaneous Extractables - mg/kg																		
2,4-Dimethylphenol	**0.029**	**0.029**	< 0.02	< 0.02	< 0.019	< 0.019	< 0.019	< 0.02	< 0.02	< 0.02	< 0.019	< 0.02	< 0.019	< 0.02	< 0.077 [2]	< 0.092 [2]	< 0.02	< 0.096 [2]
2-Methylphenol	**0.063**	**0.063**	< 0.02	< 0.02	< 0.019	< 0.019	< 0.019	< 0.02	< 0.02	< 0.02	< 0.019	< 0.02	< 0.019	< 0.02	< 0.077 [2]	< 0.092 [2]	< 0.02	< 0.096 [2]
4-Methylphenol	**0.67**	**0.67**	< 0.02	< 0.02	< 0.019	< 0.019	< 0.019	< 0.02	< 0.02	< 0.02	< 0.019	< 0.02	< 0.019	< 0.02	< 0.077	< 0.092	**0.05**	< 0.096
Benzoic Acid	**0.65**	**0.65**	< 0.2	< 0.2	< 0.19	< 0.19	< 0.19	< 0.2	< 0.2	< 0.2	< 0.19	< 0.2	< 0.19	< 0.2	< 0.077	< 0.092	< 0.2	< 0.096
Benzyl Alcohol	**0.057**	**0.073**	< 0.02	< 0.02	< 0.019	< 0.019	< 0.019	< 0.02	< 0.02	< 0.02	< 0.019	< 0.02	< 0.019	< 0.02	< 0.077 [2]	< 0.092 [2]	< 0.02	< 0.096 [2]
Pentachlorophenol	**0.36**	**0.69**	< 0.099	< 0.098	< 0.096	< 0.097	< 0.097	< 0.098	< 0.097	< 0.099	< 0.097	< 0.098	< 0.097	< 0.098	< 0.39 [1]	< 0.46 [1]	< 0.098	< 0.48 [1]
Phenol	**0.42**	**1.00**	< 0.02	< 0.02	< 0.019	< 0.019	< 0.019	< 0.02	< 0.02	< 0.02	< 0.019	< 0.02	< 0.019	< 0.02	< 0.077	< 0.092	**0.021**	< 0.096

Notes:
[1] = Value is non-detect. RDL exceeds SQS Criteria. MDL passes criteria.
[2] = Value is non-detect. RDL exceeds both SQS and CSL Criteria. MDL passes criteria.
[3] = Mean results of duplicate analyses. Individual sample results were 151 and 153 mg/kg.
* = Duplicate measurement after reextraction and reanalysis
— = No criteria value established
< = Below laboratory instrument detection limit
Bold = value exceeds laboratory detection limit
Bold and underline = value exceeds SQS Criteria
Bold , underline, and italics = value exceeds CSL Criteria

Subsample Description:
SC-XXA - sample interval 0.4 to 1.0 ft below mudline
SC-XXB - sample interval 1.0 to 1.5 ft below mudline
SC-XXC - sample interval 1.0 to 1.5 ft above the Phase I/II cap interface
SC-XXD - sample interval 1.0 to 1.5 ft above the bottom of the Phase I cap
SC-XXE - sample interval 1.0 to 1.5 ft below the bottom of the Phase I cap

Table 6-1 Summary of Crab Tissue (*Cancer magister*) Data

Sample ID	Sample Number	Total Mecury (mg/kg; wet wt)			Juvenile Crab Carapace Widths (mm)		
		Year 1 2001	Year 2 2002	Year 5 2005	Year 1 2001	Year 2 2002	Year 5 2005
SS-74	SS-74-A	0.0207	0.0289	0.0291	59, 60, 63, 53, 58, 59, 55, 68	57, 64, 68, 54, 60, 62, 54, 58, 65	72,83, 70, 90, 89, 108, 93, 108, 102
	SS-74-B	0.0487	0.0216	0.0284			
	SS-74-C	0.0176	0.0187	0.0375			
SS-75	SS-75-A	0.0171	0.0234	0.0225	56, 67, 62, 73, 58, 68	65, 78, 54, 65, 55, 57	88, 84, 90, 85
	SS-75-B	0.0237	0.0285	0.0354			
	SS-75-C	0.015	0.0215	0.0233			
SS-76	SS-76-A	0.0258	0.0143	0.0194	59, 68, 56, 66, 67, 68	53, 68, 65, 71, 52, 68	85, 79, 74, 68, 83
	SS-76-B	0.0167	0.0152	0.0359			
	SS-76-C	0.0237	0.00954	0.0214			
Reference [a]	REF-1	—	0.0365	—	—	60, 71, 83, 83, 83, 83	—
	REF-2	—	0.0199	—	—		—
	REF-3	—	0.308*	—	—		—
Average Total Mercury Concentration		**0.023**	**0.020**	**0.028**			
Standard Deviation		0.010	0.006	0.007			

Notes:
a) = Reference station for Year 2 was located near Portage Island in western Bellingham Bay.
Mercury concentrations have been blank corrected for Years 1, 2, and 5.
Values from Years 1 and 2 were provided by Anchor Environmental, LLC.
* = This sample result is an outlier. The higher result is suspected to be a laboratory artifact.

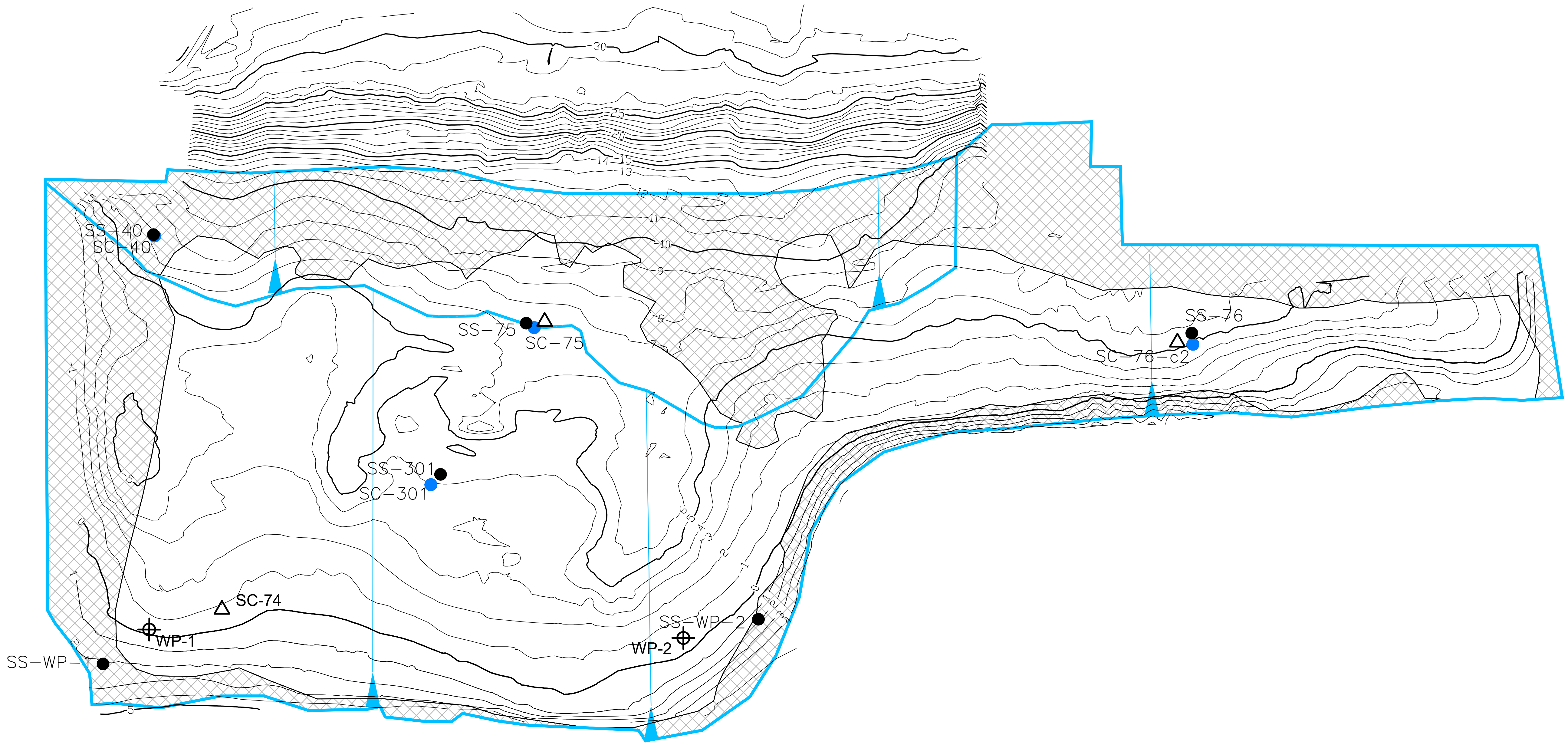
Table 6-2 Summary of Fish Seining for the Log Pond

Date	12/22/2004	12/22/2004	1/3/2005	1/3/2005	3/10/2005	4/5/2005	4/18/2005	5/2/2005	5/27/2005	6/2/2005	6/21/2005	6/27/2005	7/13/2005	7/26/2005	Total
Salmonids															
Chinook: total					1		1					1			3
Chinook: unmarked					1		1					1			3
Chum salmon							5	1							6
Other fish															
Sculpin			2	2	7	6	10	11	6	1	12	5	1		63
Stickleback			1					2							3
Starry flounder	1		2		6		2		5	1	1	5	2		25
Pipefish											2				2
Shiner perch												25	2		27
Saddle					2										2
Lamprey	1	3													4
Shrimp	2	1	12	20	20	6	10								71
Dungeness crab										1					1
Observations															
Tide Height	8.6	8.1	8.4	7.3	3.7	5.4	5.4	6	6	4.6	3	5.4	3.8	4.8	
Clarity	clear	clear	clear	clear	clear	clear	30cm	clear	clear	63cm	clear	clear	80cm	clear	
Surface Salinity	20.9	20.9	22.6	22.6	23.3	22.8	2.7	14.1	23.4	3.9	23	11.1	4.9	14.4	
Salinity @ 3 ft	20.9	20.9	30.4	30.4	27.8	24.5	5.9	22	27.9	24.6	24.6	18.3	5	20.5	
Surface Temperature	8.2	8.2	5.9	5.9	10.4	8.8	10.9	13.7	15.7	15.9	18.5	16.4	20.6	16.1	
Temperature @ 3 ft	8.2	8.2	8.3	8.3	9.6	8.8	9.6	13.7	14	16	18.1	16.6	20.6	20	

Notes:

Consistent with discussions with USFWS, NMFS, and DFW, separate fish seining was not conducted as part of the Year 5 monitoring event in order to reduce unnecessary disturbance to juvenile salmonids. The above sampling data has been reported for other seine activities conducted in the Log Pond by the Lummi Nation under the tribe's scientific collection permits.

Figures



LEGEND

PHASE I AND II CAP LIMITS FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)

THIN LAYER CAPPING AREA (0.5' TO 3') FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)

OCTOBER 2005 BATHYMETRY (MLLW)

