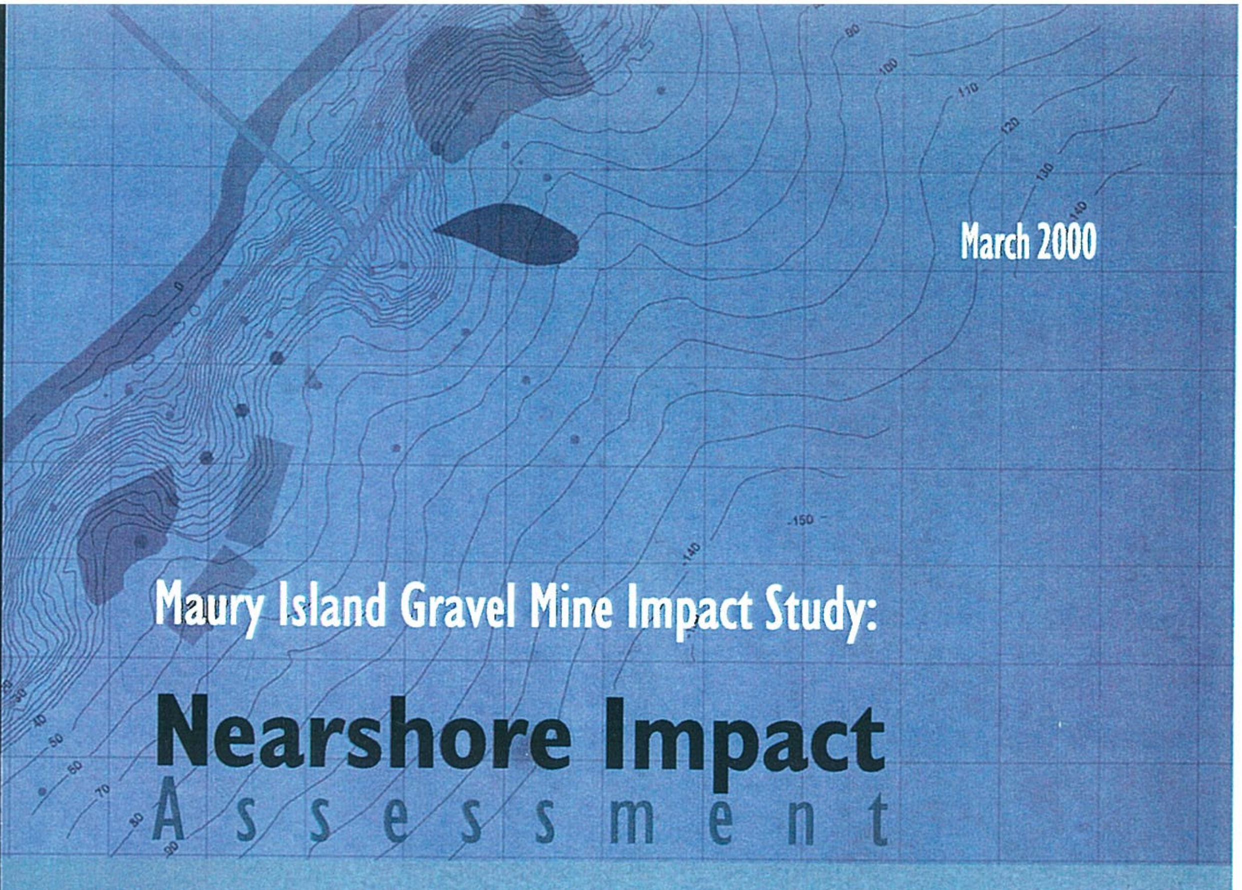
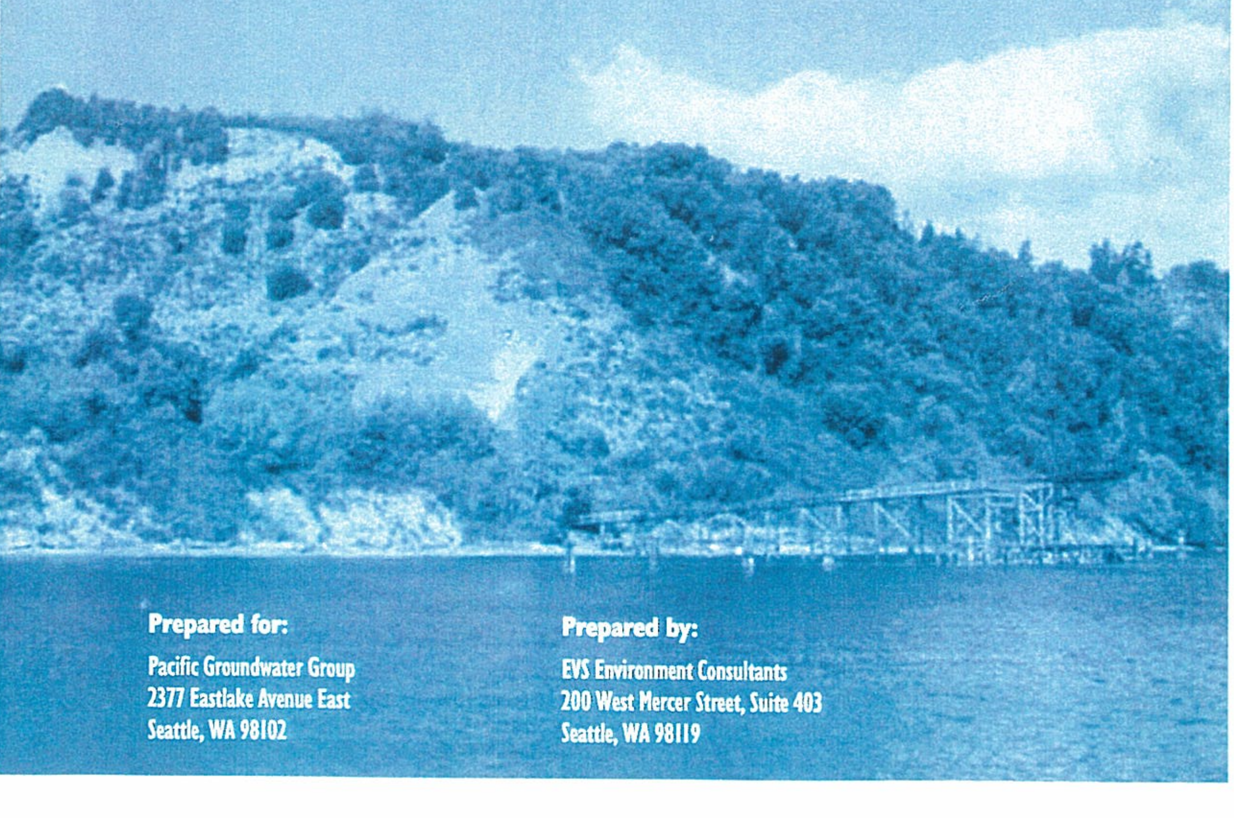


March 2000

Maury Island Gravel Mine Impact Study:

Nearshore Impact Assessment



Prepared for:

Pacific Groundwater Group
2377 Eastlake Avenue East
Seattle, WA 98102

Prepared by:

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Maury Island Gravel Mine Impact Study

NEARSHORE IMPACT ASSESSMENT

Prepared for

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EVS Project No.
2/527-02

MARCH 2000

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LIST OF ACRONYMS

ACOE	U.S. Army Corps of Engineers
ADDAMS	Automated Dredging and Disposal Alternatives Modeling System
AES	Associated Earth Sciences
ARI	Analytical Resources Incorporated
DEIS	Draft Environmental Impact Statement
DGPS	differential global positioning system
ESA	Endangered Species Act
MLLW	mean lower low water
NOAA	National Oceanographic and Atmospheric Administration
OLLD	Ocean and Lake Levels Division
PAH	polycyclic aromatic hydrocarbon
PAR	photosynthetically active radiation
PCB	polychlorinated biphenyl
PSEP	Puget Sound Estuary Program
QA	quality assurance
SPI	sediment profile imaging
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
WDFW	Washington Department of Fish and Wildlife

ACKNOWLEDGMENTS

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Precision bathymetric and side scan surveys were conducted on the vessel *Surveyor* by Mr. Tony Petrillo of Blue Water Engineering. Mr. Garrett Gray and Mr. Tim Hammermeister of EVS collected the sediment samples and deployed the Sediment Profile Imaging camera from the vessel *Kittiwake*, which is owned and operated by Mr. Charles Eaton of Bio-Marine Enterprises. Sediment chemistry analyses were conducted by Analytical Resources Inc.

The following individuals provided comments on an earlier draft of this report:

Mr. Dave Garland	Washington Department of Ecology
Ms. Pamela Erstad	Washington Department of Fish and Wildlife

1.0
INTRODUCTION

Glacier Northwest, a subsidiary of Lone Star Northwest, Inc., and referred to herein as Lone Star, has applied for a permit to increase its rate of gravel extraction from an existing mine located on the eastern shore of Maury Island in Puget Sound, Washington. The legislation commissioning the Maury Island mine impact studies specified that the study consider impacts to the nearshore environment. For this reason, the Washington Department of Ecology included a nearshore study element in the mine impact study.

This document provides an assessment of potential impacts of the proposed mine project on critical nearshore marine resources. The assessment uses the following methods:

- A field study was conducted to establish baseline benthic habitat types and conditions
- Reports from Washington Department of Fish and Wildlife (WDFW) fisheries specialists were reviewed to assess the use of the nearshore area by listed and candidate fish species
- Published scientific studies on the effects of similar impacts on the nearshore species of concern were reviewed

This document consists of the following sections:

Section 2.0	Baseline Nearshore Assessment
Section 3.0	Impact Assessment
Section 4.0	Conclusions
Section 5.0	References
Appendices	

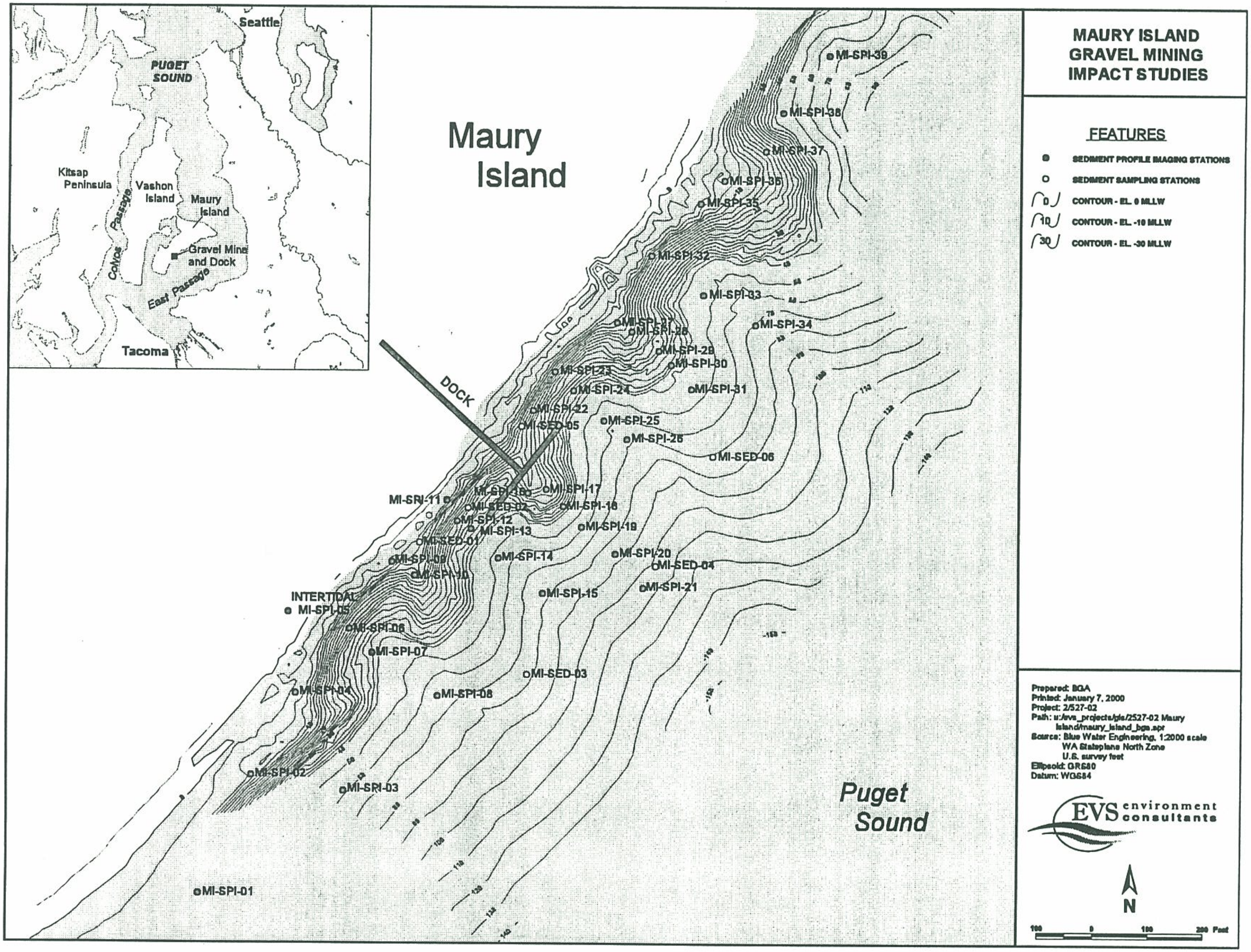

Figure 2-1. Map showing bathymetry (depths in ft) and locations of SPI and sediment sampling stations for nearshore survey of Maury Island

2.0
BASELINE NEARSHORE ASSESSMENT

This baseline nearshore assessment characterizes the sediment condition, benthic habitats, and likely use by fisheries resources of the Maury Island nearshore area. EVS Environment Consultants (EVS) conducted a field study in the fall of 1999 to characterize the sediments and benthic condition. The characterization of the use of this area by fish and marine mammal species was developed through information gained from fisheries specialists, WDFW stock assessment reports, and scientific literature.