SS-76 ● GRAB SAMPLE LOCATION

SC-76 ● CORE LOCATION

SC-76 △ CRAB TISSUE COLLECTION LOCATION

WP-1 ⌖ WELL POINT LOCATION

40 0 80

SCALE IN FEET

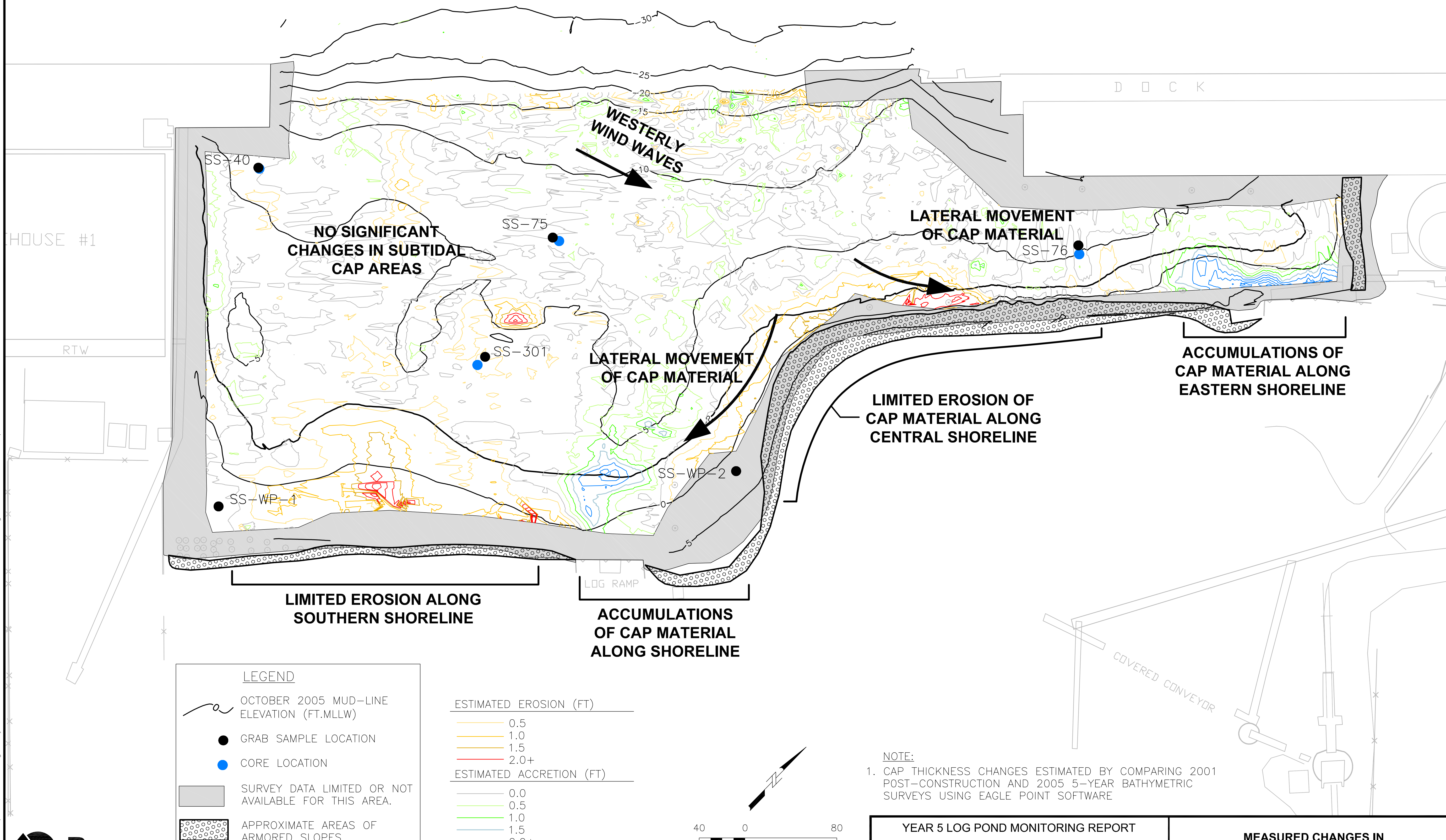
NOTES:

1. BATHYMETRY SHOWN FROM OCTOBER 12, 2005 SURVEY. PERFORMED BY BLUE WATER ENGINEERING. (FT. MLLW)

RETEC

YEAR 5 LOG POND MONITORING REPORT PORTB-18876-210	YEAR 5 LOG POND SAMPLING LOCATIONS AND BATHYMETRY
DATE: 07/31/06 DRWN: A.S./SEA	FIGURE 1-1

File: H:\18876\18876S102.dwg Layout: FIGURE 1 User: emarshall Plotted: Aug 02, 2006 - 3:06pm Xref's:



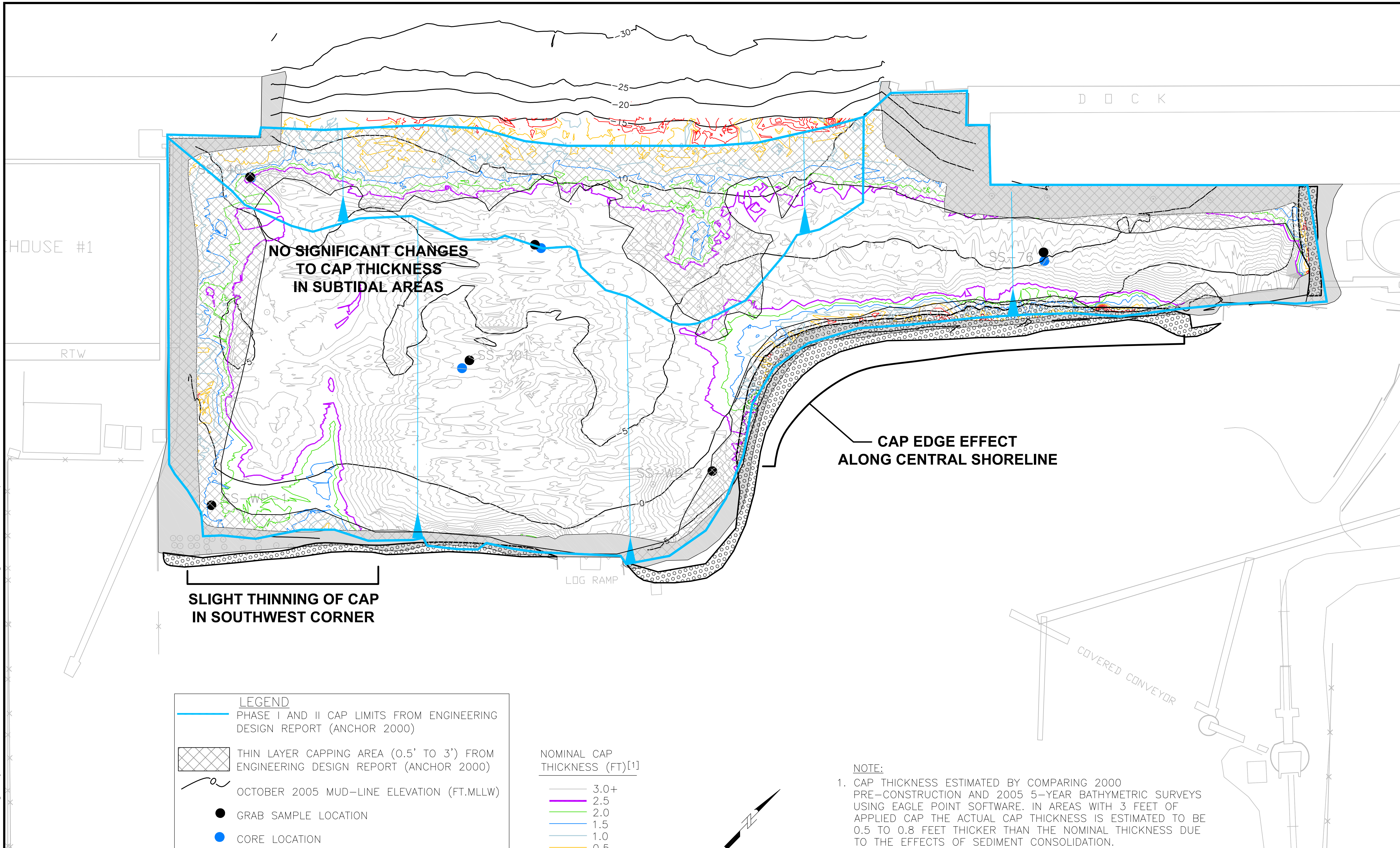
NOTE:

1. CAP THICKNESS CHANGES ESTIMATED BY COMPARING 2001 POST-CONSTRUCTION AND 2005 5-YEAR BATHYMETRIC SURVEYS USING EAGLE POINT SOFTWARE

RETEC

YEAR 5 LOG POND MONITORING REPORT	MEASURED CHANGES IN CAP THICKNESS
PORTB-18876-210	
DATE: 07/31/06 DRWN: A.S./SEA	FIGURE 2-1

File: H:\18876\18876S105.dwg Layout: FIGURE 2-1 User: emarshall Plotted: Aug 02, 2006 - 3:17pm Xref's:



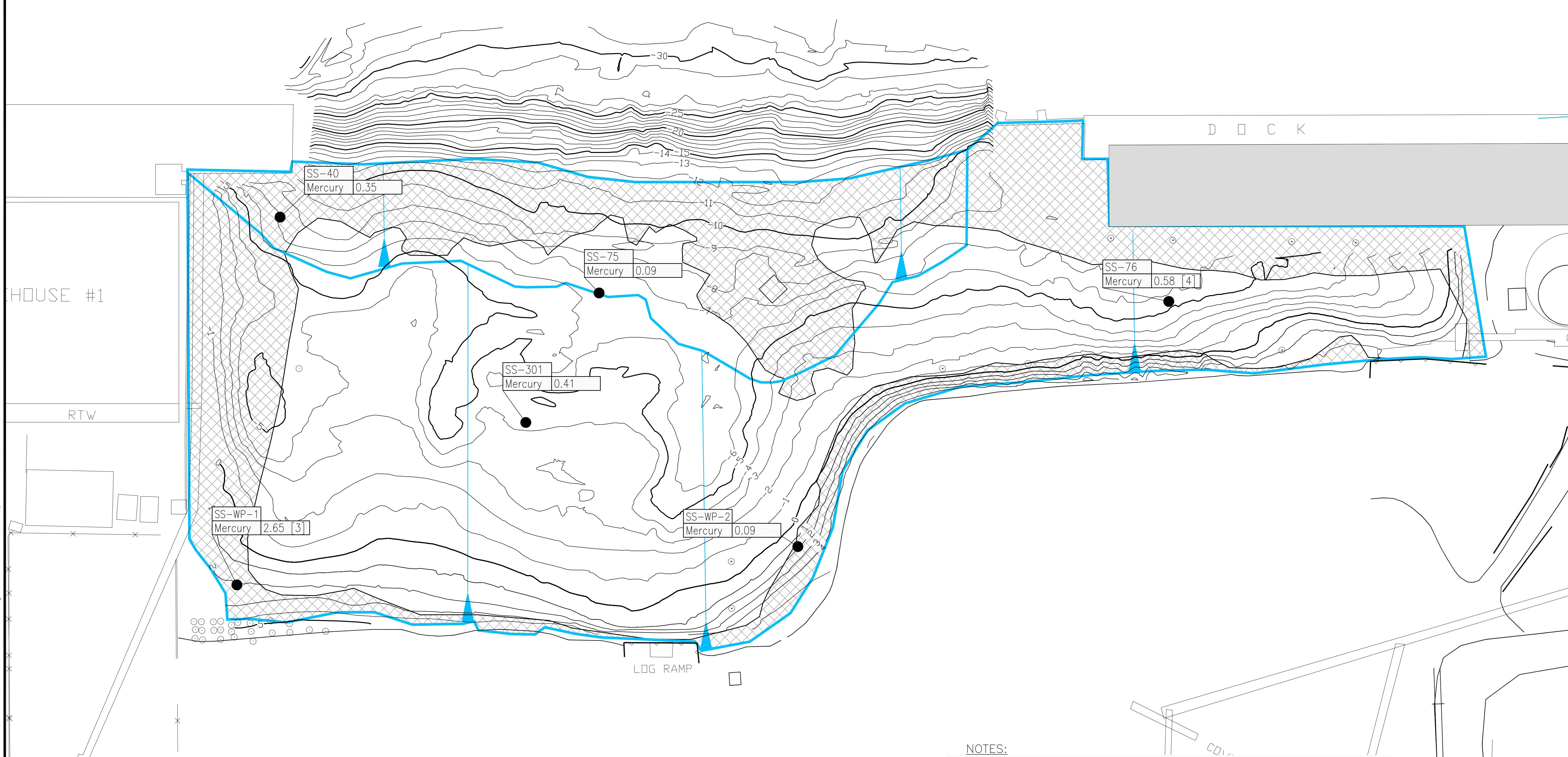
NOTE:

1. CAP THICKNESS ESTIMATED BY COMPARING 2000 PRE-CONSTRUCTION AND 2005 5-YEAR BATHYMETRIC SURVEYS USING EAGLE POINT SOFTWARE. IN AREAS WITH 3 FEET OF APPLIED CAP THE ACTUAL CAP THICKNESS IS ESTIMATED TO BE 0.5 TO 0.8 FEET THICKER THAN THE NOMINAL THICKNESS DUE TO THE EFFECTS OF SEDIMENT CONSOLIDATION.

File: H:\18876\18876S106.dwg Layout: FIGURE 2-2 User: emarshall Plotted: Aug 02, 2006 - 3:21pm Xref's:

RETEC

YEAR 5 LOG POND MONITORING REPORT	CURRENT NOMINAL CAP THICKNESS
PORTB-18876-210	
DATE: 07/31/06 DRWN: A.S./SEA	FIGURE 2-2



LEGEND

- PHASE I AND II CAP LIMITS FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)
- THIN LAYER CAPPING AREA (0.5' TO 3') FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)
- OCTOBER 2005 BATHYMETRY (MLLW)
- GRAB SAMPLE LOCATION

REFERENCE VALUES

	SQS	CSL	BSL
Mercury–mg/kg	0.41	0.59	1.2

NOTES:

1. MERCURY CONCENTRATIONS ARE REPORTED AS mg/kg DRY WEIGHT.
2. BATHYMETRY SHOWN FROM OCTOBER 12, 2005 SURVEY. (FT. MLLW)
3. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 2.7 AND 2.6 mg/kg
4. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 0.55 AND 0.60 mg/kg. SAMPLE WAS SUBMITTED FOR AND PASSED ALL CONFIRMATIONAL BIOASSAY TESTING.

40 0 80
SCALE IN FEET

RETEC

YEAR 5 LOG POND MONITORING REPORT

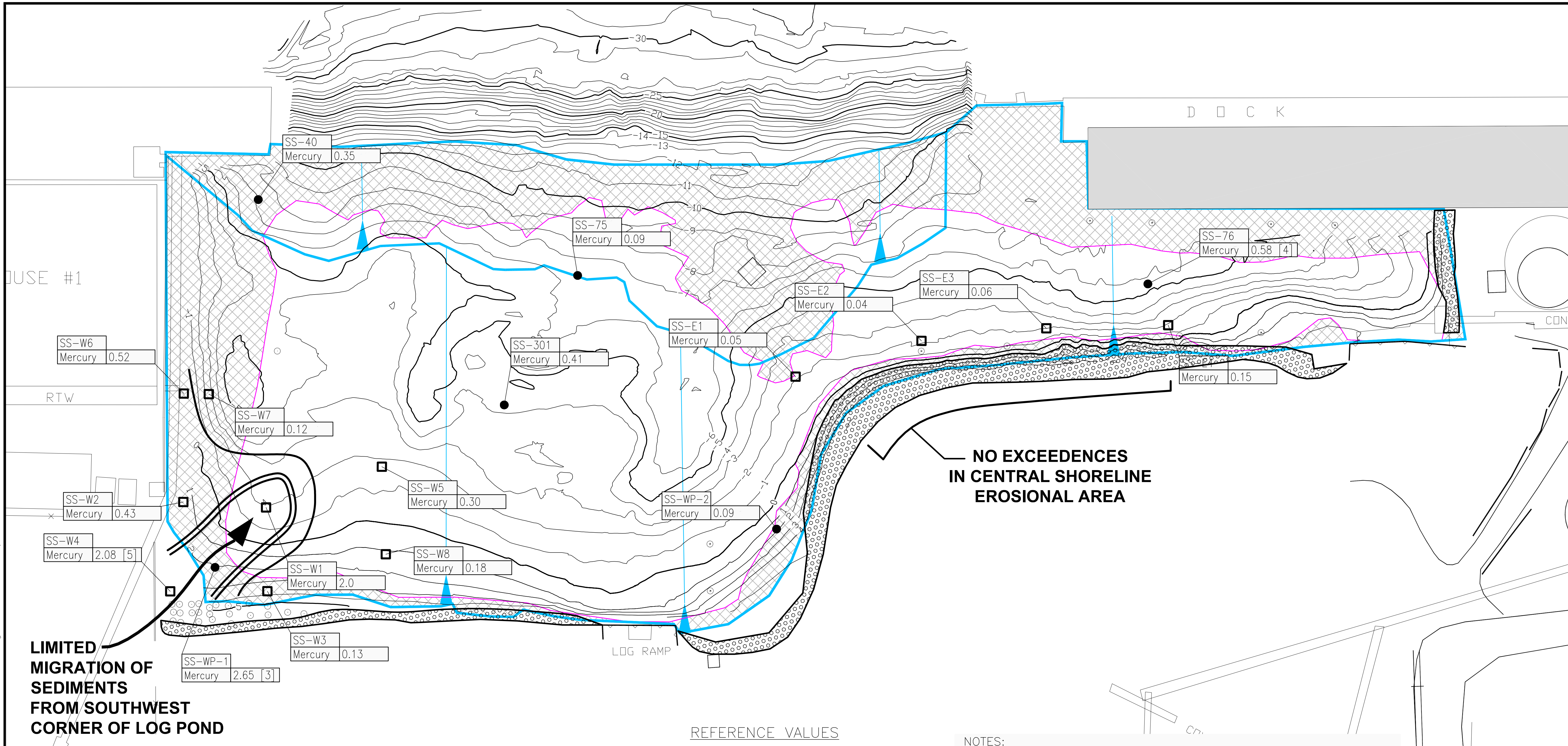
PORTB-18876-210

DATE: 07/31/06 DRWN: A.S./SEA

SURFACE SEDIMENT MERCURY CONCENTRATIONS YEAR 5 MONITORING

FIGURE 4-1

File: H:\18876\18876S104.dwg Layout: FIGURE 4-1 User: emarshall Plotted: Aug 02, 2006 - 3:14pm Xref's:



REFERENCE VALUES

SMS	SQS	CSL	BSL
Mercury–mg/kg	0.41	0.59	1.2

LEGEND

- APPROXIMATE AREAS OF ARMORED SLOPES
- PHASE I AND II CAP LIMITS FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)
- THIN LAYER CAPPING AREA (0.5' TO 3') FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)
- OCTOBER 2005 MUD-LINE ELEVATION (FT.MLLW)
- YEAR 5 SURFACE SAMPLE LOCATION
- SUPPLEMENTAL SAMPLING LOCATION

40 0 80
SCALE IN FEET

NOTES:

1. MERCURY SEDIMENT CONCENTRATIONS ARE REPORTED AS mg/kg DRY WEIGHT.
2. BATHYMETRY SHOWN FROM OCTOBER 12, 2005 SURVEY. (FT. MLLW)
3. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 2.7 AND 2.6 mg/kg.
4. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 0.55 AND 0.60 mg/kg. SAMPLE WAS SUBMITTED FOR AND PASSED ALL CONFIRMATIONAL BIOASSAYS.
5. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 2.7 AND 1.45 mg/kg.

RETEC

YEAR 5 LOG POND MONITORING REPORT

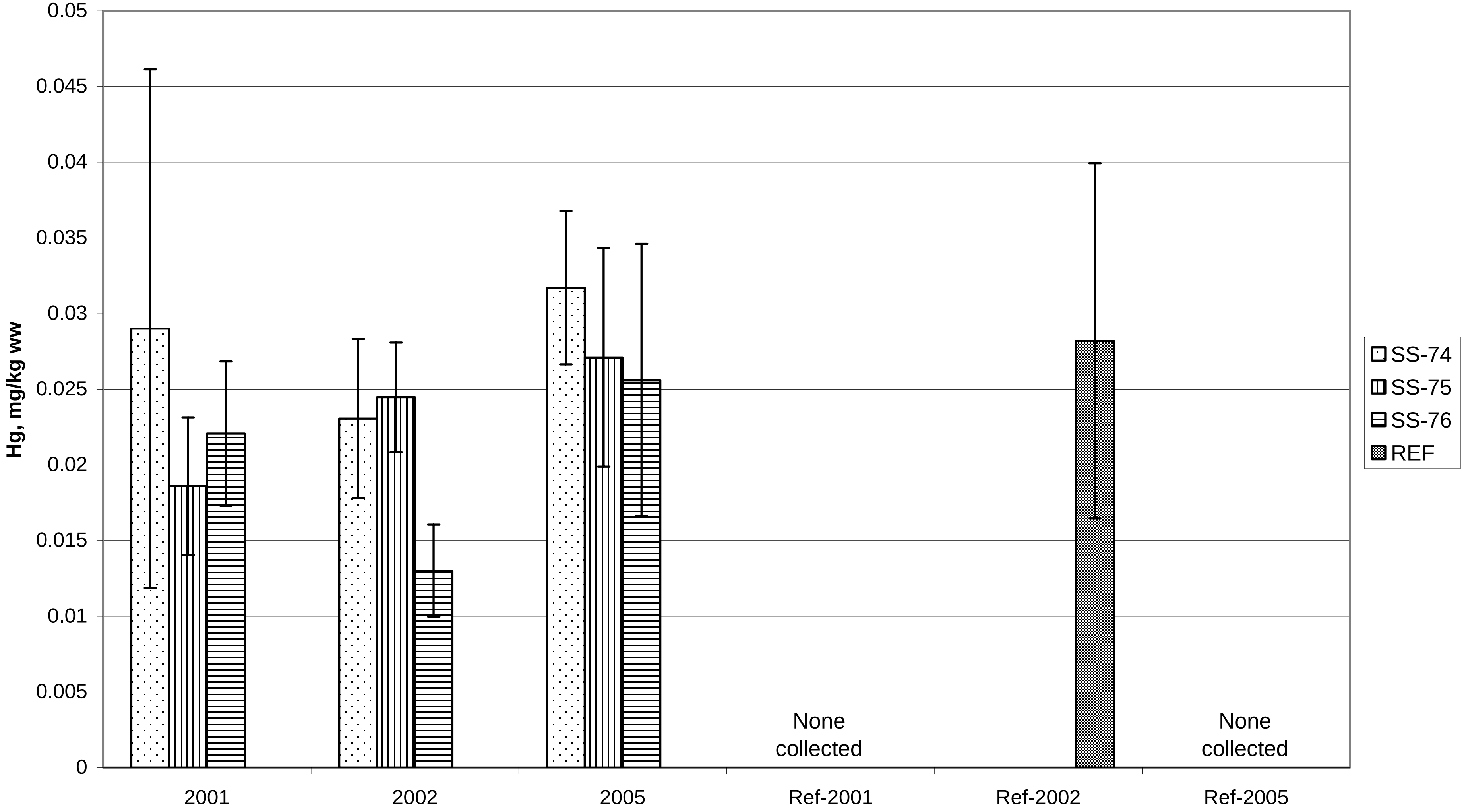
PORTB-18876-260

DATE: 07/31/06 DRWN: A.S./SEA

RESULTS OF SUPPLEMENTAL SURFACE SEDIMENT TESTING

FIGURE 4-2

File: H:\18876\18876S103.dwg Layout: FIGURE 4-2 User: emarshall Plotted: Aug 02, 2006 - 3:11pm Xref's:



Note:
1. For the 2002 reference, one of the three subsamples contained an outlier of 0.308 mg/kg ww.
2. Results from log pond samples from 2001, 2002, and 2005 are not significantly different ($p<0.05$) from the 2002 reference samples.

RETEC

YEAR 5 LOG POND MONITORING REPORT WHATCOM WATERWAY, BELLINGHAM PORTB-18876-230		LOG POND CRAB TISSUE COMPLIANCE MONITORING RESULTS
Date: 8/2006	File: 8876	FIGURE 6-1

Attachment A

Wave Energy and Sediment Stability Calculations

ATTACHMENT A

BORING LOGS FROM SUBSURFACE SAMPLING
YEAR-5 LOG POND MONITORING

RETEC

Sediment Core Log

Core: SC-301

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **4.4 feet**	Penetration Depth: **12.2 feet**
Client: **Port of Bellingham**	Water Depth (ft): **10.8**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-4.0 feet**	Recovery in ft (%): **7.4 feet (62.5)**
Contractor: **Marine Sediment Services**	N./LAT: **48 45.7962 N** E./LONG: **122 29.4508 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin, K Magruder**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Recovered depth interval in feet) Contacts are expanded	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log	Calc. In situ Depth (ft)
0					ML: Wet, medium firm, dark gray clayey SILT with trace very fine sand. Slight sulfide-like odor 0.2' worm 0.4-1.0' trace small twigs 2.4' wood fragment 2"		Phase 2 Cap	0
	A	SC-301-A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size					
1	B	SC-301-B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size					1
2								2
	C	SC-301-C (2.4-2.9)	Hg, Misc Ex, TS, TOC, Grain Size					
3					ML: Wet, firm, dark gray clayey SILT with increasing clay and fine-grained sand			3
4					SM: Moist, firm, dark gray, slightly silty SAND with trace wood fragments		Phase 1 Cap	4
					ML: Moist, firm, dark grayish brown sandy SILT			
5					SM: Moist, firm, dark gray slightly silty fine-medium grained SAND. 4.7' Large wood fragments 3" diameter			5
	D	SC-76-D (5.5-6.0)	Hg, Misc Ex, TS, TOC, Grain Size					
6					ML: Moist, firm, dark gray, clayey SILT. Moderate wood fragments 1/4 - 1/2 "			6
					SM: Moist firm, dark gray, slightly silty, fine to medium grained SAND			

The RETEC Group, Inc.
1011 SW Klickitat Way, Suite 207
Seattle, WA 98134-1162
Phone: (206) 624-9349
Fax: (206) 624-2839

Remarks: Core catcher was cut off in the lab.
Refusal from wood fragments at 7.4'
No odor or sheen. No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
7.4 / 12.5 = 62.5%

Sediment Core Log

Core: SC-301

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Actual recovered depth interval in feet)	Comments	Calc. Insitu Depths (ft) & Graphic Log	Elevation (ft)
7	3	SC-76-E (7.0-7.4)	Hg, Misc Ex, TS, TOC, Grain Size		ML: Wet, firm, black, clayey SILT. Abundant wood fragments 2-3" x 1-2". Moderate hydrocarbon-like odor. Moderate shell fragments.		Original Material	7
					End of core at 7.4 feet.			
8								8

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Fax: (206) 624-2839

Remarks: Core catcher was cut off in the lab.
Refusal from wood fragments at 7.4'
No odor or sheen. No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
7.4 / 12.5 = 62.5%

RETEC

Sediment Core Log

Core: SC-40

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **7.1 feet**	Penetration Depth: **7.0 feet**
Client: **Port of Bellingham**	Water Depth (ft): **14.0 feet**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-7.2 feet**	Recovery in ft (%): **5.6 feet (80%)**
Contractor: **Marine Sediment Services**	N./LAT: **48 44.7916 N** E./LONG: **122 29.5143 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin, K Magruder**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Recovered depth interval in feet) Contacts are expanded	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log	Calc. In situ Depth (ft)
0					ML: Moist, firm, dark grey, slightly sandy SILT. Trace wood fragments. Moderate scent of decaying aquatic life.		Phase I Cap	0
	A	SC-40-A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size		SM: Moist, firm, dark grey slighly silty, medium to fine grained SAND. Trace wood fragements up to 1" diameter.			
1	B	SC-40-B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size					1
2					ML: Moist, firm, dark grey, clayey SILT. Moderate wood fragments up to 1" diameter. Strong sulfide-like odor		Original Material	2
3	E	SC-40-E (3.0-3.5)	Hg, Misc Ex, TS, TOC, Grain Size					3
4					Unlogged from 3.9 - 5..6 feet, as no need to sample.			4
5					End of core at 5.6			5