2.1 STUDY AREA

Maury Island is an extension of Vashon Island in south central Puget Sound, Washington (Figure 2-1). Lone Star has proposed to expand mining activities on a roughly 95-ha (235-ac) site located on the eastern edge of Maury Island and along the East Passage of Puget Sound. The nearshore study area, referred to as the nearshore area in this document, is delineated by approximately 975 m (3,200 ft) of shoreline, the Glacier Northwest property boundary, from mean lower low water (MLLW) to about –9 m (-30 ft) MLLW. In addition, the approximately 366 m (1,200 ft) of the central section of shoreline out to a greater depth of approximately -40 m (-130 ft) MLLW were included in the baseline benthic assessment.

The nearshore subtidal habitat adjacent to the Lone Star mine has been characterized as a sand and silt substratum with a gradually sloping bottom from the shoreline to the seaward edge of the Lone Star dock (Jones & Stokes et al. 1999). Results from diver transects have indicated that a diverse habitat with bare sand areas, patchy eelgrass beds, and areas with kelp and green algae is present in the vicinity (Jones & Stokes and AR 1999). The Puget Sound Environmental Atlas (Evans-Hamilton and D.R. Systems 1987; Puget Sound Estuary Program [PSEP] 1992) reports the existence of eelgrass beds along most of the southeastern shoreline of Maury Island, from the mean low water mark down to a depth of approximately -7 m (-22 ft) MLLW. Geoduck (*Panope abrupta*) beds are also found along the entire southeastern shoreline of Maury Island within 183 m (200 yd) of the shore (Sizemore et al. 1998). Both piddock and geoduck clams were reported in the barge loading area (Jones & Stokes and AR 1999).

2.2 BENTHIC HABITATS WITHIN STUDY AREA

To obtain more detailed information about bottom type and habitat conditions in the project area, EVS used a combination of acoustic and photographic survey techniques, along with sediment sampling, to document baseline conditions in the fall of 1999. Approximately 16 ha (39 acres) in the nearshore environment were characterized using a precision bathymetric survey, a side-scan sonar survey, a series of sediment profile images, and the results of the chemical analysis of sediment samples collected from six locations in the immediate vicinity of the Lone Star dock.

2.2.1 Materials and Methods

2.2.1.1 Bathymetry and Side-Scan Sonar Survey

Blue Water Engineering precision conducted bathymetric and side-scan sonar surveys using the vessel *Surveyor* by on October 12, 1999. Bathymetric survey lanes were centered around the Lone Star dock and oriented perpendicular to shore; 975 m (3,200 ft) of shoreline were surveyed. Survey lanes were spaced 6 m (20 ft) apart for the nearshore profile and 18 m (60 ft) apart for the portion of survey that extended out into deep water. Bathymetric data were collected with a narrow-beam, 208 kHz transducer Odom survey fathometer. Observed tidal data were obtained through the National Oceanographic and Atmospheric Administration (NOAA) Ocean and Lake Levels Division's (OLLD) National Water Level Observation Network. These stations are equipped with the Next Generation Water Level Measurement System tide gauges and satellite transmitters that have collected and transmitted tide data to the central NOAA facility every six minutes since January 1, 1994.

Observed tidal data are available 1 to 6 hours after the time of collection in station datum or referenced to MLLW and based on Coordinated Universal Time. For the October 12, 1999, survey of Maury Island, data from the NOAA tide stations 9446484, located at Pier 7 at the Port of Tacoma, Tacoma, Washington, and 9447130, located at the Washington State Ferry Building, Seattle, Washington, were used for tidal calculations. The NOAA tide data were downloaded in the MLLW datum, interpolated for spatial correction, corrected to local time, and applied to the collected data at 30-minute intervals. Bathymetric data were analyzed using Coastal Oceanographic HYPACK® software and corrected to MLLW using the NOAA observed tides. The bathymetric data were then used to construct depth models of the surveyed area.

To characterize sediment type, the location of eelgrass beds, and the location of underwater targets, a side-scan sonar survey was conducted with a Dowty 3050 Wide-Scan towfish. Acoustic signals at a frequency of 500 kHz were emitted from the two transducers mounted in the 3050 towfish, and the returns were relayed to an EPC 1086 graphic recorder. The side-scan sonar lanes were run parallel to shore at a spacing of 9 m (30 ft); bathymetric data were also collected during the side-scan sonar survey.

Navigation data for both side-scan and bathymetric surveys were collected with a Trimble AG132 differential global positioning system (DGPS).

2.2.1.2 Sediment Profile Imaging and Sediment Sampling Survey

The sediment profile imaging (SPI) and sediment sampling were conducted on the research vessel *Kittiwake* owned and operated by Charles Eaton, Bio-Marine Enterprises, on November 4 and 5, 1999. The *Kittiwake* utilized a Trimble NT300D DGPS with internal receiver for processing the differential signal to provide navigation and positioning support for the project. The coordinates were recorded for each sampling station occupied. During this project, the differential corrections applied were those generated and transmitted by U.S. Coast Guard installations. Accuracy of the system is rated to be within ±2 m (±7 ft).

Sampling Locations—Sampling locations for the sediment profile images and sediment samples were predetermined based on the preliminary results from the side-scan and bathymetric surveys. Figure 2-1 presents the locations for both the SPI survey and 6 sediment sampling stations.

Sediment Profile Imaging Survey—Photographs of the benthic sediment profile were taken at 39 offshore stations. Two replicate images were taken with Kodak Ektachrome® color slide film (ISO 100) at each station, identified as MI-SPI-01 through MI-SPI-39 in Table 2-1; each SPI replicate is identified by the time recorded on the film and corresponding entries in the field and navigation logbooks. Even though duplicate images were taken at each location, each image was assigned a unique frame number by the data logger and cross-checked with both the hand-entered sample logs kept by the field crew and the sampling station electronic file.

On deck test exposures were made using the Kodak® Color Separation Guide (Publication No. Q-13) at the beginning and end of each roll of film to verify that all internal electronic systems were working to design specifications and to provide a color standard against which the final film emulsion could be checked for proper color balance. After deployment of the camera at each station, the frame counter was checked to make sure that the requisite number of replicates had been taken. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth to acquire a profile image. Because of the paucity of fine-grained sediments in the study area, all available prism weights (total of 113 kg [250 lbs]) were kept in the camera for the entire survey to maximize the camera's prism penetration.

Table 2-1. Station locations for sediment profile imaging survey

STATION ID	LATITUDE	LONGITUDE
MI-SPI-01	47 21.6654	122 26.5124
MI-SPI-02	47 21.7002	122 26.4906
MI-SPI-03	47 21.6962	122 26.4501
MI-SPI-04	47 21.7246	122 26.4720
MI-SPI-05	47 21.7484	122 26.4762
MI-SPI-06	47 21.7438	122 26.4493
MI-SPI-07	47 21.7369	122 26.4391
MI-SPI-08	47 21.7246	122 26.4103
MI-SPI-09	47 21.7637	122 26.4316
MI-SPI-10	47 21.7598	122 26.4215
MI-SPI-11	47 21.7821	122 26.4084
MI-SPI-12	47 21.7760	122 26.4037
MI-SPI-13	47 21.7738	122 26.3975
MI-SPI-14	47 21.7655	122 26.3853
MI-SPI-15	47 21.7554	122 26.3657
MI-SPI-16	47 21.7847	122 26.3731
MI-SPI-17	47 21.7860	122 26.3652
MI-SPI-18	47 21.7810	122 26.3577
MI-SPI-19	47 21.7751	122 26.3495
MI-SPI-20	47 21.7674	122 26.3345
MI-SPI-21	47 21.7577	122 26.3221
MI-SPI-22	47 21.8092	122 26.3718
MI-SPI-23	47 21.8206	122 26.3628
MI-SPI-24	47 21.8152	122 26.3545
MI-SPI-25	47 21.8066	122 26.3411
MI-SPI-26	47 21.8013	122 26.3307
MI-SPI-27	47 21.8355	122 26.3364
MI-SPI-28	47 21.8328	122 26.3299
MI-SPI-29	47 21.8274	122 26.3179
MI-SPI-30	47 21.8234	122 26.3124
MI-SPI-31	47 21.8164	122 26.3035
MI-SPI-32	47 21.8554	122 26.3221
MI-SPI-33	47 21.8441	122 26.2995
MI-SPI-34	47 21.8357	122 26.2767
MI-SPI-35	47 21.8709	122 26.3016
MI-SPI-36	47 21.8778	122 26.2918
MI-SPI-37	47 21.8868	122 26.2742
MI-SPI-38	47 21.8982	122 26.2671
MI-SPI-39	47 21.9153	122 26.2478

Sediment Sampling—Six locations near the Lone Star dock were established to collect sediment for chemical and benthic analyses. The sampling stations are identified as MI-SED-01 through MI-SED-06, as shown in Figure 2-1. Samples were intentionally located around the perimeter of the dock, with three locations on the inshore side of the dock, and three locations on the open-water side of the dock. The three stations on the open-water side of the dock, MI-SED-03, MI-SED-04, and MI-SED-06, were located at the nearest position to the dock that an acceptable sediment sample could be collected. Because of the proliferation of cobble and gravel on the sediment surface near the dock, the sampling vessel was repositioned at increments of approximately 4 m (13 ft) along a radial transect until sediment could be retrieved. Table 2-2 lists the coordinates for the locations where acceptable samples were retrieved.

Table 2-2. Station locations for sediment sampling

ID	LATITUDE	LONGITUDE
MI-SED-01	47 21.7696	122 26.4197
MI-SED-02	47 21.7801	122 26.3989
MI-SED-03	47 21.7315	122 26.3716
MI-SED-04	47 21.7641	122 26.3169
MI-SED-05	47 21.8038	122 26.3762
MI-SED-06	47 21.7969	122 26.2934

Sediment Collection—Surface sediment samples for all locations were collected using a double 0.1 m^2 (1.1 ft^2) van Veen grab sampler (total area sampled 0.2 m^2 [2.2 ft^2]). The grab sampler was deployed and retrieved from the stern of the boat using a hydraulic main winch equipped with 5/16-in. stainless steel wire. Upon retrieval, the sample was examined to determine acceptability based on the following sediment acceptance criteria:

- The sample does not contain foreign objects
- The sampler is not over-filled with sediment so that the sediment surface presses against the top of the sampler
- No significant leakage has occurred, as indicated by overlying water on the sediment surface
- No sample disturbance has occurred, as indicated by limited turbidity in the overlying water
- No winnowing has occurred, as indicated by a relatively flat, undisturbed surface

Once a sample was deemed acceptable, one chamber of the double van Veen was used to carefully siphon any overlying water in order to avoid disturbing the sediment surface. The upper 10 cm (4 in.) of sediment were extracted from the sampler and placed into clean stainless steel containers. Once a sufficient amount of sediment for analysis had been collected at a location, the sample was thoroughly homogenized by hand using a stainless steel spoon in order to achieve consistent color and texture. Aliquots of the homogenized mixture were carefully placed into glass sample jars. Subsamples collected for total sulfides analysis were collected prior to the homogenization of the sediment sample.

The other chamber of the double van Veen grab sample was designated for benthic community analysis. All of the sediment and overlying water from the designated chamber was extracted from the grab sample and placed in a 7-L (2-gal) plastic bucket for processing at the completion of the field effort. The processing of these samples is discussed in Section 2.2.1.3.

After the containers were filled and the outsides cleaned, each container received a label with a unique sample ID number that was sealed and affixed with clear tape. The following information was recorded on the sample labels and in the logbooks:

- Project number
- Unique sample ID number
- Date and time of collection
- Required analyses
- Sampler's initials
- Preservation type (if any)
- Any other pertinent comments (e.g., duplicate)

The quality assurance (QA) officer was present during all homogenization, container filling, labeling, document processing, and sample packing.

In addition to the field notes taken during sample collection and the sample labels affixed to the containers, additional documentation recorded during processing included a sample log and chain-of-custody forms. An individual record of each filled container was maintained in the sample log; each sample was identified by the unique sample ID number affixed to the container and included information such as the station ID, time collected, the analysis required, and the corresponding analytical laboratory to which the sample was to be shipped. Chain-of-custody forms accompanied all samples during storage and shipment to the laboratory. Samples were kept on ice and kept in proper custody (either in the presence of the sample custodian or locked up) after processing until they could be shipped. All sediment samples were personally delivered by a member of the EVS field crew to Analytical Resources Incorporated (ARI), Seattle, Washington, for chemical analysis.