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Remarks: No C sample, as Phase 2 Cap layer was not apparent.
Unlogged below 3.9 feet.
No sheen or odor. No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
5.6 / 7.0 = 80 %%

Sediment Core Log

RETEC

Core: SC-75

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **7.0.feet**	Penetration Depth: **7.0 feet**
Client: **Port of Bellingham**	Water Depth (ft): **12.1 feet**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-5.3 feet**	Recovery in ft (%): **6.4 (91 %)**
Contractor: **Marine Sediment Services**	N./LAT: **48 44.8150 N** E./LONG: **122 9.4576 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Recovered depth interval in feet) Contacts are expanded	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log	Calc. In situ Depth (ft)
0					SM: Moist, medium firm, brownish gray slightly silty SAND.			0
	A	SC-75-A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size		ML: Moist, firm, SILT. Moderate worm casings. Live clam at 0.5'. Trace bark fragments 1 x 1". Moderate scent of decaying marine life.		Phase I Cap	
1	B	SC-75-B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size		SM: Moist, firm, gray, slightly silty fine-grained SAND. Grades to medium to coarse with depth.			1
2					2.2' Small wood fragments 1" x 0.5"			2
3					3.0' Irregular shaped sandstone fragment 2 x 2.5" with black sand.			3
4	D	SC-75-D (3.7-4.2)	Hg, Misc Ex, TS, TOC, Grain Size		4.4' 2 Small wood fragments 2 x 1"			4
5					ML: Moist, dense, dark gray, clayey SILT. Trace wood fragments Strong sulfide-like odor. 5.6' Moderate wood and shell fragments. Strong sulfide-like odor		Original Material	5
6	E	SC-75-E (5.7-6.2)	Hg, Misc Ex, TS, TOC, Grain		End of Core at 6.4 feet			6

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Seattle, WA 98134-1162
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Fax: (206) 624-2839

Remarks: **No C sample, as Phase 2 Cap layer was not apparent.**
No sheen or odor unless otherwise noted
No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
6.4 / 7.0 = 80 %%

Sediment Core Log

RETEC

Sheet 1 of 1

Core: SC-76

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **7.7 feet**	Penetration Depth: **7.0 feet**
Client: **Port of Bellingham**	Water Depth (ft): **9.3 feet**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-2.5 feet**	Recovery in ft (%): **6.7 feet (95.7%)**
Contractor: **Marine Sediment Services**	N./LAT: **48 44.8669 N** E./LONG: **122 29.3766 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Recovered depth interval in feet) Contacts are expanded	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log	Calc. In situ Depth (ft)
0					ML: Moist, firm, dark gray, sandy SILT. Moderate wood fragments to 2 x 0.5". Strong sulfide-like odor at 3.5'			0
	A	SC-76-A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size		SM: Moist, firm, gray slightly silty SAND. Half clam shell 1" diameter		Phase I Cap	
1	B	SC-76-B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size					1
2					SM: SAA grading to dark gray.			2
3								3
	D	SC-76-D (3.4-3.9)	Hg, Misc Ex, TS, TOC, Grain Size					
4					CL: Several clay lenses roughly 2" in thickness			4
					SM: Moist, firm, gray slightly silty SAND.			
5					ML: Moist, firm, dark gray, clayey SILT. Abundant wood fragments 1-3 x 2 ". Trace sand. Strong HC-like odor, strong sulfide-like odor.		Original Material	5
6	E	SC-76-E (5.8-6.4)	Hg, Misc Ex, TS, TOC, Grain Size					6
					End of core at 6.7 feet			

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Seattle, WA 98134-1162
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Fax: (206) 624-2839

Remarks: **No C Sample, as Phase 2 cap layer was not apparent.**

No odor or sheen unless noted.

No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
6.7 / 7.0 = 95.7%

ATTACHMENT B
WAVE ENERGY AND SEDIMENT STABILITY CALCULATIONS

Introduction and Overview

This attachment provides preliminary wave energy and sediment stability calculations relating to the current conditions at the Log Pond. These calculations were developed in support of the Log Pond Technical Memorandum, and have been used to develop a design concept for shoreline enhancements of that area. These calculations are subject to future refinement as part of engineering design and permitting.

Hydrography, Water Levels and Variations

The existing subtidal surface of the Log Pond is covered predominately with sandy silt from application of the Phase 2 Log Pond Cap. Areas along the shoreline edges of the cap consist of sandy material from application of the Phase 1 Log Pond Cap. The Phase 1 materials have a median particle size (d_{50}) of approximately 1.0 mm. The Phase 2 materials have a median particle size closer to 0.1 mm (Anchor, 2000).

Both the horizontal and vertical extent of wave action in the log pond is controlled by the varying water level in the log pond. The water level varies daily as a consequence of the tides. On rare occasions, the tide elevations may be augmented by flooding, storm surge, and tsunamis.

The tides in Bellingham Bay are semi-diurnal mixed, meaning that there are two unequal highs and lows each day. The mean tide range is 5.43 feet and the diurnal range is 7.79 feet. The tidal datums for the 1983-2001 tidal epoch are given in Table B-1. The tides determine the varying water depths and elevations of wave action in the log pond. The corresponding fixed datums, which include the National Geodetic Vertical Datum of 1929 (NGVD 29) and its replacement the North American Vertical Datum of 1988 (NAVD 88), are obtained from the National Ocean Service (NOS) tidal bench mark sheets and the National Geodetic Survey (NGS) data sheets. The difference between NGVD 29 and NAVD 88 is 3.93 ft. These datum elevations are shown in Table B-1.

Flooding, storm surge, and tsunamis (in decreasing order of probability of occurrence) may increase the water level in the log pond on rare occasions. Flooding in the Whatcom Waterway, and by extrapolation into the log pond, is obtained from the Federal Emergency Management Agency (FEMA) flood insurance rate maps (FIRMs) for Bellingham (FEMA, 2004). FIRM Panel 1213D shows a base flood elevation at the mouth of Whatcom Creek of 8 feet (NGVD 29). Extrapolating this elevation to the log pond yields a conservatively high 100-year flood elevation of (8 feet plus 4.41 feet) 12.4 feet (MLLW) at the log pond.

Storm surge is obtained by subtracting the highest observed tide on 5 January 1975 from the predicted tide for that day. The predicted high tide as obtained from NOS (per Nobeltec, 2004) for 5 January 1975 was 9.6 feet. The actual measured high tide was 10.4 feet (MLLW). The difference is a storm surge of 0.8 feet. The properties of the storm, especially the wind speed and direction, are unknown. The storm surge may or may not be independent of any flooding in the area, but is assumed to occur over a sufficiently long period of time to occur over the period of higher high water.

Table B-1. The 1983-2001 Tidal Datums, Fixed Datums, and Flood Elevations for the Log Pond.

Tidal Datum	Meters	Feet
100-Yr Flood Elevation	3.78	12.4
Highest Observed Tide (HOT) 1/5/1975	3.177	10.42
Mean Higher High Water (MHHW)	2.594	8.51
Mean High Water (MHW)	2.375	7.79
Mean Tide Level (MTL)	1.546	5.07
Mean Sea Level (MSL)	1.510	4.95
NGVD 29	1.344	4.41
Mean Low Water (MLW)	0.718	2.36
NAVD 88	0.147	0.48
Mean Lower Low Water (MLLW)	0.0	0.0
Lowest Observed Tide (LOT) 12/30/1974	-1.057	-3.47

Tsunami inundation for Bellingham Bay is given by Walsh et al (2004). At the log pond, they show the tsunami depth of inundation to be between 0 and 0.5 m (0 – 1.6 ft). If a tsunami were to occur, this inundation depth would be added to the water elevation in the bay at that time. This means that the water elevation in the log pond may increase by up to 1.6 feet above the tidal elevation at the time. This assumes that the tsunami occurs independently from either flooding storm surge.

Wind Data

The dominant disturbance to the sediment of a log pond cap is expected to be wind-generated waves. A literature search indicates that there are no known wave data for Bellingham Bay. Therefore, waves will have to be forecast/hindcast from wind data. The wind parameters that influence wave generation include: wind speed, wind direction, wind duration, and fetch (the distance over which the wind blows). Wave growth is directly proportional to wind speed, wind duration, and fetch.

Fetch was obtained by scaling off the nautical chart (NOAA-NOS Chart No. 18424) for Bellingham Bay. The fetches associated with each principle wind direction are presented in Tables B-2 and B-3. The log pond is protected by land mass from northeast (NE) clockwise to southwest (SW). The longest fetch is to the west (W), a distance of 31,600 feet.

Wind data for Bellingham Bay are sparse. Data from the Georgia Pacific weather station in Bellingham were used as part of the Engineering Design Report (Anchor, 2000) at the time of cap construction. Additional publicly-available data were used as part of this Technical

Memorandum to cross-check these data. Results were found to be similar. The resulting wind data were used to assess both typical storm waves and extreme storm waves in addressing the issue of a stable armor cap on the log pond. The wind-to-wave analyses are done for typical storm conditions and extreme storm conditions.

The typical storm conditions are obtained from a wind rose for Bellingham Bay prepared by the U.S. Army Corps of Engineers – Seattle District Figure A-1. The maximum wind speed from each direction is assumed to be representative of a typical storm from that direction. The duration of a typical storm by directions was obtained from a U.S. Army Corps of Engineers – Seattle District Figure A-2 Wind Duration Curves for Bellingham Bay. The winds are assumed to have been measured at the airport just north of the bay. The elevation of the airport is about 170 feet above MLLW. The height of the wind instrument is about 33 feet above ground. This places the wind measurement about 203 feet above MLLW.

The typical storm wind conditions to be used in the wave analysis are summarized in Table B-2. The longest fetch into the log pond is from the W with typical storm winds up to 24 mph for up to 24 hours duration.

Table B-2. Typical Storm Winds Influencing Wave Development in the Log Pond Based on Wind Rose Data (1948-1954).

Direction	Fetch (ft)	Wind Speed (mph)	Duration (hours)
N	800	38	3
NE	0	38	3
E	0	24	8
SE	0	38	5
S	0	24	24
SW	41,300	24	24
W	31,600	24	2
NW	500	24	6

Extreme storm winds representative of Bellingham Bay are collected from a variety of sources. The storm of 21 October 1934 (Read, 2003) produced a sustained wind in Bellingham from the SSE at 60 mph with a peak wind at 70 mph. The 4 December 1945 storm (Read, 2004) produced a peak wind from the SSE at 66 mph and a gust to 80+ mph. The 12 October 1962 (Columbus Day Storm) storm (Lynott and Cramer, 1966) recorded a gust of 92 mph from the S. And a storm on 24 November 1998 (http://www.usatoday.com/weather/news/1998/w1124rpt.html) produced a gust of 76 mph, believed to be from the S. Sustained winds (with 1-hour duration) are obtained from the U.S. Army Corps of Engineers – Seattle District Figure A-2 Wind Duration Curves for Bellingham. Peak winds (1-minute duration) and gusts (1-second duration) were obtained from storm reports. The extreme storm wind data for Bellingham Bay is summarized on Table B-3. The extreme storms winds are out of the south, but the long pond is protected in that direction, with a fetch of 0 feet. The longest fetch of 31,600 feet is to the west, but there are no recorded peak winds or gusts from that direction; and the sustained wind speed of 26 mph is relatively low. The SW wind has an even longer fetch, 41,300 feet, but that direction is parallel to the mouth of the pond and only diffracted waves could enter the pond from that direction.

Table B-3. Extreme Storm Winds Influencing Wave Development in the Log Pond Based on Storm Reports.

Direction	Fetch (ft)	Sustained (1-hour) Wind Speed (mph)	Peak (1-minute) Wind Speed (mph)	Gust (1-second) Wind Speed (mph)
N	800	44		-
NE	0	44	-	-
E	0	42	-	-
SE	0	56	-	-
S	0	60	70	92
SW	41,300	52	-	-
W	31,600	26	-	-
NW	500	NA*	-	-

- No Data.
* No Data, but assumed to be 35 mph.

Wave Estimates

The wind data are used to calculate the typical and extreme (storm) wind-generated waves in Bellingham Bay using the methods presented in the *Shore Protection Manual* (U.S. Army Corps of Engineers, 1984). Waves are calculated along the longest fetch for the typical storm (W wind at 24 mph for 24 hours) and the extreme sustained storm (W wind at a speed of 26 mph and duration of 1 hour). Diffracted waves from the SW are also checked (SW wind speed of 52 mph and a duration of 1 hour).

Depths along the fetches are controlled by the depths in the outer or middle Whatcom Waterway, or the shoal west of the waterway and adjacent to the aeration stabilization basin (ASB). At low tide, the outer waterway depth is approximately 30 feet, the middle waterway is 22, and the shoal has a depth of about 12 feet. High tide increases the depths by about 9 feet.

The typical and extreme storm wind speeds from Tables B-2 and B-3 are adjusted (Table B-6) for use in the wave calculations (Table B-7). The results of the wind-generated wave calculations (Attachment B-7) are presented in Tables B-4 and B-5. The largest typical storm waves are from the southwest (SW) with a significant wave height of 1.9 feet and a period of 2.7 seconds at high tide. The largest extreme storm waves appear to be from the southwest (SW) with a wave period of 3.3 seconds, and a significant wave height of 3.2 feet at high tide. These waves still need to be diffracted into the log pond. Diffraction should lower the wave height in the log pond by at least half.

Table B-4. Typical Storm Wave Summary at the Log Pond.

Wind Direction (from)	SW	W	NW	N
Wind Speed (mph)	24	24	24	38
Duration (minutes) for Fully Developed Waves	94	77	4	5
Fetch (feet)	41,300	31,600	500	800
Wave period (second)	2.7	2.3	0.7	0.9
At Low Tide:				
Significant (33-Percentile) Wave Height (feet)	1.9	1.4	0.2	0.4
10-Percentile Wave Height (feet)	2.4	1.8	0.3	0.5
1-Percentile Wave Height (feet)	3.2	2.3	0.3	0.7
At High Tide:				
Significant (33-Percentile) Wave Height (feet)	1.9	1.5	0.2	0.4
10-Percentile Wave Height (feet)	2.4	1.9	0.3	0.5
1-Percentile Wave Height (feet)	3.2	2.5	0.3	0.7

Waves directly into the log pond come from the west (W). Both typical and extreme storm waves from the west are fetch and depth limited and the wave period is 2.3 seconds and the significant wave height is about 1.4 feet at low tide; and 2.4 seconds and 1.5 feet, respectively, at high tide. The wave parameters for W wind-generated waves are used for further analysis of the log pond cap armor layer. Since there is no discernable difference between the typical and extreme storm wave characteristics, no further distinction will be made between typical and extreme storms. The main distinctions will be between low and high tide conditions.

Table B-5. Extreme Storm Wave Summary at the Log Pond.

Wind Direction (from)	SW	W	NW	N
Wind Speed (mph)	52	26	35*	44
Duration (minutes) for Fully Developed Waves	71	75	4	5
Fetch (feet)	41,300	31,600	500	800
Wave period (second)	3.3	2.4	0.7	0.9
At Low Tide:				
Significant (33-Percentile) Wave Height (feet)	3.1	1.4	0.2	0.4
10-Percentile Wave Height (feet)	3.9	1.8	0.3	0.5
1-Percentile Wave Height (feet)	5.2	2.3	0.3	0.7
At High Tide:				
Significant (33-Percentile) Wave Height (feet)	3.2	1.5	0.2	0.4
10-Percentile Wave Height (feet)	4.1	1.9	0.3	0.5
1-Percentile Wave Height (feet)	5.3	2.5	0.3	0.7

* Not available, but assumed to be 35 mph for calculation purposes.

Vessel Wakes

The log pond will be situated adjacent to the Whatcom Waterway. Typical boat traffic within the waterway may include small to mid-sized vessels including motor yachts, small tugs and other vessels. For completeness, an assessment of boat wakes was performed. Generally, boat wake parameters lie within the envelope of wind-generated wave parameters.

The largest boats transiting the waterway between the bay and the marina entrance will generate the largest wakes. The largest boat is assumed to be a 110-foot long motor yacht, transiting in 30 feet of water and passing within 100 feet of the log pond, and crossing the mouth of the Log Pond at a speed of 7 knots (11.8 feet /sec). The wake calculation (Attachment B-10) indicates a wake period of 1.9 seconds and a wake height of 0.4 feet. These parameters are well within the storm wave parameters envelope given above.

Sediment Stability Analyses

The size of particles that is expected to be stable depends on the magnitude of the wave-generated currents impinging on top of the cap, the size of the sediment particles and the depth of the overlying water.

The water depth over the log pond will be controlled by the tides. Using MLLW as the controlling tide datum for the subtidal portion of the log pond, the minimum depth of water over the cap is assumed to vary from 12 feet to 0 feet. Storm waves will begin to feel the bottom at the outer edges of the log pond, in about 13 feet of water depth. Inshore of the edge, the waves begin to change from deepwater waves to transitional waves. The wavelength begins to shorten, the waves begin to steepen and increase in height and, as the water depth becomes shallower, the waves may break and reform. The waves eventually break against the shoreline (location determined by water level).

Elevation range over which the waves will break against the shoreline, based on tides only, is from about -4 feet to about +10 feet (MLLW). Flooding, storm surge, and tsunami could raise the water level variation to about +12 feet (MLLW). At higher elevations waves would break against armored or bulkheaded shorelines. The critical water elevations are in fact those at relatively low tides which allow the waves to break against sandy shoreline materials and which transmit wave energy to shallow subtidal sediments.

The methods in the Shore Protection Manual are used to provide a preliminary assessment of stable stone size exposed to storm waves. The calculations (see Attachment B-9) indicate that under existing conditions, the sandy materials of the Phase 1 cap should be stable at depths of between 4 and 6 feet below MLLW in areas subjected to westerly winds and waves. In other areas of the Log Pond not subjected to direct effects of westerly winds, these sediments may be stable at shallower depths.

For intertidal areas subjected to direct effects of westerly winds and wind-driven waves, stability is expected to require armor stone in water depths above elevation -4 feet MLLW. This will require a median (D_{50}) stone size (Table B-8) of 9 to 10 inches (cobble size) along the Central shoreline.

In more sheltered areas of the Log Pond such as the Southern and Western shorelines, a beach material consisting of fine to coarse gravel will be stable under anticipated wind, wave and vessel wake conditions. If the Log Pond shoreline is to be upgraded with the placement of new material, then the final particle sizes should be determined after additional computer wave simulations during remedial design and permitting. Design and permitting should also include further evaluation of proposed beach geometries (slopes, groin locations and curves) and the geotechnical issues associated with placement of additional materials near bulkheads and structures.

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Wind Corrections for Wave Forecasting Calculations

Per the *Shore Protection Manual* (USACE, 1984)*

Port of Bellingham
Log Pond

Typical Storm Windspeed in mph:

Step	Item/Description	Symbol	Unit	Calculations			
1	Calculation identification	-	-	SW	W	NW	N
2	Observed windspeed	U_Z	mph	24.0	24.0	24.0	38.0
3	Elevation of observed windspeed	Z	ft	203	203	203	203
4	Duration of observed windspeed	t	sec	86,400	7,200	21,600	10,800
5	Location of observed windspeed: ship (S), land (L)	-	-	L	L	L	L
6	Air temperature at wind observation location	T_a	°C	15.0	15.0	15.0	15.0
7	Water temperature adjacent to wind observation	T_w	°C	10.0	10.0	10.0	10.0
8	Air -water temperature difference	DT_{aw}	°C	5.0	5.0	5.0	5.0
9	Windspeed corrected to 10 m (33 ft) elevation	U(10)	mph	18.5	18.5	18.5	29.3
10	Stability correction ratio, from Figure 3-14	R_T	-	0.87	0.87	0.87	0.87
11	Location correction ratio, from Figure 3-15	R_L	-	1.00	1.10	1.10	0.95
12	Windspeed corrected to over-water	U_W	mph	18.5	20.4	20.4	27.8
13	Windspeed corrected to 1-hour duration	U_{3600}	mph	23.3	21.3	23.1	30.0
14	Windspeed corrected for stability	U	mph	20.3	18.6	20.1	26.1
15	Windspeed converted to wind-stress factor	U_A	mph	23.9	21.4	23.5	32.5
16	Windspeed converted to wind-stress factor	U_A	ft/sec	35.1	31.4	34.5	47.7

* U.S. Army Corps of Engineers. Shore Protection Manual. Volume I, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS, 1984.

1-7	User input calculation identification, observed windspeed, elevation, duration, and location of observed windspeed, air temperature at windspeed obseration location, and water temperature of adjacent water body.
8	$DT_{aw} = T_a - T_w$
9	$U(10) = U_Z (33/Z)^{1/7}$
10-11	User input stability correction ratio and location correction ratio.
12	$U_W = R_L U(10)$, if observation taken on land (L); $U_W = 2.16[(5280/6080)U(10)]^{7/9}$, if observation taken on ship at sea (S).
13	$U_{3600} = U_W/\{1.277+0.296\tanh[0.9\log_{10}(45/t)]\}$, if t<3,600 sec; $U_{3600} = U_W/(-0.15\log_{10}t + 1.5334)$, if t>3,600 sec.
14	$U = R_T U_{3600}$
15	$U_A = 0.589U^{1.23}$
16	$U_{A[ft/sec]} = (5280/3600)U_{A[mph]}$

Extreme Storm Windspeed in mph:

Step	Item/Description	Symbol	Unit	Calculations			
1	Calculation identification	-	-	SW	W	NW	N
2	Observed windspeed	U_Z	mph	52.0	26.0	35.0	44.0
3	Elevation of observed windspeed	Z	ft	203	203	203	203
4	Duration of observed windspeed	t	sec	3,600	3,600	3,600	3,600
5	Location of observed windspeed: ship (S), land (L)	-	-	L	L	L	L
6	Air temperature at wind observation location	T_a	˚C	15.0	15.0	15.0	15.0
7	Water temperature adjacent to wind observation	T_w	˚C	10.0	10.0	10.0	10.0
8	Air -water temperature difference	DT_{aw}	˚C	5.0	5.0	5.0	5.0
9	Windspeed corrected to 10 m (33 ft) elevation	U(10)	mph	40.1	20.1	27.0	33.9
10	Stability correction ratio, from Figure 3-14	R_T	-	0.87	0.87	0.87	0.87
11	Location correction ratio, from Figure 3-15	R_L	-	0.90	1.10	0.95	0.90
12	Windspeed corrected to over-water	U_W	mph	36.1	22.1	25.6	30.5
13	Windspeed corrected to 1-hour duration	U_{3600}	mph	36.1	22.1	25.6	30.5
14	Windspeed corrected for stability	U	mph	31.4	19.2	22.3	26.6
15	Windspeed converted to wind-stress factor	U_A	mph	40.9	22.3	26.8	33.3
16	Windspeed converted to wind-stress factor	U_A	ft/sec	60.0	32.7	39.4	48.8

* U.S. Army Corps of Engineers. Shore Protection Manual. Volume I, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS, 1984.

1-7	User input calculation identification, observed windspeed, elevation, duration, and location of observed windspeed, air temperature at windspeed obseration location, and water temperature of adjacent water body.
8	$DT_{aw} = T_a - T_w$
9	$U(10) = U_Z\,(33/Z)^{1/7}$
10-11	User input stability correction ratio and location correction ratio.
12	$U_W = R_L U(10)$, if observation taken on land (L); $U_W = 2.16[(5280/6080)U(10)]^{7/9}$, if observation taken on ship at sea (S).
13	$U_{3600} = U_W/\{1.277+0.296\tanh[0.9\log_{10}(45/t)]\}$, if t<3,600 sec; $U_{3600} = U_W/(-0.15\log_{10}t + 1.5334)$, if t>3,600 sec.
14	$U = R_T U_{3600}$
15	$U_A = 0.589U^{1.23}$
16	$U_{A[ft/sec]} = (5280/3600)U_{A[mph]}$

Wind-generated Wave Forecasting Calculations

Per the *Shore Protection Manual* (USACE, 1984)*

Port of Bellingham
Log Pond

Typical Storm Waves at Low Tide:

Step	Item/Description	Symbol	Unit	Calculations			
1	Calculation identification	-	-	SW	W	NW	N
2	Wind-stress factor (adjusted wind speed)	U_A	ft/sec	35.1	31.4	34.5	47.7
3	Fetch length	F	ft	41,300	31,600	500	800
4	Constant or average water depth	d	ft	30	14	22	22
5	Significant wave height	H	ft	1.9	1.4	0.2	0.4
6	Significant wave period	T	sec	2.7	2.3	0.7	0.9
7	Duration for fully developed waves	t	sec	5,532	4,439	231	276

* U.S. Army Corps of Engineers. Shore Protection Manual. Volume I, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS, 1984.

1-4	User input calculation identification, wind stress factor (adjusted wind speed), fetch, constant or average water depth.
5	If d>300' and if $0.000282U_AF^{1/2}<0.007553U_A^2$, then $H = 0.000282U_AF^{1/2}$, otherwise $H = 0.007553U_A^2$; if d<300', then $H = (U_A^2/g)0.283\tanh[0.53(gd/U_A^2)^{3/4}]\tanh\{[0.00565(gF/U_A^2)^{1/2}]/\tanh[0.53(gd/U_A^2)^{3/4}]\}$.
6	If d>300' and if $(0.95)0.02825(U_AF)^{1/3}<(0.95)0.253U_A$, then $T = (0.95)0.02825(U_AF)^{1/3}$, otherwise $T = (0.95)0.253U_A$; if d<300', then $T = 0.95(U_A/g)7.54\tanh[0.833(gd/U_A^2)^{3/8}]\tanh\{[0.0379(gF/U_A^2)^{1/3}]/\tanh[0.833(gd/U_A^2)^{3/8}]\}$.
7	If d>300' and if $21.6(F^2/U_A)^{1/3}<2220U_A$, then $t = 21.6(F^2/U_A)^{1/3}$, otherwise $t = 2220U_A$; if d<300', then $t = (U_A/g)537(gT/U_A)^{7/3}$.