2.2.1.3 Benthic Community Samples

When an acceptable sample was obtained, the sediment from the designated chamber was emptied into a high-density polyethylene bucket for temporary storage. The benthic community samples were processed at the completion of the survey, after all sediment samples had been collected. The sediment was sieved through a 1-mm (0.04-in) mesh screen using a saltwater rinse aboard the *Kittiwake*. Sieving was performed until the water draining through the bottom of the sieve buckets ran relatively clear. Visible foreign objects were carefully removed from the retained material. The remaining material was then placed into plastic jars, covered with 10 percent formalin, and labeled appropriately. Sample jar lids were wrapped with electrical tape to prevent any leaking during storage or transport. Samples were archived at EVS in Seattle, Washington. No benthic taxonomic analysis was performed.

2.2.2 Results

2.2.2.1 Bathymetry

A two-dimensional contour map of the bathymetric results is presented as Figure 2-2. Water depths along the face of the dock ranged from approximately 6 m (18 ft) at their shallowest, along the center portion of the dock, to between 11 and 12 m (35 and 38 ft) at the ends of the dock. Depth increased at a fairly uniform rate as one heads offshore, reaching depths of over 31 m (100 ft) within 84 m (275 ft) straight out from the middle of the dock. The most notable distinction was the series of rhythmic shoreline features, or submerged beach cusps, that were perpendicular to the shoreline (see Figure 2-2). The crests of these cusps are regularly spaced at approximately 91-m (300-ft) intervals; the middle of the Lone Star dock happened to be located on one of these crests.

These shoreline cuspate deposits, which typically occur on sand and gravel bottoms, have attracted a great deal of interest in the field of coastal geomorphology. However, for practically every theory that has been put forth by one author as to the origin of these rhythmic formations, a different, contradicting theory has been offered by another author. As a result, a great deal of controversy still exists among geomorphologists regarding which processes of wave motion and sediment transport control their rhythmic spacings (Komar 1998). The strongest evidence to date has been advanced by Guza and Inman (1975). Their studies show that standing edge waves play a prominent role in the formation of nearshore beach cusps; when conditions are such that the edge waves have a period that is twice that of the normal incident waves, then cusps are formed. However, it is not possible to identify with absolute certainty the process that caused the submerged cuspate formation found offshore Maury Island.

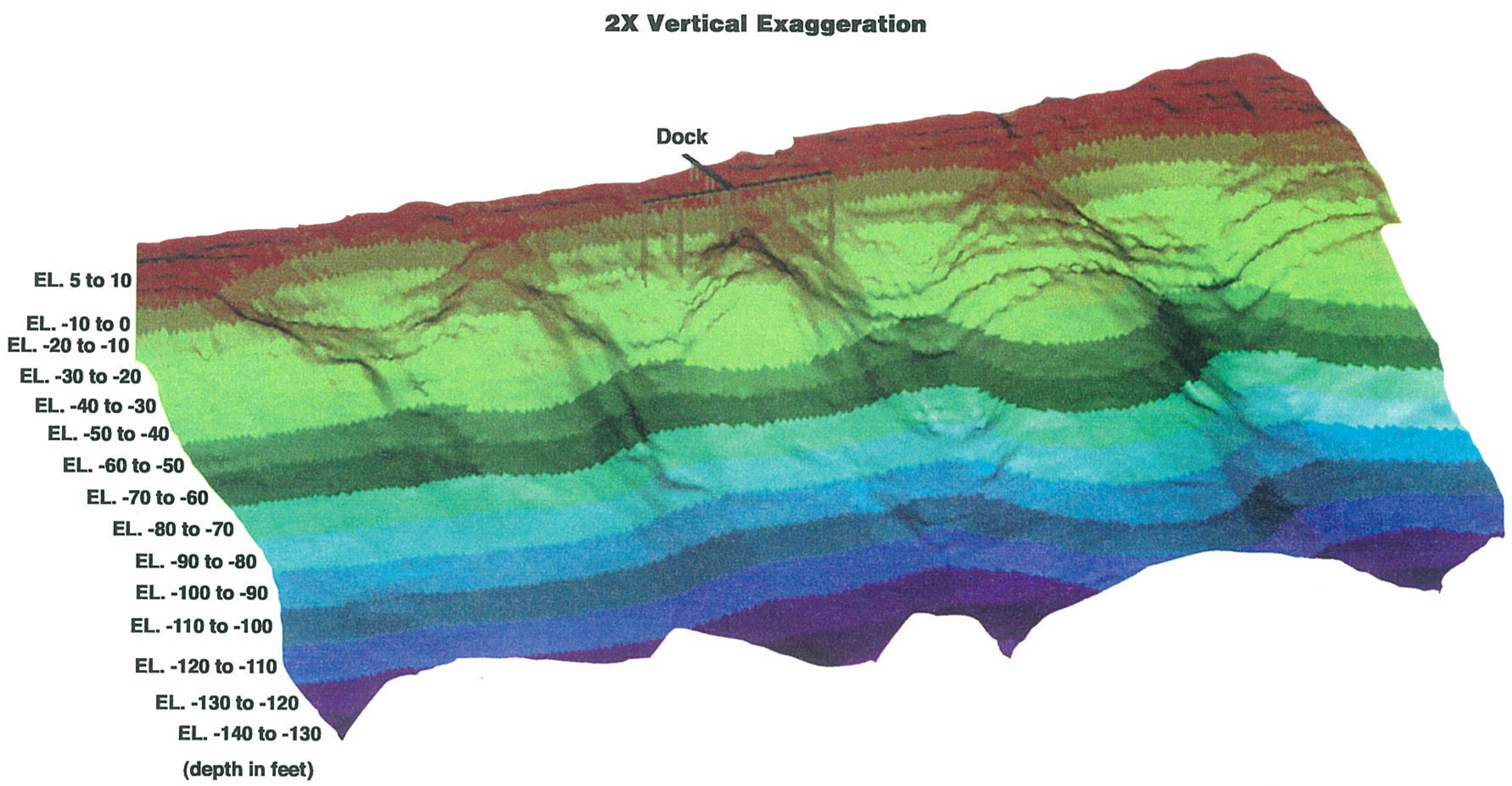

Figure 2-2. Three-dimensional representation of nearshore Maury Island bathymetry showing the "hill and valley" topography of the submerged beach cusp formations

2.2.2.2 Side-Scan Sonar

Side-scan sonar transmits a specially shaped acoustic beam 90 degrees from either side of the survey vessel and records the sound energy that reflects back to the towfish. The results are recorded as a gray-scale image depicting the varied strengths of the returning beam; strong reflectors are displayed as dark areas on the image, and a total lack of returning energy as white. From a photographic analysis, this gives an image that appears to be a negative. In the side-scan sonar image, shadows are often the most important interpretive tool. In many cases, shadows can indicate more about the makeup of a reflector than the acoustic returns from the reflector itself because they provide a three-dimensional quality to the two-dimensional sonar record. They are produced by objects projecting above or depressed into the sea floor.

For the Maury Island survey, the side-scan sonar survey was used to characterize sediment type, target locations, and provide a more accurate delineation of eelgrass beds. If the density of eelgrass plants was sufficiently high, the plants reflected the side-scan signal. A variety of seabed features were readily apparent from an examination of the side-scan image. These included two sunken barges and a small vessel off the southern end of the dock (Figure 2-3), patches of coarse-grained sediment (Figure 2-4), and the presence of eelgrass (Figure 2-5). In combination with the bathymetric and sediment profile data (Section 2.2.2.3), an overall interpretive map was compiled to show the prominent features of the nearshore habitat (Figure 2-6).

The acoustic information from both the side-scan sonar survey and the bathymetric records confirmed that the sediments off Maury Island were primarily sands (fine to coarse) with some concentrated patches of coarser-grained sediment from gravel, cobble, or rocks on the bottom (Figure 2-6). There were two major eelgrass beds to the northeast and southwest of the Lone Star dock in water depths shallower than 6 m (20 ft) (Figure 2-6), as well as two smaller patches on either side of the dock on the crests of the submerged cusps. While other isolated patches of eelgrass at densities too low to reflect sound waves were identified in the sediment profile images (see Section 2.2.2.3), the side-scan sonar mapped an approximate total of 1.0 ha (2.5 ac) of bottom covered by eelgrass, or a little over 6 percent of the total area surveyed.

Other nearshore features included patches of coarse sediment along the shore and rough bottom. One larger debris pile, consisting of logs and rocks, started at approximately 15 m (50 ft) SE of the dock and extended downslope roughly 46 m (150 ft). A few isolated logs or planks on the seabed are indicated on the map, as is the line of dolphins, five to the northeast and five to the southwest of the existing dock; these are proposed to be repaired for use in tugboat and barge operations at the dock.

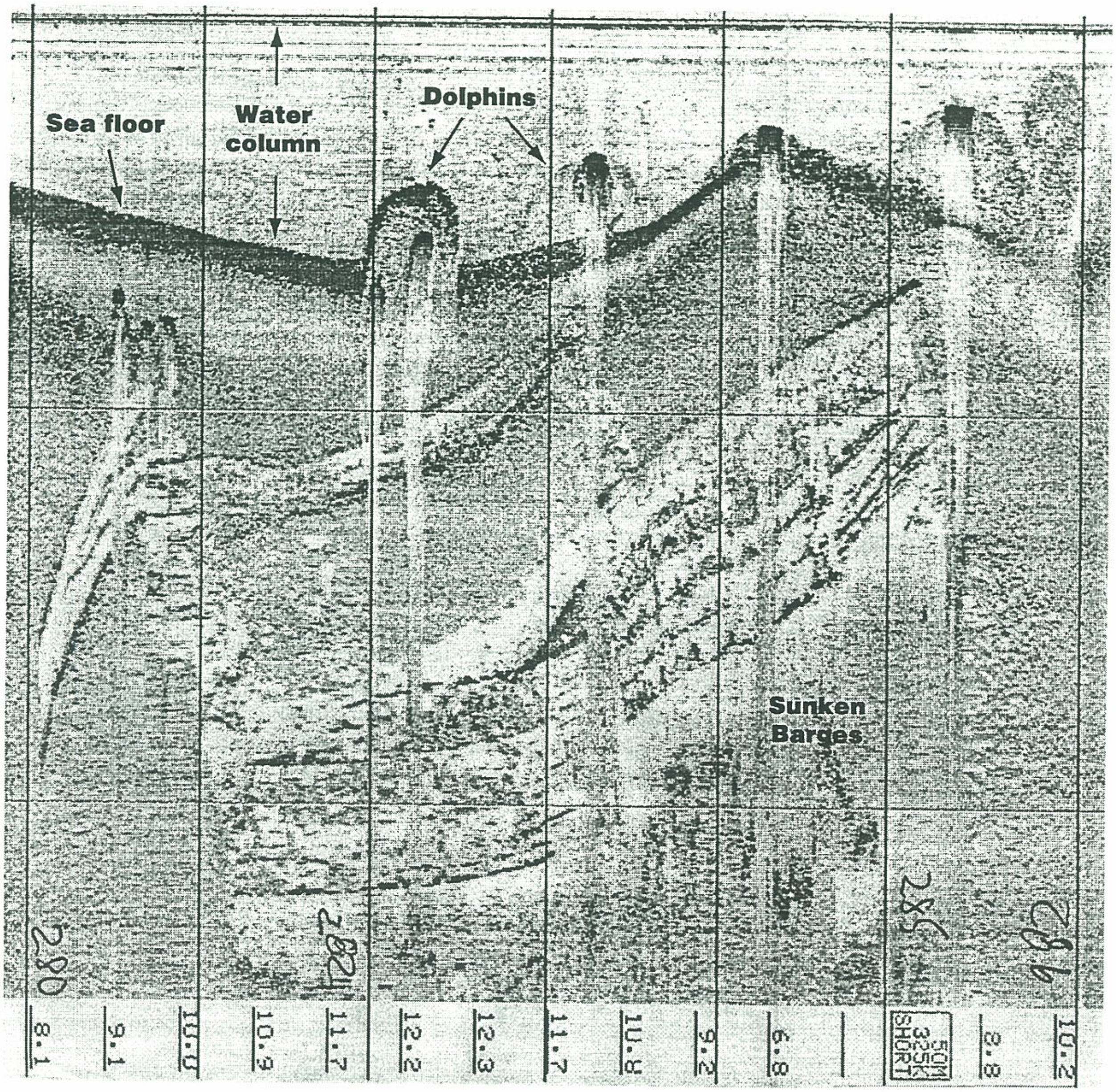

Figure 2-3. Side-scan sonar image of the two sunken barges located off the southern end of the Lone Star dock

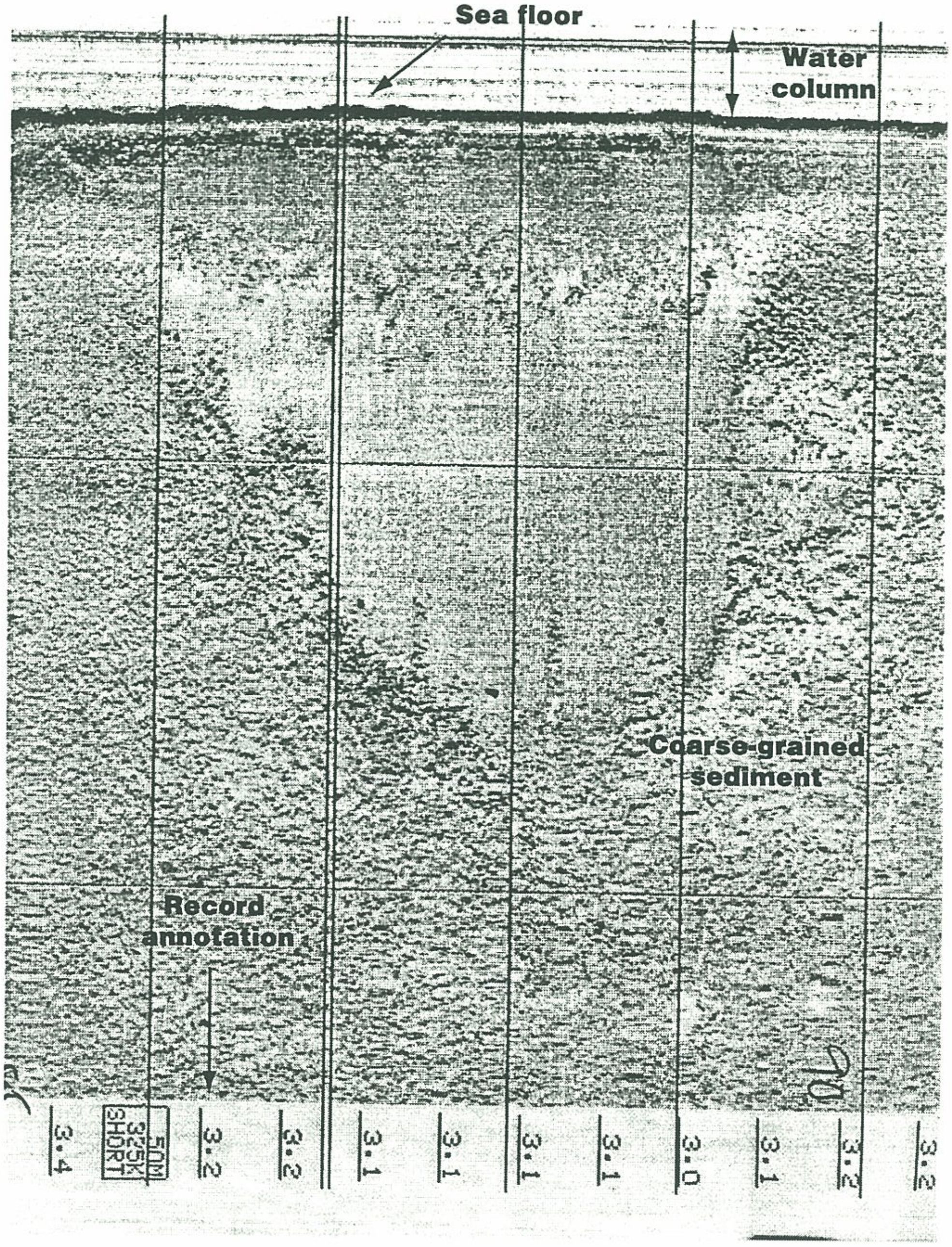

Figure 2-4. Side-scan sonar image of a patch of coarse-grained sediment distinct from the surrounding sandy bottom

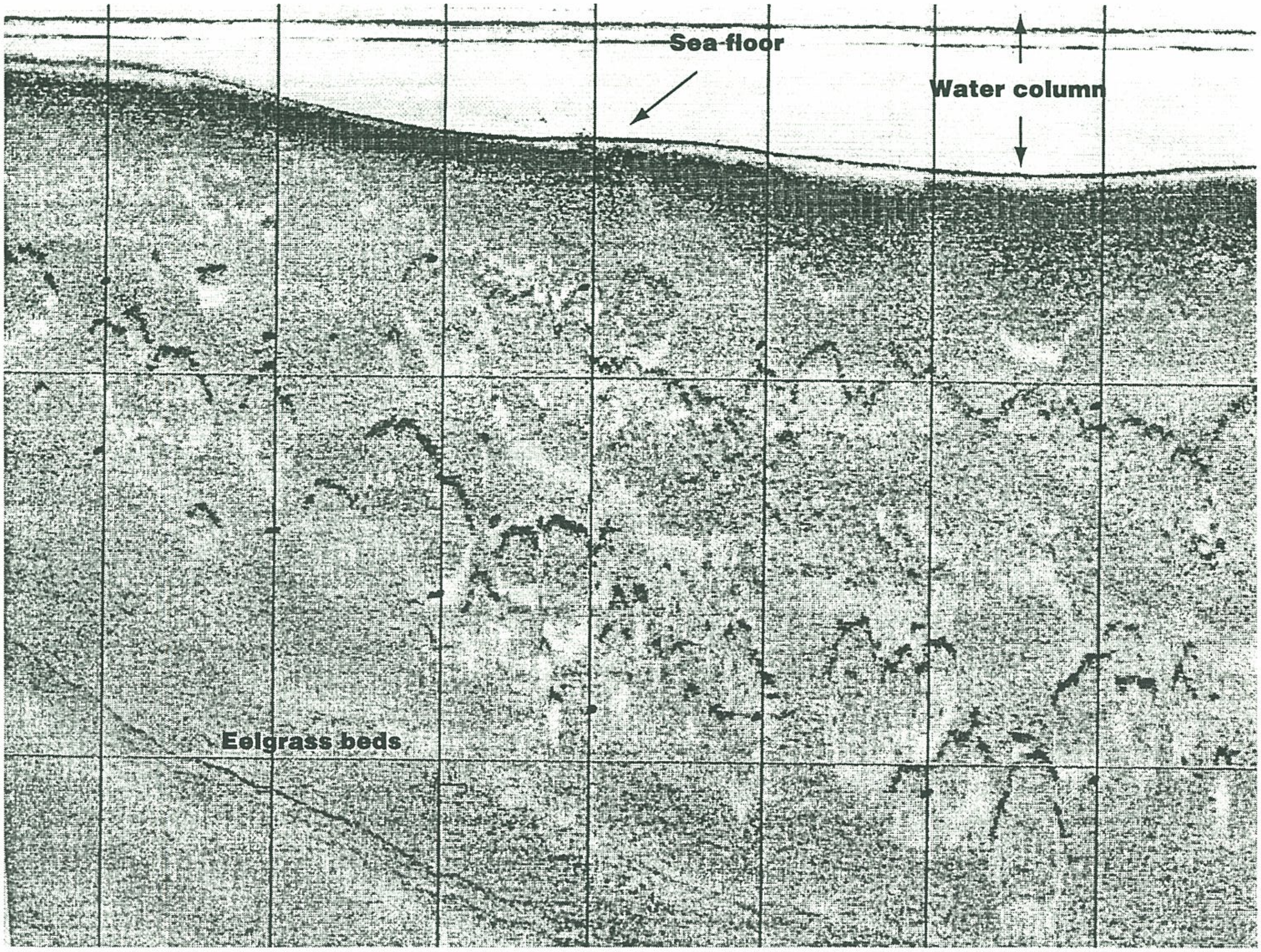

Figure 2-5. Side-scan sonar image of eelgrass patches

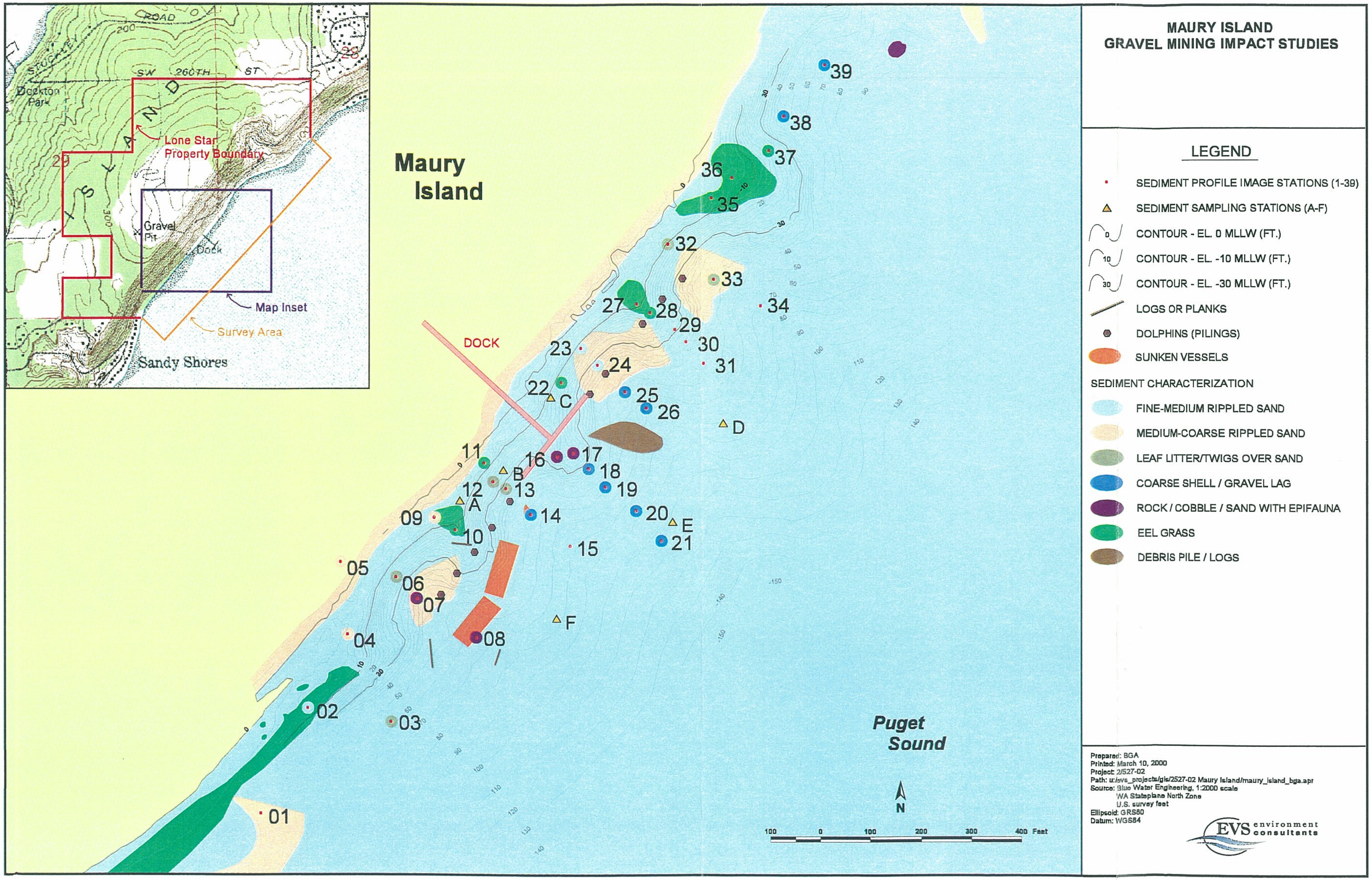

Figure 2-6. Characterization of sediment type and seabed features of the nearshore environment from side-scan sonar interpretation combined with bathymetric results

2.2.2.3 Sediment Profile Images

The results from the sediment profile images confirmed and, in some cases, enhanced the sediment characteristics mapped by the side-scan sonar (see Appendix A for detailed results from all images). The majority of the bottom surveyed was rippled medium sand; a typical profile image from the area is shown in Figure 2-7. Several of the shallower stations near the shore showed evidence of leaf litter and wood twigs on the bottom, not an unusual pattern for nearshore areas that receive runoff from land (Figure 2-8). The presence of leaf and twig debris may have contributed to the patches of rough bottom noted in side-scan data. While images from stations within the eelgrass patches delineated by the side-scan sonar confirmed the presence of plants (Figure 2-9), eelgrass was also found at Stations 11 and 22 where plant densities were low enough or the bottom slope steep enough to avoid detection by the side-scan sonar (Figure 2-10).

Prism penetration was fairly shallow at most stations (less than 10 cm [4 in.]), reflecting the higher shear strength of sandy sediments; however, a few isolated stations had sands with lower shear strength, most likely due to dilation caused by burrowing organisms (Figure 2-11). Surface layers of gravel were found at Stations 17, 19, 20, 21, 26, 33, 38, and 39, and an area of hard bottom with large rocks was found at Station 16. While the source of this gravel could easily be inferred as having originated from past gravel mining operations because of the proximity of the stations to the dock (Stations 16, 17, 19, 20, 21, and 26), there were also stations far away from the dock with surface gravel layers (Stations 33, 38, and 39; see Figure 2-12). Similarly, there were stations close to the dock without continuous gravel layers (Stations 11, 12, 13, 14, and 15). In any event, the presence of gravel increases the habitat diversity, providing a substratum for colonial epifauna, including barnacles and bryozoans (Figure 2-13), macrophytes (Figure 2-14), and suspension-feeding bivalves such as mussels (Figure 2-15). Many stations showed armored surface layers of shell or gravel lag deposits, typical of areas experiencing strong bottom currents (Figure 2-16).