Extreme Storm Waves at Low Tide:

Step	Item/Description	Symbol	Unit	Calculations			
1	Calculation identification	-	-	SW	W	NW	N
2	Wind-stress factor (adjusted wind speed)	U_A	ft/sec	60.0	32.7	39.4	48.8
3	Fetch length	F	ft	41,300	31,600	500	800
4	Constant or average water depth	d	ft	30	14	22	22
5	Significant wave height	H	ft	3.1	1.4	0.2	0.4
6	Significant wave period	T	sec	3.3	2.3	0.7	0.9
7	Duration for fully developed waves	t	sec	4,193	4,348	214	273

* U.S. Army Corps of Engineers. Shore Protection Manual. Volume I, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS, 1984.

1-4	User input calculation identification, wind stress factor (adjusted wind speed), fetch, constant or average water depth.
5	If d>300' and if $0.000282U_AF^{1/2}<0.007553U_A^2$, then $H = 0.000282U_AF^{1/2}$, otherwise $H = 0.007553U_A^2$; if d<300', then $H = (U_A^2/g)0.283\tanh[0.53(gd/U_A^2)^{3/4}]\tanh\{[0.00565(gF/U_A^2)^{1/2}]/\tanh[0.53(gd/U_A^2)^{3/4}]\}$.
6	If d>300' and if $(0.95)0.02825(U_AF)^{1/3}<(0.95)0.253U_A$, then $T = (0.95)0.02825(U_AF)^{1/3}$, otherwise $T = (0.95)0.253U_A$; if d<300', then $T = 0.95(U_A/g)7.54\tanh[0.833(gd/U_A^2)^{3/8}]\tanh\{[0.0379(gF/U_A^2)^{1/3}]/\tanh[0.833(gd/U_A^2)^{3/8}]\}$.
7	If d>300' and if $21.6(F^2/U_A)^{1/3}<2220U_A$, then $t = 21.6(F^2/U_A)^{1/3}$, otherwise $t = 2220U_A$; if d<300', then $t = (U_A/g)537(gT/U_A)^{7/3}$.

Typical Storm Waves at High Tide:

Step	Item/Description	Symbol	Unit	Calculations			
1	Calculation identification	-	-	SW	W	NW	N
2	Wind-stress factor (adjusted wind speed)	U_A	ft/sec	35.1	31.4	34.5	47.7
3	Fetch length	F	ft	41,300	31,600	500	800
4	Constant or average water depth	d	ft	39	23	31	31
5	Significant wave height	H	ft	1.9	1.5	0.2	0.4
6	Significant wave period	T	sec	2.7	2.4	0.7	0.9
7	Duration for fully developed waves	t	sec	5,704	4,787	231	277

* U.S. Army Corps of Engineers. Shore Protection Manual. Volume I, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS, 1984.

1-4	User input calculation identification, wind stress factor (adjusted wind speed), fetch, constant or average water depth.
5	If d>300' and if $0.000282U_AF^{1/2}<0.007553U_A^2$, then $H = 0.000282U_AF^{1/2}$, otherwise $H = 0.007553U_A^2$; if d<300', then $H = (U_A^2/g)0.283\tanh[0.53(gd/U_A^2)^{3/4}]\tanh\{[0.00565(gF/U_A^2)^{1/2}]/\tanh[0.53(gd/U_A^2)^{3/4}]\}$.
6	If d>300' and if $(0.95)0.02825(U_AF)^{1/3}<(0.95)0.253U_A$, then $T = (0.95)0.02825(U_AF)^{1/3}$, otherwise $T = (0.95)0.253U_A$; if d<300', then $T = 0.95(U_A/g)7.54\tanh[0.833(gd/U_A^2)^{3/8}]\tanh\{[0.0379(gF/U_A^2)^{1/3}]/\tanh[0.833(gd/U_A^2)^{3/8}]\}$.
7	If d>300' and if $21.6(F^2/U_A)^{1/3}<2220U_A$, then $t = 21.6(F^2/U_A)^{1/3}$, otherwise $t = 2220U_A$; if d<300', then $t = (U_A/g)537(gT/U_A)^{7/3}$.

Extreme Storm Waves at High Tide:

Step	Item/Description	Symbol	Unit	Calculations			
1	Calculation identification	-	-	SW	W	NW	N
2	Wind-stress factor (adjusted wind speed)	U_A	ft/sec	60.0	32.7	39.4	48.8
3	Fetch length	F	ft	41,300	31,600	500	800
4	Constant or average water depth	d	ft	39	23	31	31
5	Significant wave height	H	ft	3.2	1.5	0.2	0.4
6	Significant wave period	T	sec	3.3	2.4	0.7	0.9
7	Duration for fully developed waves	t	sec	4,340	4,693	215	274

* U.S. Army Corps of Engineers. Shore Protection Manual. Volume I, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS, 1984.

1-4	User input calculation identification, wind stress factor (adjusted wind speed), fetch, constant or average water depth.
5	If d>300' and if $0.000282U_AF^{1/2}<0.007553U_A^2$, then $H = 0.000282U_AF^{1/2}$, otherwise $H = 0.007553U_A^2$; if d<300', then $H = (U_A^2/g)0.283\tanh[0.53(gd/U_A^2)^{3/4}]\tanh\{[0.00565(gF/U_A^2)^{1/2}]/\tanh[0.53(gd/U_A^2)^{3/4}]\}$.
6	If d>300' and if $(0.95)0.02825(U_AF)^{1/3}<(0.95)0.253U_A$, then $T = (0.95)0.02825(U_AF)^{1/3}$, otherwise $T = (0.95)0.253U_A$; if d<300', then $T = 0.95(U_A/g)7.54\tanh[0.833(gd/U_A^2)^{3/8}]\tanh\{[0.0379(gF/U_A^2)^{1/3}]/\tanh[0.833(gd/U_A^2)^{3/8}]\}$.
7	If d>300' and if $21.6(F^2/U_A)^{1/3}<2220U_A$, then $t = 21.6(F^2/U_A)^{1/3}$, otherwise $t = 2220U_A$; if d<300', then $t = (U_A/g)537(gT/U_A)^{7/3}$.

Armor Stone Calculations
Per Shore Protection Manual (USACE, 1984)*

Step	Item/Description	Unit	Symbol	Calculations	
1	Calculation Identification Number	-	-	W/MHHW	W
2	Design Wave Height	ft	H	1.8	2
3	Unit Weight of Armor Stone	lbf/ft^3	w_r	165	165
4	Unit Weight of Water	lbf/ft^3	w_w	64.0	64.0
5	Armor Stone Stability Coefficient	-	K_D	3	3
6	Layer Coefficient	-	k_Δ	1.02	1.02
7	Average Porosity of Armor Layer	%	P	38	38
8	Cotangent of Structure Slope	-	cotΘ	2.0	2.0
9	Stones Per Armor Layer Thickness	-	n	2	2
10	Specific Gravity of Armor Stone	-	S_r	2.58	2.58
11	Minimum Armor Stone Weight	lbf	W_{min}	31	42
12	Average Armor Stone Weight	lbf	W	41	56
13	Maximum Armor Stone Weight	lbf	W_{max}	51	70
14	Minimum Nominal Armor Stone Dimension	in	D_{min}	8	9
15	Average Nominal Armor Stone Dimension	in	D	9	10
16	Maximum Nominal Armor Stone Dimension	in	D_{max}	9	10
17	Structure Crest Width	ft	B	1.9	2.1
18	Minimum Armor Layer Thickness	ft	r	1.3	1.4
19	Armor Stones Per 1,000 ft^2 Surface Area	-	N_r	3210	2600

* *Shore Protection Manual*. 1984. 4th Ed., 2 Vols., US Army Corps of Engineers Waterways Experiment Station, Coastal Engineering Research Center, US Government Printing Office, Washington, DC.

1	User input calculation identification number.
2	User input design wave height, valid range is 0.1 to 100 ft.
3	User input unit armor stone weight, valid range is 120 to 210 lbf/ft^3.
4	User input unit weight of water, valid range is 62 to 65 lbf/ft^3.
5	User input armor stone stability coefficient (SPM Fig. 7-8), valid range is 1 to 24.
6	User input layer coefficient, valid range is 1.00 to 1.10.
7	User input average armor layer porosity, valid range is 27 to 47%.
8	User input cotangent of structure slope, valid range is 1 to 6.
9	User input armor layer thickness per number of stones, valid range is 1 to 3.

10 $S_r = w_r/w_w$

11 $W_{min} = 0.75W$

12 $W = w_r H^3/K_D(S_r-1)^3 \cot\Theta$

13 $W_{max} = 1.25W$

14 $D_{min} = (12)(1.15)(W_{min}/w_r)^{1/3}$

15 $D = (12)(1.15)(W/w_r)^{1/3}$

16 $D_{max} = (12)(1.15)(W_{max}/w_r)^{1/3}$

17 $B = 3k_\Delta(W/w_r)^{1/3}$

18 $r = nk_\Delta(W/w_r)^{1/4}$

19 $N_r = nk_\Delta(1-P/100)(w_r/W)^{2/3}$

Port of Bellingham
Log Pond
Storm Stable Cap Armor at Low Tide

Existing Conditions:

Offshore/Deepwater Wave Height	H_o	ft	1.4
Offshore/Deepwater wave period	T	sec	2.3
Offshore/Deepwater wave length	Lo	ft	27
Wave steepness	H_o/gT^2	-	0.0082

Distance from shoreline	x	ft	15,000	6,000	2,000	800	500	420	400	350	110	60	40	30	12
Water depth	d	ft	48	30	18	30	30	20	15	10	6	5	3	2	1
Cotangent of bottom angle	cotθ	-	777	300	250	500	10	4	3	12	200	10	12	12	12
Bottom slope	m	-	0.00129	0.003	0.004	0.002	0.100	0.250	0.333	0.083	0.005	0.100	0.083	0.083	0.083
Wave length	L	ft	27	27	25	27	27	26	24	21	17	16	13	10	7
Breaker height index (SPM Fig. 7-3)	H_b/H_o	–	1.00	1.00	1.00	1.00	1.15	1.15	1.15	1.12	1.00	1.15	1.12	1.12	1.12
Breaker height	H_b	ft	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.6	1.4	1.6	1.6	1.6	1.6
Breaker steepness	H_b/gT^2	-	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.009	0.009
Upper breaker depth curve (SPM Fig. 7-2)	α	-	1.55	1.55	1.55	1.55	1.57	1.57	1.57	1.57	1.55	1.57	1.57	1.57	1.57
Lower breaker depth curve (SPM Fig. 7-2)	β	-	1.28	1.28	1.28	1.28	0.97	0.90	0.90	1.02	1.28	0.97	1.02	1.02	1.02
Depth at breaking	d_{bmax}	ft	2.2	2.2	2.2	2.2	2.5	2.5	2.5	2.5	2.2	2.5	2.5	2.5	2.5
Depth at breaking	d_{bmin}	ft	1.8	1.8	1.8	1.8	1.6	1.4	1.4	1.6	1.8	1.6	1.6	1.6	1.6
Wave height at x	H	ft	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.6	1.4	1.6	1.6	1.6	1.6
Maximum horizontal velocity at bottom	u_{max}	ft/sec	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.7	1.0	2.0	3.1	5.7
Median stable stone size at bottom	D_{50}	ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0006	0.0031	0.0073	0.0265	0.0641	0.2211
Median stable stone size at bottom	D_{50}	mm	0.000	0.000	0.005	0.000	0.000	0.003	0.021	0.174	0.956	2.218	8.073	19.527	67.394

Table B-9

Capping Conditions:

Offshore/Deepwater Wave Height	H_o	ft	1.4
Offshore/Deepwater wave period	T	sec	2.3
Offshore/Deepwater wave length	Lo	ft	27
Wave steepness	H_o/gT^2	-	0.0082

Distance from shoreline	x	ft	15,000	6,000	2,000	800	500	420	400	350	110	60	40	30	12
Water depth	d	ft	48	30	18	30	30	20	12	7	3	2	0.5	0	0
Cotangent of bottom angle	cotθ	-	777	300	250	500	10	4	3	12	200	10	12	12	12
Bottom slope	m	-	0.00129	0.003	0.004	0.002	0.100	0.250	0.333	0.083	0.005	0.100	0.083	0.083	0.083
Wave length	L	ft	27	27	25	27	27	26	23	19	13	10	5	0	0
Breaker height index (SPM Fig. 7-3)	H_b/H_o	--	1.00	1.00	1.00	1.00	1.15	1.15	1.15	1.12	1.00	1.15	1.12	1.12	1.12
Breaker height	H_b	ft	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.6	1.4	1.6	1.6	1.6	1.6
Breaker steepness	H_b/gT^2	-	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.009	0.009
Upper breaker depth curve (SPM Fig. 7-2)	α	-	1.55	1.55	1.55	1.55	1.57	1.57	1.57	1.57	1.55	1.57	1.57	1.57	1.57
Lower breaker depth curve (SPM Fig. 7-2)	β	-	1.28	1.28	1.28	1.28	0.97	0.90	0.90	1.02	1.28	0.97	1.02	1.02	1.02
Depth at breaking	d_{bmax}	ft	2.2	2.2	2.2	2.2	2.5	2.5	2.5	2.5	2.2	2.5	2.5	2.5	2.5
Depth at breaking	d_{bmin}	ft	1.8	1.8	1.8	1.8	1.6	1.4	1.4	1.6	1.8	1.6	1.6	1.6	1.6
Wave height at x	H	ft	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.6	1.4	1.6	1.6	1.6	1.6
Maximum horizontal velocity at bottom	u_{max}	ft/sec	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.8	3.1	9.4	#DIV/0!	#DIV/0!
Median stable stone size at bottom	D_{50}	ft	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.021	0.068	0.603	#DIV/0!	#DIV/0!
Median stable stone size at bottom	D_{50}	mm	0.000	0.000	0.005	0.000	0.000	0.003	0.077	0.713	6.436	20.587	183.683	#DIV/0!	#DIV/0!