Habitat conditions were typical of a nearshore, sandy bottom; there was no evidence of an accumulation of fine-grained sediments or organic loading at any of the locations sampled. A wide variety of fauna and flora were detected in the images, from worm tubes and eelgrass projecting above the sediment-water interface to starfish, mussels, hermit crabs, and invertebrate egg clusters found on both the sand and gravel bottoms (Figure 2-17). The community in this area and in the shallower depths is obviously adapted to high-energy regimes and frequent disturbances.

Figure 2-7. Sediment profile image from Station 5; note the well-sorted, medium sand with surface ripples and evidence of emerging eelgrass fronds at the sediment-water interface. Width of image = 15 cm

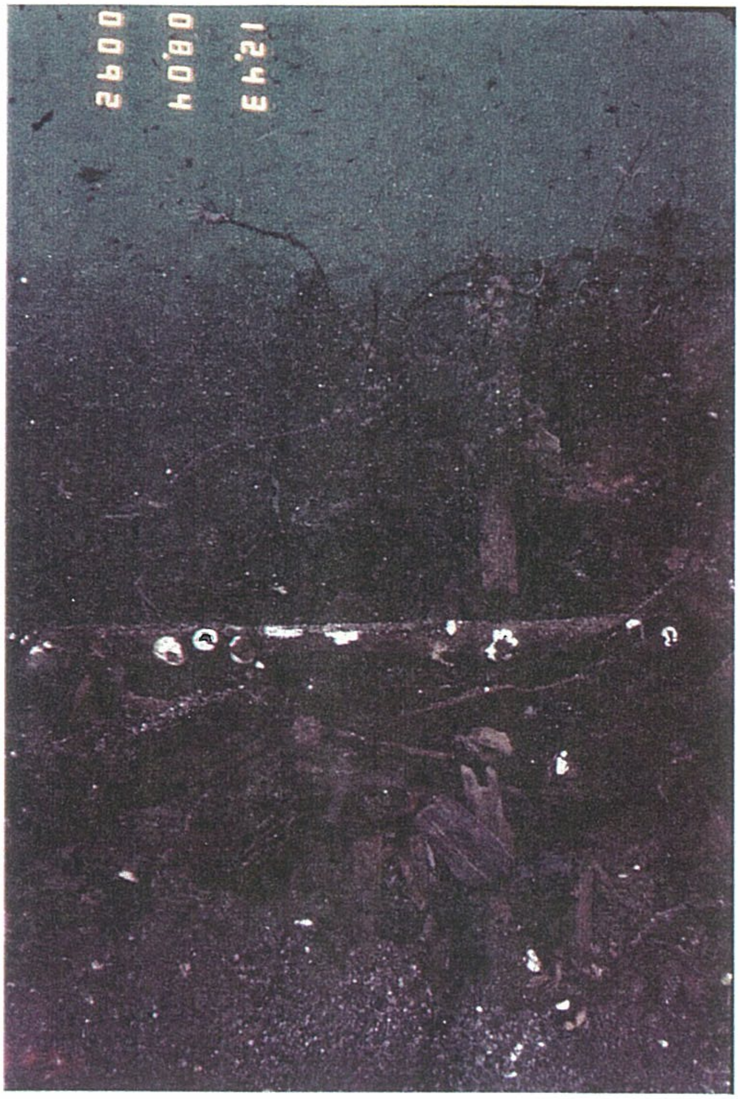

Figure 2-8. Sediment profile image from Station 6; wood twigs and leaf litter are very common in nearshore areas. Width of image = 15 cm

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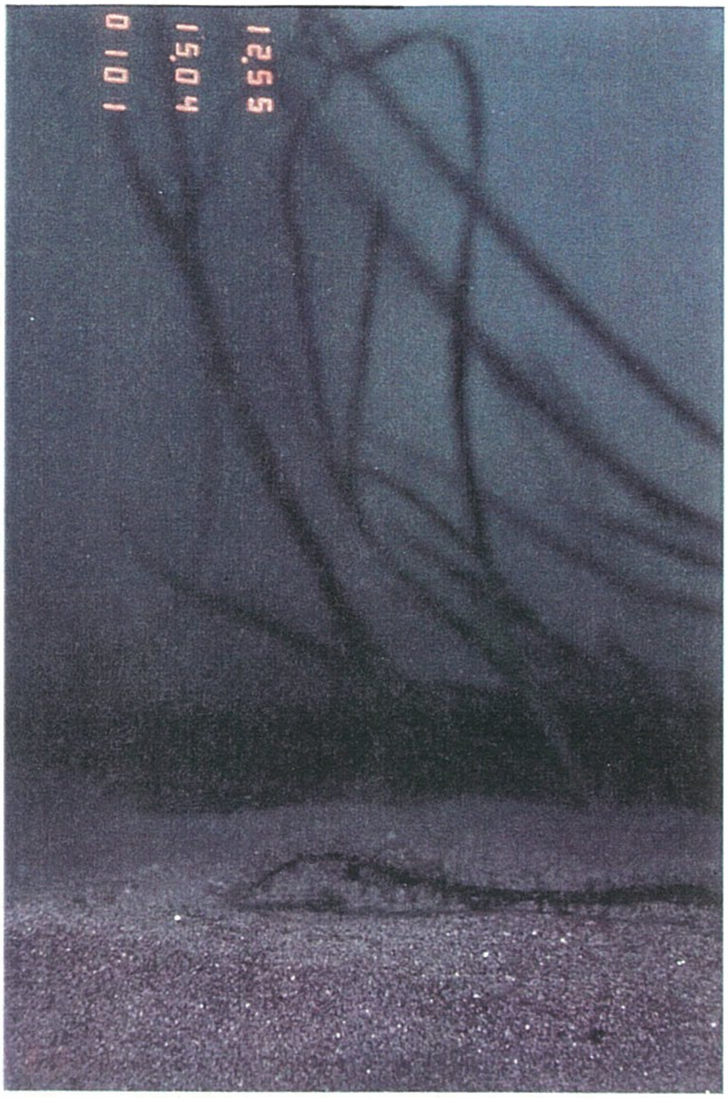

Figure 2-9. Sediment profile image from Station 10; eelgrass fronds are readily apparent projecting above the sediment-water interface. Width of image = 15 cm

Figure 2-10. Sediment profile image from Station 11; both eelgrass and sea lettuce (*Ulva sp.*) can be seen bent over from the current at this shallow station (5 ft water depth). Width of image = 15 cm

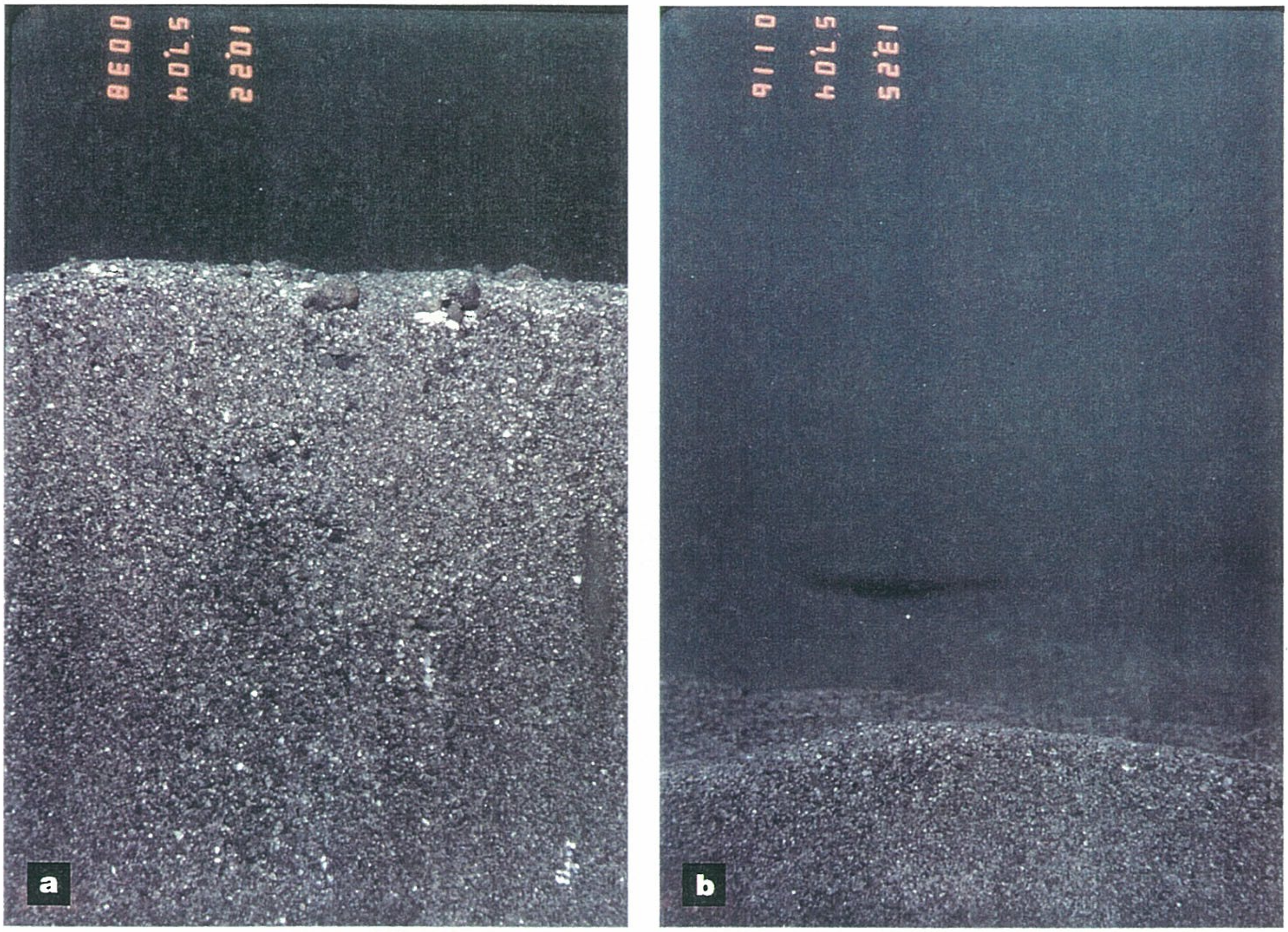

Figure 2-11. Sediment profile images from Station 18 (a) and Station 4 (b). Note the uniform cross section of well-sorted sand in each image; the greater SPI prism penetration at Station 18 is likely due to increased bioturbation activity. Width of image = 15 cm

Figure 2-12. Sediment profile image from Station 39; note the uniform surface layer of gravel that was most likely deposited due to natural physical transport mechanisms. Width of image = 15 cm

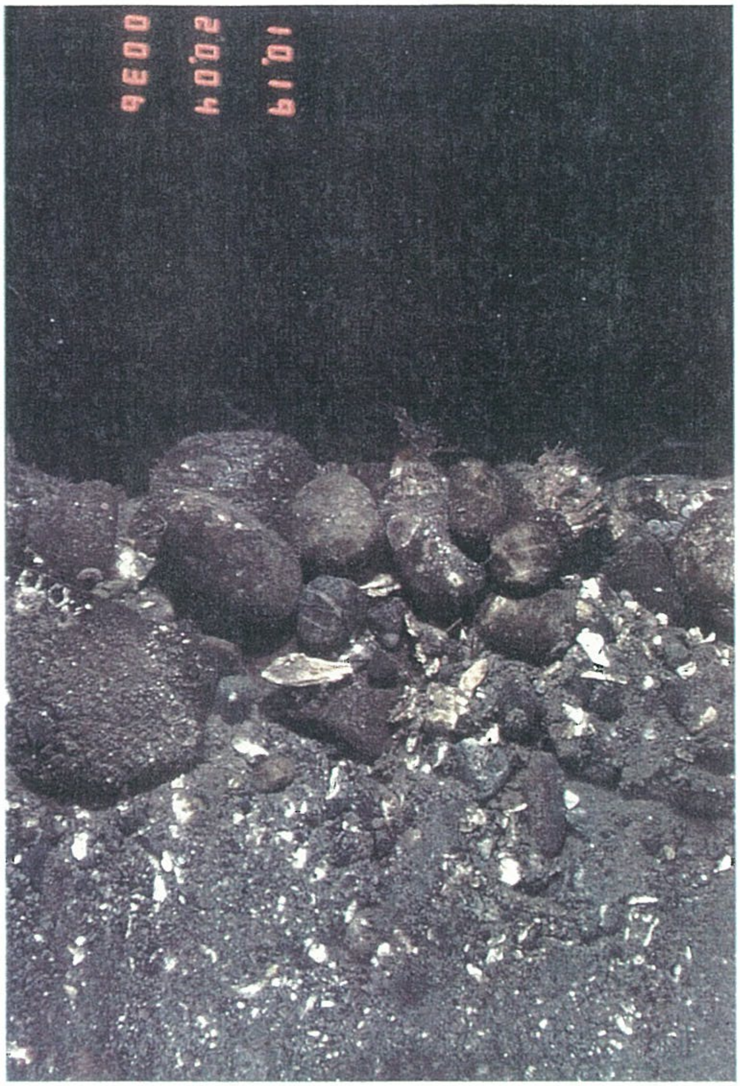

Figure 2-13. Sediment profile image from Station 19 showing a layer of gravel on the sand surface; note the colonial epifauna growing on the surface of the gravel. Width of image = 15 cm

Figure 2-14. Sediment profile image from Station 17; both barnacles and kelp are utilizing the surface gravel layer as a substratum for growth. Width of image = 15 cm

Figure 2-15. Sediment profile image from Station 21; the mussels on the gravel surface provide a food source for larger foraging predators. Note the tip of a starfish arm at the right edge of the image.
Width of image = 15 cm

Figure 2-16. Sediment profile image from Station 25; the thick layer of shells from dead bivalves prevented any substantial penetration by the sediment profile camera prism. Width of image = 15 cm

Figure 2-17. Sediment profile image from Station 23; note the hermit crab and the cluster of what are most likely squid eggs on the sediment surface. Width of image = 15 cm

2.2.2.4 Sediment Chemistry

Sediment chemistry data were collected at six stations (Figure 2-1). The sediment samples were analyzed for grain size, organic carbon content, and selected organic concentrations and trace element contaminants. The measured contaminant concentrations were compared to Washington State Marine Sediment Quality Standards.