Port of Bellingham
Log Pond
Storm Stable Cap Armor at High Tide

Existing Conditions:

Offshore/Deepwater Wave Height	Ho	ft	1.5
Offshore/Deepwater wave period	T	sec	2.4
Offshore/Deepwater wave length	Lo	ft	30
Wave steepness	H_o/gT^2	-	0.0081

Distance from shoreline	x	ft	15,000	6,000	2,000	800	520	470	440	410	160	50	12	8	4
Water depth	d	ft	57	39	27	39	39	30	25	20	15	10	5	3	1
Cotangent of bottom angle	cotθ	-	777	300	250	500	10	4	3	12	200	7	4	4	2
Bottom slope	m	-	0.00129	0.003	0.004	0.002	0.100	0.250	0.333	0.083	0.005	0.143	0.250	0.250	0.500
Wave length	L	ft	30	29	29	29	29	29	29	28	26	23	17	13	8
Breaker height index (SPM Fig. 7-3)	H_b/H_o	–	1.00	1.00	1.00	1.00	1.17	1.17	1.17	1.14	1.00	1.17	1.17	1.17	1.17
Breaker height	H_b	ft	1.5	1.5	1.5	1.5	1.8	1.8	1.8	1.7	1.5	1.8	1.8	1.8	1.8
Breaker steepness	H_b/gT^2	-	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.009	0.009
Upper breaker depth curve (SPM Fig. 7-2)	α	-	1.55	1.55	1.55	1.55	1.57	1.57	1.57	1.57	1.55	1.57	1.57	1.57	1.57
Lower breaker depth curve (SPM Fig. 7-2)	β	-	1.28	1.28	1.28	1.28	0.96	0.89	0.89	0.99	1.28	0.96	0.89	0.89	0.89
Depth at breaking	d_{bmax}	ft	2.3	2.3	2.3	2.3	2.8	2.8	2.8	2.7	2.3	2.8	2.8	2.8	2.8
Depth at breaking	d_{bmin}	ft	1.9	1.9	1.9	1.9	1.7	1.6	1.6	1.7	1.9	1.7	1.6	1.6	1.6
Wave height at x	H	ft	1.5	1.5	1.5	1.5	1.8	1.8	1.8	1.7	1.5	1.8	1.8	1.8	1.8
Maximum horizontal velocity at bottom	u_{max}	ft/sec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	1.2	2.3	6.5
Median stable stone size at bottom	D_{50}	ft	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.010	0.037	0.291
Median stable stone size at bottom	D_{50}	mm	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.029	0.290	3.095	11.313	88.627

Table B-9

Capping Conditions:

Offshore/Deepwater Wave Height	Ho	ft	1.5
Offshore/Deepwater wave period	T	sec	2.4
Offshore/Deepwater wave length	Lo	ft	30
Wave steepness	H_o/gT^2	-	0.0081

Distance from shoreline	x	ft	15,000	6,000	2,000	800	520	470	440	410	160	50	12	8	4
Water depth	d	ft	57	39	27	39	39	30	22	17	12	7	2	0	0
Cotangent of bottom angle	cotθ	-	777	300	250	500	10	4	3	12	200	7	4	4	2
Bottom slope	m	-	0.00129	0.003	0.004	0.002	0.100	0.250	0.333	0.083	0.005	0.143	0.250	0.250	0.500
Wave length	L	ft	30	29	29	29	29	29	28	27	24	20	11	0	0
Breaker height index (SPM Fig. 7-3)	H_b/H_o	--	1.00	1.00	1.00	1.00	1.17	1.17	1.17	1.14	1.00	1.17	1.17	1.17	1.17
Breaker height	H_b	ft	1.5	1.5	1.5	1.5	1.8	1.8	1.8	1.7	1.5	1.8	1.8	1.8	1.8
Breaker steepness	H_b/gT^2	-	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.009	0.009
Upper breaker depth curve (SPM Fig. 7-2)	α	-	1.55	1.55	1.55	1.55	1.57	1.57	1.57	1.57	1.55	1.57	1.57	1.57	1.57
Lower breaker depth curve (SPM Fig. 7-2)	β	-	1.28	1.28	1.28	1.28	0.96	0.89	0.89	0.99	1.28	0.96	0.89	0.89	0.89
Depth at breaking	d_{bmax}	ft	2.3	2.3	2.3	2.3	2.8	2.8	2.8	2.7	2.3	2.8	2.8	2.8	2.8
Depth at breaking	d_{bmin}	ft	1.9	1.9	1.9	1.9	1.7	1.6	1.6	1.7	1.9	1.7	1.6	1.6	1.6
Wave height at x	H	ft	1.5	1.5	1.5	1.5	1.8	1.8	1.8	1.7	1.5	1.8	1.8	1.8	1.8
Maximum horizontal velocity at bottom	u_{max}	ft/sec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.7	3.6	#DIV/0!	#DIV/0!
Median stable stone size at bottom	D_{50}	ft	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.087	#DIV/0!	#DIV/0!
Median stable stone size at bottom	D_{50}	mm	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.017	0.093	1.099	26.596	#DIV/0!	#DIV/0!

Vessel Generated Waves
Blaauw et al (1984)

Port of Bellingham
Log Pond

Vessel Type	Yacht
Vessel Speed, kt (V_s)	7
Water Depth, ft (h)	30
Side Distance, ft (S)	100
Interference Peak Coefficient (a)*	0.25
Wave Height, ft (H_i)	0.4
Wave Length, ft (L_i)	18
Wave Period, sec (T)	1.9

*For "a", select from the following:
0.25 for a canal motor boat
0.35 for a tug
0.80 for a barge

Blaauw, H.G., F.C.M. van der Knapp, M.T. de Groot and K.W. Pilarczyk (1984) "Design of Bank Protection of Inland Navigation Fairways." *Proceedings of the International Conference on Flexible Armoured Revetments Incorporating Geotextiles*, London, England, 29-30 March 1984.

Attachment B

Field Logs

WP-1 COORDINATES NAD 83 N? LAT = 48 44.760 LONG = 122 29.471

FIELD SAMPLING DATA SHEET

ANCHOR ENVIRONMENTAL, L.L.C.
1423 3rd Avenue Suite 300
Seattle, WA 98101
Office: (206) 287-9130 Fax: (206) 287-9131

PROJECT NAME: GP Log Pond **WELL ID:** WP-1
SITE ADDRESS: Bellingham, WA **BLIND ID:**
PURGE RATE = 300 ml / 2 min 20 sec **DUP ID:** NA

WIND FROM:	N	NE	E	SE	S	(SW)	W	NW	(LIGHT)	MEDIUM	HEAVY
WEATHER:	(SUNNY)	CLOUDY	RAIN	?	TEMPERATURE:	(°F) 65 °C					

(Circle appropriate units)

HYDROLOGY/LEVEL MEASUREMENTS (Nearest 0.01 ft)

Date	Time	DT-Bottom	DT-Product	DT-Water	DTP-DTW [Product Thickness]	DTB-DTW [Water Column]		Volume (gal) [Water Column x Gal/ft]
21/JUL/05	11:52	3.0	NA	2.05	NA	0.95	X 1	0.03895
/ /	:	.	.	.	.		X 3	.

Gal/ft = (dia./2)^2 x 0.163	1" = (0.041)	2" = 0.163	3" = 0.367	4" = 0.653	6" = 1.469	10" = 4.080	12" = 5.875

§ METHODS: (A) Submersible Pump (B) Peristaltic Pump (C) Disposable Bailer (D) PVC/Teflon Bailer (E) Dedicated Bailer (F) Dedicated Pump (G) Other =

GROUNDWATER SAMPLING DATA (if product is detected, do NOT sample)

Sample Depth: ~0.65' → ~1.6' (√ if used)

Bottle Type	Date	Time	Method §	Amount	Volume mL	Preservative (circle)	Ice	Filter	pH	√
VOA Glass	/ /	:		3	40 ml	HCl	YES	NO		
Amber Glass	/ /	:			250, 500, 1L	(None) (HCl) (H_2SO_4)	YES	NO		
White Poly	21/JUL/05	12:10	B	1	250, (500), 1L	None	YES	NO	NA	√
Yellow Poly	/ /	:			250, 500, 1L	H_2SO_4	YES	NO		
Green Poly	/ /	:			250, 500, 1L	NaOH	YES	NO		
K? ~~Red~~ Total Poly	21/JUL/05	12:15	B	1	(250), 500, 1L	K? ~~HNO_3~~ NONE	YES	NO	NA	√
K? ~~Red~~ Diss. Poly	21/JUL/05	12:17	B	1	(250), 500, 1L	K? ~~HNO_3~~ NONE	YES	YES	NA	√
	/ /	:			250, 500, 1L		YES			

Total Bottles (include duplicate count): 3

Analysis Allowed per Bottle Type

BOTTLE TYPE	TYPICAL ANALYSIS ALLOWED PER BOTTLE TYPE (Circle applicable or write non-standard analysis below)
VOA - Glass	(8021) (8260B) (BTEX) (NWTPH-G)
AMBER - Glass	(PAH) (TPH-HCID) (NWTPH-Dx) (TPH-418.1) (Oil &Grease) (8081A)
WHITE - Poly	(pH) (Conductivity) (TDS) ((TSS)) (BOD) (Turbidity) (Alkalinity) (HCO_3/CO_3) (Cl) (SO_4) (NO_3) (NO_2) (F)
YELLOW - Poly	(COD) (TOC) (Total PO_4) (Total Keldahl Nitrogen) (NH_3) (NO_3/NO_2)
GREEN - Poly	(Cyanide)
~~RED~~ TOTAL - Poly	(As) (Sb) (Ba) (Be) (Ca) (Cd) (Co) (Cr) (Cu) (Fe) (Pb) (Mg) (Mn) (Ni) (Ag) (Se) (Tl) (V) (Zn) ((Hg)) (K) (Na)
K? ~~RED~~ DISSOLVED - Poly	(As) (Sb) (Ba) (Be) (Ca) (Cd) (Co) (Cr) (Cu) (Fe) (Pb) (Mg) (Mn) (Ni) (Ag) (Se) (Tl) (V) (Zn) ((Hg)) (K) (Na) (Hardness) (Silica)

WATER QUALITY DATA

Purge Start Time: : Pump/Bailer Inlet Depth:

Meas. [Casing]	Method § [Select A-G]	Purged (gal) [Cumulative Totals]	pH	E Cond (µS)	(°F) Temp °C [Circle units]	TURB NTU Other	Diss O_2 (mg/l)	Water Quality [Clarity, Color]
4		.	.		.		.	Sal 22.2‰; -304mV Redox
3	B	0.423	7.3	34,000 µS/cm	18.7	1	3.3	@ 12:37
2	B	0.1585	—	—	—	2	.	@ 12:10
1	B	0.0793	—	—	—	11	.	
0	B	0.00	.		.		.	

Removed probe from flow thru cell and used ~~[illegible]~~ Kemmerer for WQ measurements using water bottle. Used turbidity as indicator due to lack of time (tide filling in).