The sediment organic carbon content and grain size data are presented in Table 2-3. The samples were all coarse-grained, sandy sediments with relatively low organic carbon content, ranging from 0.14 to 1.9 percent organic carbon.

Table 2-3. Sediment organic carbon content and grain size[a]

	MI-SED-01 A[b]	MI-SED-02 B[b]	MI-SED-03 F[b]	MI-SED-04 E[b]	MI-SED-05 C[b]	MI-SED-06 D[b]
Percent organic carbon	0.24	1.9	0.25	0.32	0.33	0.14
Total Solids	77.3	76.8	78	75.1	77.5	78
Gravel	1.3	14.9	8.3	3.7	6.8	2.2
Sand	96.3	81.1	89.3	91.5	88.6	94.7
Silt	1.2	2.7	0.9	2.8	3.2	1.8
Clay	1.2	1.4	1.5	2.1	1.2	1.3

[a] All units are percent.

[b] Letters correspond to sediment sample locations on Figure 2-6.

Sediment polycyclic aromatic hydrocarbon (PAH) concentrations are presented in Table 2-4. In general, very low concentrations were measured, with the highest concentrations measured in sample MI-SED-5. The sediment pesticide and polychlorinated biphenyl (PCB) concentrations are presented in Table 2-5. All pesticide and PCB concentrations were reported as not detected. In order to compare the PAH, pesticide, and PCB concentrations to marine sediment quality standards, organic-carbon normalized sediment concentrations were calculated, and they are presented in Table 2-6. The only concentration that exceeded the corresponding criterion was that of one individual PAH compound, fluoranthene, in MI-SED-05. It should be noted that the magnitude of the organic-carbon normalized values is driven, in large part, by the low organic carbon content of these sediments.

Sediment trace element concentrations are presented in Table 2-7. There were no detected concentrations of arsenic, cadmium, or silver. The measured concentrations of all trace elements were less than the corresponding marine sediment criteria.

Table 2-4. Sediment PAH concentrations[a]

	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
Naphthalene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
2-Methylnaphthalene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
Acenaphthylene	8 U	8.2 U	8 U	8 U	11	8 U
Acenaphthene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
Fluorene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
Phenanthrene	8 U	29	8 U	8 U	54	8 U
Anthracene	8 U	24	8 U	8 U	22	8 U
Fluoranthene	12	140	8 U	4.8 J	790	8 U
Pyrene	6.4 J	75	6.4 J	5.6 J	450	8 U
Benzo(a)anthracene	8 U	24	8 U	8 U	110	8 U
Chrysene	8 U	39	8 U	8 U	240	8 U
Benzo(b)fluoranthene	8 U	28	8 U	8 U	170	8 U
Benzo(k)fluoranthene	8 U	22	8 U	8 U	130	8 U
Benzo(a)pyrene	8 U	18	8 U	8 U	86	8 U
Indeno(1,2,3-cd)pyrene	8 U	9.8	8 U	8 U	48	8 U
Dibenzo(a,h)anthracene	8 U	8.2 U	8 U	8 U	9.9	8 U
Benzo(g,h,i)perylene	8 U	7.3 J	8 U	8 U	38	8 U
Dibenzofuran	8 U	8.2 U	8 U	8 U	8.2 U	8 U

NOTE: U – chemical was not detected; the value shown is the detection limit
J – value reported as an estimate

[a] All units are μg/kg dry weight.

Table 2-5. Sediment pesticide and PCB concentrations

	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
alpha-BHC	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
beta-BHC	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
delta-BHC	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
gamma-BHC (Lindane)	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Heptachlor	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Aldrin	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Heptachlor Epoxide	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Endosulfan I	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Dieldrin	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
4,4'-DDE	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endrin	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endosulfan II	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
4,4'-DDD	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endosulfan Sulfate	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
4,4'-DDT	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Methoxychlor	8.6U	8.8U	8.6U	8.6U	8.9U	8.6U
Endrin Ketone	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endrin Aldehyde	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
gamma Chlordane	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
alpha Chlordane	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Toxaphene	86U	88U	86U	86U	89U	86U
Aroclor 1016	17U	18U	17U	17U	18U	17U
Aroclor 1242	17U	18U	17U	17U	18U	17U
Aroclor 1248	17U	18U	17U	17U	18U	17U
Aroclor 1254	17U	18U	17U	17U	18U	17U
Aroclor 1260	17U	18U	17U	17U	18U	17U
Aroclor 1221	35U	35U	35U	35U	35U	34U
Aroclor 1232	17U	18U	17U	17U	18U	17U

NOTE: U – chemical was not detected; the value shown is the detection limit

[a] All units are µg/kg dry weight.

Table 2-6. Organic carbon normalized PAH and pesticide concentrations

	SMS CRITERIA	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
Naphthalene	99	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
2-Methylnaphthalene	38	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
Acenaphthylene	66	3.33 U	0.43 U	3.20 U	2.50 U	3.33	5.71 U
Acenaphthene	16	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
Fluorene	23	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
Phenanthrene	100	3.33 U	1.53	3.20 U	2.50 U	16.36	5.71 U
Anthracene	220	3.33 U	1.26	3.20 U	2.50 U	6.67	5.71 U
Fluoranthene	160	5.00	7.37	3.20 U	1.50 J	239.39	5.71 U
Pyrene	1000	2.67 J	3.95	2.56 J	1.75 J	136.36	5.71 U
Benzo(a)anthracene	110	3.33 U	1.26	3.20 U	2.50 U	33.33	5.71 U
Chrysene	110	3.33 U	2.05	3.20 U	2.50 U	72.73	5.71 U
Benzo(b)fluoranthene	na	3.33 U	1.47	3.20 U	2.50 U	51.52	5.71 U
Benzo(k)fluoranthene	na	3.33 U	1.16	3.20 U	2.50 U	39.39	5.71 U
Benzo(a)pyrene	99	3.33 U	0.95	3.20 U	2.50 U	26.06	5.71 U
Indeno(1,2,3-cd)pyrene	34	3.33 U	0.52	3.20 U	2.50 U	14.55	5.71 U
Dibenzo(a,h)anthracene	12	3.33 U	0.43 U	3.20 U	2.50 U	3.00	5.71 U
Benzo(g,h,i)perylene	31	3.33 U	0.38 J	3.20 U	2.50 U	11.52	5.71 U
Dibenzofuran	15	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
LPAH	370	20.00	4.52	19.20	15.00	33.82	34.29
HPAH	960	34.33	19.54	31.36	23.25	627.85	57.14
Total benzofluoranthenes	230	6.67	2.63	6.40	5.00	90.91	11.43
alpha-BHC	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
beta-BHC	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
delta-BHC	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
gamma-BHC (Lindane)	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Heptachlor	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Aldrin	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Heptachlor Epoxide	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Endosulfan I	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Dieldrin	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
4,4'-DDE	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endrin	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endosulfan II	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
4,4'-DDD	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endosulfan Sulfate	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
4,4'-DDT	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Methoxychlor	–	3.58 U	0.46 U	3.44 U	2.69 U	2.70 U	6.14 U
Endrin Ketone	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endrin Aldehyde	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
gamma Chlordane	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U

Table 2-6, continued

	SMS Criteria	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
alpha Chlordane	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Toxaphene	–	35.83 U	4.63 U	34.40 U	26.88 U	26.97 U	61.43 U
Aroclor 1016	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1242	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1248	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1254	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1260	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1221	–	14.58 U	1.84 U	14.00 U	10.94 U	10.61 U	24.29 U
Aroclor 1232	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U

NOTE: U – chemical was not detected; the value shown is the detection limit
J – value reported as an estimate

[a] All units are mg/kg percent organic carbon

Table 2-7. Sediment trace element concentrations[a]

	SMS criteria	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
Arsenic	57	3 U	3 U	3 U	3 U	3 U	3 U
Cadmium	5.1	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Copper	390	9.5	11.1	6.9	8.9	11.4	7
Lead	540	3	4	6	6	4	5
Mercury	0.41	0.01 U	0.01 U	0.02	0.02	0.02	0.01
Nickel	na	31.2	29.3	25	34	33.3	25.5
Silver	3.3	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Zinc	410	26.9	27.4	27.8	29.8	28.6	27.5

NOTE: U – chemical was not detected; the value shown is the detection limit
na – not applicable

[a] All units are mg/kg dry weight

2.2.3 Conclusions

The nearshore environment off the southeastern portion of Maury Island in the vicinity of the Lone Star dock was typical of nearshore, sandy bottoms in Puget Sound. One of the most interesting features discovered through this survey was the submerged cusp formation of the bottom topography. While it is impossible to state definitively what caused this submarine topography, it does have implications for sediment deposition and transport in the nearshore area. If source or current conditions were such that any fine-grained material were to settle on the bottom, it would be more likely to do so on the crests where the kinetic regime is at its lowest as opposed to in the valleys of these rhythmic formations.

Eelgrass beds were found in water depths shallower than 6 m (20 ft). The presence of eelgrass has been mapped in two previous studies (Jones & Stokes et al. 1999; Jones & Stokes and AR 1999) in the immediate vicinity of the dock. This survey provides a much more comprehensive overview and shows the locations of major eelgrass patches over a larger area. However, it is important to keep in mind that seagrass beds move over time and shrink and expand seasonally (Fonseca et al. 1998); one-time surveys are inadequate as a means of providing a thorough characterization of seagrass habitats. Bed form migration, the presence of seed banks, annual population cycles, recent nonpoint source anthropogenic impacts, as well as natural disturbance events can all affect the presence and size of eelgrass patches. Given all of these caveats, the one consistent finding from the three surveys in the immediate area of the dock is that there are no major eelgrass beds directly at the dock face where the barges would be loading. The edge of the closest large patch is 46 m (150 ft) southwest of the southern end of the dock.

The biological community, as interpreted from the SPI, is typical for a nearshore, sandy bottom. This area appears to be a relatively high-energy environment, as evidenced by the lack of accumulation of fine sediments in the area surveyed; frequent disturbance from land runoff, as evidenced by leaf litter and twigs; gravel deposits, both anthropogenic and storm-generated; and currents. A wide variety of fauna and flora was present both on the sand and gravel areas of the bottom, and there appeared to be no substantial adverse affects to any bottom communities from past commercial activities. The sunken barges and vessel off the southern end of the dock, while definitely an anthropogenic disturbance, appeared to have had the same long-term effect as that of the gravel deposits off the end of the dock: increasing habitat niche diversity by providing increased surface area upon which new organisms can grow.

2.3 NEARSHORE FISHERIES RESOURCES

2.3.1 Expected Fish Community

The aquatic habitats in the study area are fairly typical of the nearshore, non-estuarine environments that are present in many areas of south central Puget Sound (Evans-Hamilton and D.R. Systems1987; PSEP 1992). Most nearshore species that reside in Puget Sound can be expected to occur in the study area at some time. Table 2-8 presents a list of fish species that have been identified in the study area (Associated Earth Sciences [AES] 1998; Jones & Stokes and AR 1999) or are species managed by the State of Washington and likely to reside in the study area (Lemberg et al. 1997; Palsson et al. 1997).

Table 2-8. Managed fish species that have been identified in the study area or are likely present

Common Name	Scientific Name	Species Status[a]	Identified in Study Area	Habitat Use		
				Spawning Area	Juvenile Rearing	Adult Resident
Salmonids						
Chinook salmon	*Oncorhynchus tshawytscha*	Declining/ Threatened[b]	◆		◆[c]	
Coho salmon	*Oncorhynchus kisutch*	Declining			◆[c]	
Pink salmon	*Oncorhynchus gorbuscha*	Stable			◆[c]	
Chum salmon	*Oncorhynchus keta*	Stable			◆[c]	
Steelhead trout	*Oncorhynchus mykiss*	Declining			◆[c]	
Cutthroat trout	*Oncorhynchus clarki*	Declining			◆[c]	
Sea Perch						
Pile perch	*Rhacocheilus vacca*	Below Average	◆	◆	◆	◆
Striped sea perch	*Embiotoca lateralis*	Unknown	◆	◆	◆	◆
Shiner perch	*Cymatogaster aggregata*	Unknown	◆	◆	◆	◆
Cods						
Pacific cod	*Gadus macrocephalus*	Critical/Candidate[b]			◆	
Pacific hake	*Merluccius productus*	Critical/Candidate[b]			◆	
Walleye pollock	*Theragra chalcogramma*	Critical/Candidate[b]			◆	
Greenlings						
Painted greenling	*Oxylebius pictus*	Very Poor	◆	◆	◆	◆
Whitespot greenling	*Hexagrammos stelleri*	Very Poor	◆	◆	◆	◆
Kelp greenling	*Hexagrammos decagrammus*	Very Poor		◆	◆	◆
Lingcod	*Ophiodon elongatus*	Below Average	◆	◆	◆	◆
Rockfish						
Copper rockfish	*Sebastes caurinus*	Below Average/ Candidate[b]	◆		◆	
Brown rockfish	*Sebastes auriculatus*	Below Average/ Candidate[b]	◆		◆	
Sculpins						
Cabezon	*Scorpaenichthys marmoratus*	Above Average	◆	◆	◆	◆
Buffalo sculpin	*Enophrys bison*	Above Average	◆	◆	◆	◆
Great sculpin	*Myoxocephalus polyacanthocephalus*	Above Average		◆	◆	◆
Other sculpins	Cottidae	Above Average	◆	◆	◆	◆
Flatfish						
English sole	*Pleuronectes vetulus*	Unknown	◆		◆	◆
C-O sole	*Pleuronectes coenosus*	Unknown	◆		◆	◆
Starry flounder	*Platichthys stellatus*	Unknown	◆		◆	◆
Sanddab	*Citharichthys* spp.	Unknown	◆		◆	◆
Dover sole	*Microstomus pacificus*	Unknown			◆	◆
Rock sole	*Pleuronectes bilineatus*	Unknown			◆	◆
Sand sole	*Psettichthys melanostictus*	Unknown			◆	◆

Table 2-8, continued

COMMON NAME	SCIENTIFIC NAME	SPECIES STATUS[a]	IDENTIFIED IN STUDY AREA	HABITAT USE		
				SPAWNING AREA	JUVENILE REARING	ADULT RESIDENT
Forage Fish						
Pacific herring	*Clupea harengus*	Healthy/ Candidate[b]	◆	◆	◆	◆
Sand lance	*Ammodytes hexapterus*	Unknown	◆	◆	◆	◆
Surf smelt	*Hypomesus pretiosus*	Unknown		◆	◆	◆
Tube snout	*Aulorhynchus flavidus*	Unknown	◆	◆	◆	◆
Crescent gunnel	*Pholis laeta*	Unknown	◆	◆	◆	◆
Snake prickleback	*Lumpenus sagitta*	Unknown	◆	◆	◆	◆
Cartilaginous Fish						
Spiny dogfish	*Squalus acanthias*	Above Average	◆			◆
Ratfish	*Hydrolagus colliei*	Unknown	◆			◆
Skates	*Raja* spp.	Unknown				◆
Other Fish						
Sablefish	*Anaplopoma fimbria*	Critical			◆	

[a] WDFW stock status
[b] Federal ESA listing
[c] Although limited rearing may occur, the area is likely used primarily as a migratory corridor

Six anadromous salmonid species are expected to be present in south central Puget Sound (Table 2-8). The four Pacific salmon and steelhead spawn in natal streams of the central Sound and use the study area as a migratory corridor during juvenile outmigration to the ocean and adult spawning migration to natal streams. No natal streams for Pacific salmon and steelhead are known to exist on Maury Island. Three small streams on Vashon Island contain runs of coho salmon—an unnamed stream which drains to Tramp Harbor, Judd Creek which drains to Quartermaster Harbor, and Needle Creek which drains to Fern Cove. These streams are 11, 12, and 24 km (7, 7.5, and 15 mi) from the study area (Schneider 2000). Jones & Stokes and AR (1999) documented juvenile chinook salmon in the study area at low densities. The low densities observed by Jones & Stokes and AR (1999) are consistent with other studies that indicate that the greatest use of nearshore habitats occurs in estuaries proximal to natal stream mouths. In these latter areas, juveniles complete the smoltification process to adult stage before entering freshwater (Miyamoto et al. 1980; Meyer et al. 1980; Shepard 1981). Both juvenile and adult Pacific salmon and steelhead likely use the study area only transitionally.

Mileta Creek, which drains to Quartermaster Harbor approximately 10 km (6 mi) from the study area, is the only stream on Maury Island that contains populations of resident and sea-run cutthroat trout. Several other streams on Vashon Island including Jod Creek, Needle Creek, Fisher Creek, Judd Creek, Beals Creek, and several unnamed streams contain populations of resident and sea-run cutthroat trout. Several of these streams are located between 6 to 8 km (4 to 5 mi) from the study area (Schneider 2000). Anadromous cutthroat trout do not migrate to the open ocean, rather, most remain in shallow nearshore beach environments of less than 3 m (9 ft) in depth (Johnston 1982). Jones (1976) found that the species preferred shorelines and were reluctant to cross bodies of water between 3 and 8 km (2 and 5 mi) in width. Although sea-run cutthroat trout were not observed in the study area, island spawning populations could use the study area as both a migratory corridor and forage area.

The sea perch listed in Table 2-8 are shallow water residents of Puget Sound and reside in bays and estuaries (Hart 1973), likely using the study area for spawning, juvenile rearing, and adult residence. Jones & Stokes and AR (1999) and AES (1998) documented three species of sea perch in the study area that are usually associated with pilings and seagrass. The latter study qualitatively classified shiner and pile perch as "common" in abundance. These findings are consistent with the known behavior and habitat requirements of the fish. All of the species are associated with docks, piers, jetties, and other nearshore structures in Puget Sound (Palsson et al. 1997). Although some offshore movement may occur during the winter, the three species listed on Table 2-8 are not known to migrate and so are likely year-round residents of the study area (Hart 1973).

Lingcod and greenlings are common demersal fish of Puget Sound, occupying rocky shores, reefs, pilings, and eelgrass beds from the intertidal zone up to -50 m (-164 ft) for greenlings and from the intertidal zone to -400 m (-1,313 ft) for lingcod (Hart 1973; Eschmeyer et al. 1983). The pilings, sunken barges, and eelgrass beds present within the study area likely provide suitable habitat for spawning, juvenile rearing, and adult residence. Jones & Stokes and AR (1999) observed two white-spot greenlings and one painted greenling in the study area, while AES (1998) reported lingcod (number not specified). None of the species are known to migrate extensively and so are likely year-round residents in the study area (Hart 1973).

About 20 species of rockfish are present in Puget Sound, but the copper and brown rockfish are among the most common in the south Sound (Palsson et al. 1997; Bargmann 1984). Copper and brown rockfish are common to shallow bays and rocky areas from the intertidal zone to -130 m (-427 ft) (Eschmeyer et al. 1983). The pilings and sunken barges present within the study area likely provide suitable juvenile rearing and adult habitat.

Jones & Stokes and AR (1999) qualitatively classified the abundance of brown rockfish as "common" and the copper rockfish as "occasional" in the study area, both associated with the pilings. AES (1998) reported rockfish near the sunken barges. Tagging studies suggest that older fish may move to offshore waters but do not move far from chosen locations (Mathews and Barker 1983). Overall, studies suggest that, at the least, juvenile and subadult rockfish would utilize the study area year-round. Spawning likely occurs in offshore waters outside of the study area.

Pacific cod, walleye pollock, and Pacific hake are three cod-like species that were once common in Puget Sound, but have undergone drastic declines over the past 20 years. Although the three species have not been observed in the study area, they have been documented in nearshore areas with similar habitats. Pacific cod and walleye pollock are known to spawn in Dalco Passage, located approximately 5 km (3 mi) southwest of the study area. Pacific cod have also been observed by Washington Department of Fish and Wildlife (WDFW) biologists to spawn in waters 18 m (60 ft) deep off of Rosehilla, located 2 km (1.2 mi) southwest of the study area. Pacific hake are known to spawn primarily in Port Susan located approximately 80 km (50 mi) north of the study area, but juvenile and adult hake have been documented in nearshore and offshore areas throughout south Puget Sound (Palsson 2000).

Sculpins are demersal fish species common to Puget Sound and several occupy nearshore areas (Hart 1973). Buffalo sculpin and cabezon are two of the largest species and are found from the intertidal zone to about -75 m (-246 ft). Both are known to spawn in very shallow water; migratory movements are not known to occur (Hart 1973; Eschmeyer et al. 1983). Jones & Stokes and AR (1999) reported the abundance of buffalo sculpin as occasional and reported one cabezon. Other unidentified sculpins were classified as common in abundance. The habitat requirements of the various sculpin species found in Puget Sound indicate that spawning, juvenile rearing, and adult residence is likely to occur in the study area.

Many flatfish species are present in Puget Sound, and several occupy soft to sandy environments in very shallow water, particularly as juveniles. English, rock, and Dover sole show this behavior of young fish residing in the nearshore with larger adults moving offshore. Offshore movement in the winter is apparent for English and Dover sole (Hart 1973). Jones & Stokes and AR (1999) found four flatfish species in the study area; English sole were classified as common, and C-O sole, starry flounder, and sanddabs were classified as occasional. Studies indicate that except for possible offshore movement during spawning periods and the winter, flatfish species likely use the study area for juvenile rearing and adult residence year-round.

Pelagic forage fish, such as the Pacific herring, sand lance, and surf smelt, spawn in distinct nearshore areas year after year. All three species are known to spawn in the vicinity of the study area. The Quartermaster Harbor herring stock, one of 18 distinct herring populations in Puget Sound with distinct spawning periods, spawns in Quartermaster Harbor between January and mid-April (Lemberg et al. 1997). Normally, spawning is limited to the harbor, but during large year classes, spawning extends around the harbor mouth to near the study area. Since 1975, herring spawn has been documented in the study area on two occasions—1975 and 1995 (WDFW). During 1995, the spawning biomass of herring was estimated to be 2,001 tons, the highest on record. The spawning biomass was not available for 1975 (Lemberg et al. 1997). During several other large spawning year classes, spawning herring have been documented to extend around Piner Point but not up to the study area (Schreffler and Moursund 1999).

Similar to herring, surf smelt and sand lance spawn in or near the study area, although it is not known if discrete spawning stocks exist. Jones & Stokes and AR (1999) observed large schools of sand lance in the study area.

Demersal forage fish species such as tube snout, crescent gunnel, and snake prickleback are year-round intertidal and nearshore subtidal residents likely using the study area for spawning, juvenile rearing and adult residence. Tube snout and gunnel are often associated with marine macroalgae (Hart 1973). Jones & Stokes and AR (1999) reported the tube snout and gunnels as common in abundance, while one prickleback was observed.

Dogfish, rays, and ratfish are not associated with nearshore habitats but occasionally can be found in shallow water, probably associated with feeding (Hart 1973; Eschmeyer et al. 1983). This observation is consistent with Jones & Stokes and AR (1999), which reported one dogfish and one ratfish in the study area. Similarly, sablefish are an open-water coastal fish, but migratory juveniles are found in Puget Sound. The species has occasionally been observed to occupy nearshore areas of the Sound, although none have been observed in the study area (Palsson et al. 1997).

As shown in Table 2-8, the status of many of the species potentially present in the nearshore area is not known. Very little stock assessment data are available to analyze populations, particularly with the decline of commercial and recreational catches, which provide major sources of data. Of those species for which sufficient data are available, ten fish species have below average or declining populations, and only five species have stable to healthy populations. Of the salmonids that use central Puget Sound streams, only pink and chum stocks are stable. Chinook stocks have declined such that they were recently federally listed as Threatened. Several Puget Sound coho salmon and steelhead trout stocks are in decline. Overfishing and stream habitat degradation are the most often cited causes for declines (Spence et al. 1996).

Similarly, rockfish and greenling populations are considered to be in very poor condition, while lingcod populations in the south Sound are considered stable. It is not known why these populations have declined, and stock assessment data quality is considered poor. Sculpin populations appear to be increasing. Sablefish populations in the south Sound are critically low; but this is a coastal stock of migratory juveniles, and it may be affected by regional oceanic variables (Palsson et al. 1997). The Quartermaster Harbor herring stock is considered healthy, although Sound-wide populations are declining. The stock status of surf smelt and sand lance is not known because of poor assessment data (Lemberg et al. 1997).

2.3.2 Marine Mammals

Marine mammals that can be present off Maury Island include harbor seals (*Phoca vitulina*); California and Steller sea lions (*Zaloplus californianus* and *Eumetopia jubatus*); killer (*Orcinus orca*), gray (*Eschrichtus robustus*), minke (*Balaenoptera acutorostrata*), and humpback whales (*Megaptera novaengliae*); and Dall's (*Phocoenoides dalli*) and harbor porpoise (*Phocoena phocoena*) (Jones & Stokes and AR 1999; Calambokidis pers. comm. 1999).