SAMPLER: KIMBERLY MAGRUDER (PRINTED NAME) [signature] (SIGNATURE)

Surface Sediment Field Log

Job: Log Pond
Job No: 18876-270
Field Reps: LMcKee, DBerlin
Contractor: MSS

Core Location: SS-WP 1
Date: 8/30/05
Sample Method: hydraulic grab sampler
Proposed Coordinates:

Water Height

DTS Boat:

DTS Lead Line: ~~5.3'~~ 5.9'

Mudline Elevation (datum):

Tide Measurements
Time/Height:
Time/Height:

Sample Acceptability Criteria:
1) Overlying water is present
2) Water has low turbidity
3) Sampler is not overfilled
4) Surface is flat
5) Desired penetration depth

Notes: ~~grab pot dropped at 1252~~

Grab #	Time	Confirmed Coordinates (datum)		Sample Accept (Y/N)	Recovery Depth	Comments: winnowing, jaws close, biota, overfill, good seal, and sample depth
		Northing	Easting			
1	1535	48 44.7521 N	122° 29.4665' W	N	X	Jaws open (photo) - big rock
2	1558	48° 44.7535' N	122° 29.4682 W	Y	8.0"	good seal, good grab, algae, juvenile fish 1", abundant polychaetes

Sample Description: surface cover, (density), moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota)

Surface Cover (0-½cm) ~~algae covers top 3~~ thin layer - ½cm of light brown silt
½cm-4" Slightly sandy clayey silt, black, wet, medium dense
abundant nereids (polychaete), trace shell fragments throughout
4"-12 grades to silty sand; black/gray-spotted
1cm crab hemigrapsis (shore crab), green
trace ½ mussel shells

Composite sample:

Sample Containers: mercury, toc, ts, misc. extractables
Analyses:

Surface Sediment Field Log

Job: Log Pond
Job No: 18876-270
Field Reps: LMcKee, DBerlin
Contractor: MSS

Core Location: SS-301
Date: 8/30/05
Sample Method: hydraulic grab sampler
Proposed Coordinates:

Water Height

DTS Boat:

DTS Lead Line: 10.1'

Mudline Elevation (datum):

Tide Measurements

Time/Height:

Time/Height:

Sample Acceptability Criteria:
1) Overlying water is present
2) Water has low turbidity
3) Sampler is not overfilled
4) Surface is flat
5) Desired penetration depth

Notes:

Grab #	Time	Confirmed Coordinates NAD83 ~~Lat~~ Lat (N) (datum) Long (W)		Sample Accept (Y/N)	Recovery Depth	Comments: winnowing, jaws close, biota, overfill, good seal, and sample depth
		~~Northing~~	Easting			
1	1416	48° 44.7958'	122° 29.4509' W	Y	8.0"	4 blades eel grass, great grab

Sample Description: (trace fine sand) surface cover, (density), moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota)

Surface - wet, loose dark brown silt 1 inch thick over black wet firm silt, ~~[illegible]~~ ~~[illegible]~~ 1 long thin stick, common polychaetes, grading to wet firm black sl. sandy silt
wood 1-4" diameter at least 2 feet long - stuck in jaws of grab

Composite sample:

Sample Containers:
Analyses:

Surface Sediment Field Log

Job: 18876-270
Job No: Log Pond
Field Reps: LMcKee, DBerlin
Contractor: MSS

Core Location: SS-76
Date: 8/30/05
Sample Method: ~~sa~~ hydraulic grab sampler
Proposed Coordinates:

Water Height

Tide Measurements
Time/Height:
Time/Height:

DTS Boat: DTS Lead Line:

Mudline Elevation (datum): 9.3'

Sample Acceptability Criteria:
1) Overlying water is present
2) Water has low turbidity
3) Sampler is not overfilled
4) Surface is flat
5) Desired penetration depth

Notes: crab pot dropped at 1205
over for crab log →

Grab #	Time	Confirmed Coordinates ~~LAT~~ N (datum) NAD 83 ~~Northing~~	~~Easting~~ LONG W	Sample Accept (Y/N)	Recovery Depth	Comments: winnowing, jaws close, biota, overfill, good seal, and sample depth
1	11:32	48° 44.8677'	122° 29.3781'	Y	~~9.3'~~ 8½"	jaws close, eel grass blade great grab

Sample Description: surface cover, (density), moisture, color, minor modifier, MAJOR modifier, other constituents, odor, sheen, layering, anoxic layer, debris, plant matter, shells, biota)

8½" penetration · Light brown, wet, silt = surface cover (3mm)
· Black, soft, wet, silt with abundant wood fragments up to 3"-2"
strong sulfide odor, slightly sandy = 3mm - 2"
· Dark grey ~~sand~~ silty sand, moist, firm, odorless with a
2½" wide clam at 2-3" (living)

Composite sample: ✓

Sample Containers: grain size, MISC extractables, mercury, TS, TOC, bioassays
Analyses:

Sediment Core Log

Core: SC-76

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **7.7 feet**	Penetration Depth: **7.0 feet**
Client: **Port of Bellingham**	Water Depth (ft): **9.3 feet**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-2.5 feet**	Recovery in ft (%): **6.7 feet (95.7%)**
Contractor: **Marine Sediment Services**	N./LAT: **48 44.8669 N** E./LONG: **122 29.3766 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID
0.4–1.0	A	SC-76-A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size	
1.0–1.5	B	SC-76-B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size	
3.4–3.9	D	SC-76-D (3.4-3.9)	Hg, Misc Ex, TS, TOC, Grain Size	
5.8–6.4	E	SC-76-E (5.8-6.4)	Hg, Misc Ex, TS, TOC, Grain Size	

Sediment Description
Classification Scheme: USCS
(Recovered depth interval in feet)
Contacts are expanded

Sediment Description	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log
ML: Moist, firm, dark gray, sandy SILT. Moderate wood fragments to 2 x 0.5". Strong sulfide-like odor at 3.5'		
SM: Moist, firm, gray slightly silty SAND. Half clam shell 1" diameter		Phase I Cap
SM: SAA grading to dark gray.		Phase I Cap
CL: Several clay lenses roughly 2" in thickness		Phase I Cap
SM: Moist, firm, gray slightly silty SAND.		Phase I Cap
ML: Moist, firm, dark gray, clayey SILT. Abundant wood fragments 1-3 x 2 ". Trace sand. Strong HC-like odor, strong sulfide-like odor.		Original Material
End of core at 6.7 feet		

The RETEC Group, Inc.
1011 SW Klickitat Way, Suite 207
Seattle, WA 98134-1162
Phone: (206) 624-9349
Fax: (206) 624-2839

Remarks: No C Sample, as Phase 2 cap layer was not apparent.

No odor or sheen unless noted.

No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
6.7 / 7.0 = 95.7%

Sediment Core Log

Core: SC-75

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **7.0.feet**	Penetration Depth: **7.0 feet**
Client: **Port of Bellingham**	Water Depth (ft): **12.1 feet**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-5.3 feet**	Recovery in ft (%): **6.4 (91 %)**
Contractor: **Marine Sediment Services**	N./LAT: **48 44.8150 N** E./LONG: **122 9.4576 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Recovered depth interval in feet) Contacts are expanded	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log	Calc. In situ Depth (ft)
0					SM: Moist, medium firm, brownish gray slightly silty SAND.		↑	0
	A	SC-75-A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size		ML: Moist, firm, SILT. Moderate worm casings. Live clam at 0.5'. Trace bark fragments 1 x 1". Moderate scent of decaying marine life.			
1	B	SC-75-B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size		SM: Moist, firm, gray, slightly silty fine-grained SAND. Grades to medium to coarse with depth.			1
2					2.2' Small wood fragments 1" x 0.5"		Phase I Cap	2
3					3.0' Irregular shaped sandstone fragment 2 x 2.5" with black sand.			3
4	D	SC-75-D (3.7-4.2)	Hg, Misc Ex, TS, TOC, Grain Size		4.4' 2 Small wood fragments 2 x 1"			4
5							↓	5
					ML: Moist, dense, dark gray, clayey SILT. Trace wood fragments Strong sulfide-like odor. 5.6' Moderate wood and shell fragments. Strong sulfide-like odor		Original Material	
6	E	SC-75-E (5.7-6.2)	Hg, Misc Ex, TS, TOC, Grain		End of Core at 6.4 feet			6

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1011 SW Klickitat Way, Suite 207
Seattle, WA 98134-1162
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Fax: (206) 624-2839

Remarks: No C sample, as Phase 2 Cap layer was not apparent.

No sheen or odor unless otherwise noted

No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
6.4 / **7.0** = **80** %

Sediment Core Log

Core: SC-40

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **7.1 feet**	Penetration Depth: **7.0 feet**
Client: **Port of Bellingham**	Water Depth (ft): **14.0 feet**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-7.2 feet**	Recovery in ft (%): **5.6 feet (80%)**
Contractor: **Marine Sediment Services**	N./LAT: **48 44.7916 N** E./LONG: **122 29.5143 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin, K Magruder**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Recovered depth interval in feet) Contacts are expanded	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log	Calc. In situ Depth (ft)
0					ML: Moist, firm, dark grey, slightly sandy SILT. Trace wood fragments. Moderate scent of decaying aquatic life.		Phase I Cap	0
	A	SC-40-A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size		SM: Moist, firm, dark grey slighly silty, medium to fine grained SAND. Trace wood fragements up to 1" diameter.			
1	B	SC-40-B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size					1
2					ML: Moist, firm, dark grey, clayey SILT. Moderate wood fragments up to 1" diameter. Strong sulfide-like odor		Original Material	2
3	E	SC-40-E (3.0-3.5)	Hg, Misc Ex, TS, TOC, Grain Size					3
4					Unlogged from 3.9 - 5.6 feet, as no need to sample.			4
5					End of core at 5.6			5

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Remarks: No C sample, as Phase 2 Cap layer was not apparent.
Unlogged below 3.9 feet.
No sheen or odor. No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
5.6 / **7.0** = **80** %

Sediment Core Log

Sheet 1 of 2

Core: SC-301

Project: **Log Pond Sediment Cores**	Water Body Type: **Marine**	Tube Length: **8.0 feet**
Project #: **PORTB-18876-270**	SW Elevation (ft)/Tide: **4.4 feet**	Penetration Depth: **12.2 feet**
Client: **Port of Bellingham**	Water Depth (ft): **10.8**	Sample Quality: **good**
Collection Date: **8/29/05**	Mudline Elevation (ft): **-4.0 feet**	Recovery in ft (%): **7.4 feet (62.5)**
Contractor: **Marine Sediment Services**	N./LAT: **48 45.7962 N** E./LONG: **122 29.4508 W**	Process Date: **8/31/05**
Vessel: **MSS aluminum motor vessel**	Horiz. Datum: **NAD 83** Vert. Datum: **MLLW**	Process Method: **cut tube**
Operator: **Dale Dickenson**	Method/Tube ID: **4 " round aluminum**	Logged By: **D Berlin, K Magruder**

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID
0.4–1.0	A	SC-301A (0.4-1.0)	Hg, Misc Ex, TS, TOC, Grain Size	
1.0–1.5	B	SC-301B (1.0-1.5)	Hg, Misc Ex, TS, TOC, Grain Size	
2.4–2.9	C	SC-301C (2.4-2.9)	Hg, Misc Ex, TS, TOC, Grain Size	
5.5–6.0	D	SC-301D (5.5-6.0)	Hg, Misc Ex, TS, TOC, Grain Size	

Sediment Description
Classification Scheme: USCS
(Recovered depth interval in feet)
Contacts are expanded

Sediment Description	Comments Expanded Depths	Calc. In situ Depths (ft) & Graphic Log
ML: Wet, medium firm, dark gray clayey SILT with trace very fine sand. Slight sulfide-like odor 0.2' worm 0.4-1.0' trace small twigs 2.4' wood fragment 2"		Phase 2 Cap (0–3.9)
ML: Wet, firm, dark gray clayey SILT with increasing clay and fine-grained sand		Phase 2 Cap
SM: Moist, firm, dark gray, slightly silty SAND with trace wood fragments		Phase 1 Cap (3.9–)
ML: Moist, firm, dark grayish brown sandy SILT		Phase 1 Cap
SM: Moist, firm, dark gray slightly silty fine-medium grained SAND. 4.7' Large wood fragments 3" diameter		Phase 1 Cap
ML: Moist, firm, dark gray, clayey SILT. Moderate wood fragments 1/4 - 1/2 "		Phase 1 Cap
SM: Moist firm, dark gray, slightly silty, fine to medium grained SAND		Phase 1 Cap

Depth scale (ft): 0, 1, 2, 3, 4, 5, 6

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Fax: (206) 624-2839

Remarks: Core catcher was cut off in the lab.

Refusal from wood fragments at 7.4'

No odor or sheen. No PID measurements taken.

Calculated Recovery
Sample Length/Penetration Length:
7.4 / 12.5 = 62.5%

Sediment Core Log

Core: SC-301

Recovered Depth (ft)	Recovered Interval	Sample #	Analysis	Headspace PID	Sediment Description Classification Scheme: USCS (Actual recovered depth interval in feet)	Comments	Calc. Insitu Depths (ft) & Graphic Log	Elevation (ft)
7	E	SC-301E (7.0-7.4)	Hg, Misc Ex, TS, TOC, Grain Size		ML: Wet, firm, black, clayey SILT. Abundant wood fragments 2-3" x 1-2". Moderate hydrocarbon-like odor. Moderate shell fragments.		Original Material	7
					End of core at 7.4 feet.			
8								8

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Remarks: Core catcher was cut off in the lab.

Refusal from wood fragments at 7.4'

No odor or sheen. No PID measurements taken.

Calculated Recovery

Sample Length/Penetration Length:

7.4 / **12.5** = **62.5**%

Attachment C

Analytical Data Reports
(on CD-ROM)

Attachment D

Bioassay Data
(see CD-ROM behind Attachment C)

Attachment E

Benthic and Epibenthic Summary Report

(see CD-ROM behind Attachment C)