Harbor seals are common in the vicinity of Maury Island. However, there are no harbor seal haulout areas near the Lone Star dock; the nearest is on Gertrude Island several miles away (Jones & Stokes and AR 1999; Calambokidis pers. comm. 1999). Harbor porpoises and killer, gray, minke, and humpback whales are rare in south central Puget Sound (Calambokidis pers. comm. 1999). Because of its benthic habitat and fish resources, it is likely that the Maury Island nearshore area provides feeding habitat for marine mammals, but this area is not critical or unique in providing such habitat (Evans Hamilton 1987; PSEP 1992).

2.3.3 Critical Habitat

Sections 2.2 and 2.3.1 provide descriptions of the nearshore habitats, fish presence, and likely fish usage in the study area. The assessment indicates that the study area is composed of aquatic habitats and a fish community that are fairly typical of many nearshore areas of Puget Sound. In order to determine whether project-related activities affect fish populations, it must be ascertained whether the study area provides critical habitats necessary for the survival and maintenance of a fish population or discrete geographical stocks as they currently exist. According to Washington Administrative Code (WAC) 220-110-285: "Critical food fish and shellfish habitats...are those habitats that serve an essential function in the developmental life history of fish or shellfish. These habitats include but are not limited to the following:

(a) Pacific herring, surf smelt, Pacific sand lance, and rock sole spawning beds;
(b) Intertidal wetland vascular plants (except noxious weeds);
(c) Eelgrass (*Zostera* spp.);
(d) Kelp (Order Laminariales);
(e) Lingcod settlement and nursery areas;
(f) Rockfish settlement and nursery areas;
(g) Juvenile salmonid migration corridors and rearing and feeding areas."

By the definition provided in the Washington Administrative Code, the study area contains critical habitat for fish species of Puget Sound. As reported, eelgrass beds; spawning grounds for herring, sand lance, and smelt; salmonid migratory corridors; and lingcod and rockfish nurseries have been documented in the study area. However, the task undertaken by this Nearshore Impact Assessment is to assess the potential for impacts to the nearshore area from proposed dock and shipping operations associated with gravel mine expansion. This assessment evaluates impacts in terms of their potential to disrupt the maintenance of fish populations or the population of discrete geographical stocks as they currently exist. This definition is essentially the same as that used under the Endangered Species Act of 1973, as amended:

> The term "critical habitat" for a threatened or endangered species means (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of this Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential for the conservation of the species. (B) Critical habitat may be established for those species now listed as threatened or endangered species for which no critical habitat has heretofore been established as set forth in subparagraph (A) of this paragraph. (C) Except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species.

Using the ESA definition of critical habitat, while the nearshore area of this project does provide habitat that supports a variety of marine biological resources, including listed and candidate fish species, it is not essential to the conservation of species or maintenance of existing populations.

The geographic distribution of habitats and species in Puget Sound, such as forage fish spawning beaches, groundfish areas, salmonid migratory corridors, and eelgrass and kelp beds, indicates that habitats found in the study area are widely available throughout Puget Sound (Evans Hamilton 1987; PSEP 1992). Overall, the fish surveys conducted in the study area, known habitat requirements, and stock assessment studies indicate that the study area does not provide habitats essential for the conservation of fish populations or discrete geographical stocks in Puget Sound.

For the salmonids, critical rearing habitats are in estuaries of natal streams, which are not present in the study area (Shepard 1981). For Vashon and Maury Island sea-run cutthroat trout populations, the likely critical habitat would be the nearshore, shallow beach environments around the two islands (Schneider 2000). This area totals about 70 km (44 mi) of nearshore environment, while the study area totals less than 1 km (0.6 mi).

For Pacific herring, spawning has been documented in the study area in only 2 years between 1975 and 1997, likely the result of large year classes (WDFW). The critical spawning habitats where the bulk of annual spawning occurs is in Quartermaster Harbor (Lemberg et al. 1997).

Surf smelt and sandlance, both of which spawn near or in the study area, have spawning areas that are distributed throughout Puget Sound. Surveys have documented 193 km (120 mi) of spawning habitat for sand lance and 314 km (195 mi) for surf smelt in Puget Sound (Lemberg et al. 1997). As reported, the study area occupies less than 1 km (0.6 mi) of beach environment that may be used by spawning surf smelt and sandlance.

Rockfish appear to be common inhabitants associated with the structures within the study area. However, demersal habitats with natural or artificial structures are found throughout Puget Sound (Evans Hamilton 1987; PSEP 1992) and spawning is not expected to occur within the study area.

The cod-like species, which have not been documented in the study area, have been observed in both nearshore and offshore habitats within Puget Sound. Nearshore habitats are not critical to the survival of these species. In addition, major spawning areas are not associated with the study area (Palsson 2000).

The demersal forage species, sea perch, and sculpins inhabit and reproduce in nearshore areas throughout Puget Sound and do not have specific geographical spawning areas or estuarine requirements (Evans Hamilton 1987; PSEP 1992).

2.3.4 Federally Listed Fish Species

On March 24, 1999, the Puget Sound chinook salmon was listed under the Endangered Species Act (ESA) as Threatened. On June 23, 1999, seven additional species were listed as candidate species for listing. These species are the Pacific herring, Pacific cod, Pacific hake, walleye pollock, brown rockfish, copper rockfish, and quillback rockfish. Species listed as candidates are not afforded protected status under ESA but will be further evaluated to determine if listing and federal protection are necessary. Because of the federally protected status of listed species and the concern associated with candidate species, an extended biological profile is provided, including a determination of whether a species is present in the study area. Tables 2-9 through 2-14 present stock status, habitat requirements, study area habitats, and the likelihood that the species inhabits the study area.

The following summarizes the ESA evaluation regarding the potential presence of these species in study area:

Puget Sound chinook salmon (threatened)

- Juvenile chinook salmon is the lifestage most likely present in the study area and has been documented in small numbers. Juveniles and adults use the area primarily as a migratory corridor.
- Natal streams are not known to occur on Vashon or Maury Island. Estuaries of natal streams hold the highest densities of both juvenile and adult fish in Puget Sound.
- The nearest natal stream and estuary is 10 km (6 mi) to the south of the study area.

Pacific herring (candidate)

- Nearby Quartermaster Harbor is a spawning area for a discrete stock of Pacific herring.
- Spawning in the study area occurs infrequently. Spawning has been documented on nearshore vegetation in the study area during 2 separate years between 1975 and 1997.
- Juvenile and adult herring likely reside in the study area on a regular basis.

Brown, copper, and quillback rockfish (candidates)

- Brown and copper rockfish are the most common species in south central Puget Sound and have been documented in the study area.
- The sunken barges and dolphins likely provide attractive habitat. Large juveniles or adults are likely year-round residents while spawning occurs offshore.

Pacific cod (candidate)

- Pacific cod have not been documented at the site, but have been documented in nearby nearshore areas with similar habitat features.
- Adults are associated with both nearshore and offshore areas.
- Cod spawn in Dalco Passage and have been observed off Rosehilla about 5 to 8 km (3 to 5 mi) from the study area. The bulk of spawning in Puget Sound

occurs in Agate Passage and Port Townsend Bay, located about 45 and 85 km (28 and 53 mi), respectively, north of the study area.

- Spawning adults, larvae, and juveniles appear associated with embayments and nearshore areas.

Pacific hake (candidate)

- Pacific hake have not been documented in the study area, but have been documented in nearshore areas with similar habitat features.
- The study area is not near known hake spawning areas, but juvenile and adult fish have been documented in both nearshore and offshore waters.
- No information was found regarding the early life stages of hake in Puget Sound.

Walleye pollock (candidate)

- Pollock have not been documented in the study area, but juvenile and adult fish have been documented in both nearshore and offshore waters.
- Dalco Passage has been identified as a spawning area for pollock.
- Although little information is available, Puget Sound populations of walleye pollock are associated with both nearshore and offshore habitats.

Table 2-9. Endangered species evaluation – Puget Sound chinook salmon

1. Species listing	**Type of listing, date** Listed as Threatened under the Endangered Species Act – March 24, 1999
2. Current stock	**South Puget Sound** Separate stocks of Puget Sound chinook salmon spawn in the Puyallup River basin located 10 km (6 miles) south of the study area and the Nisqually Basin, located about 35 km (22 miles) south of the study area. A small stock is present in the Deschutes River, located an additional 15 km (9 miles) southeast of the Nisqually Basin. Very small stocks are present in Goldborough Creek, which discharges to Hammersley Inlet, and Kennedy Creek, which discharges to Totten Inlet, both in southeastern Puget Sound. **Study area** No natal streams for Puget Sound chinook salmon are known to occur on Vashon or Maury Island. The closest natal stream is the Puyallup River, 10 km (6 miles) south of the study area.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 m and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 m to 61m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 m to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long and is situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. • A habitat survey using divers that was conducted in 1999 documented four juvenile chinook salmon at three different transects.

Table 2-9, continued

4. Spawning	**Spawning habitat** No chinook salmon spawning habitats occur in the vicinity of proposed project activities. Large natal chinook streams within the migratory pathway include the Puyallup River and Nisqually River Basins. Streams with smaller populations of chinook salmon in south Puget Sound include the Deschutes River, Goldsborough Creek, Kennedy Creek, and several other smaller stream basins. No salmon streams occur on Maury or Vashon Island. **Spawning season** Spring and fall varieties of chinook salmon use natal streams in south Puget Sound. These adult fish pass the site on the way to spawning streams from May through September. **Adult use of nearshore area** Use of the study area by adult fish has not been documented. Since no natal streams are known to occur on Vashon or Maury Island, the study area would only be used as migratory corridor by adult fish.
5. Juvenile requirements	**Habitat** Studies have shown that juvenile chinook use shoreline areas extensively in waters of a few centimeters to over a meter with substrates of gravel, sand, or mud. Preferences for soft, packed substrates have also been documented. There is evidence to indicate that smaller juveniles use inshore areas, while larger juveniles move progressively to deeper waters. The largest aggregations of juvenile chinook salmon are found in estuarine embayments at the mouths of natal streams. During estuarine rearing, chinook salmon exhibit significant growth. **Timing** Outmigration of fall chinook juveniles generally occurs from mid-February to mid-July, depending upon the estuary, with the average residence time per estuary of 12 weeks.

Table 2-9, continued

6. Likelihood of study area use	The nearshore orientation of juvenile chinook salmon indicates that this is the lifestage most likely present in the study area. Preferred habitats of juvenile salmon appear to be present in the study area, and the latest diving surveys documented juvenile salmon in low densities. Local habitat studies appear consistent with the regional juvenile salmonid studies conducted in Puget Sound. Juvenile salmon likely use the study area in small numbers year-round. Although good habitat exists, the study area is not expected to be used as a major rearing area during the outmigration of juvenile salmon. These heavy-use areas occur in estuarine waters at the mouths of natal streams.

SOURCES: Healey 1980, 1982; Meyer et al. 1980; Miller et al. 1977, 1980; Miyamoto et al. 1980; Shepard 1981

Table 2-10. Endangered species evaluation – Pacific herring

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** • 18 discrete herring stocks are present in Puget Sound; stocks are defined by the location of annual spawning areas: – 7 are considered healthy (2-yr abundance within 10 percent of the 20-year mean). – 3 are considered moderately healthy (2-yr abundance within 30 percent of the 20-year mean). – 5 are considered depressed (recent abundance well below long-term mean but not so low that permanent damage to the stock is likely). – 2 are considered critical (recent abundance so low that permanent damage to the stock is likely or has already occurred). – 1 is unknown (insufficient assessment data to identify stock status with confidence). **Study area** • Quartermaster Harbor herring population is a discrete stock that spawns in Quartermaster Harbor and around southern Maury Island to the edge of the study area. • Between 1977 and 1997, population biomass ranged from 667 to 2001 tons. • Quartermaster Harbor herring stock is fifth largest in Puget Sound over the past 20 years; third largest over the past 5 years. • Quartermaster Harbor herring stock is considered healthy by WDFW; from 1977 to 1997, no long-term declines are evident: – 21-year mean biomass: 1238 tons. – 5-year mean biomass (1993-1997): 1360 tons.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW.

Table 2-10, continued

3. Study area habitat types, cont.	• From the beach (0 m MLLW), the nearshore slopes gradually for 46 m to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 170 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 sq ft) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. • WDFW has documented spawning herring in the study area in two different years between 1975 and 1995. • Habitat surveys conducted in 1999 and 1998 did not document herring in the study area.
4. Spawning	**Spawning habitat** Pacific herring spawn primarily on vegetation and substrates in intertidal or shallow subtidal waters. Herring eggs are deposited between the upper limits of high tide to a depth of -12 m (-40 ft) MLLW, but most spawning takes place between 0 and -3 m (0 and -10 ft). Studies in Puget Sound have found that eelgrass, the brown macro alga *Desmarestia* spp. and the red alga *Odonthalia* spp may be preferred substrates of herring eggs. Other macroalgae where herring spawn has been found include *Laminaria, Alaria, Iridaea*, kelp, and *Ulva.* **Spawning season** The Quartermaster Harbor herring stock spawns during late winter and early spring between January and mid-April. Most spawning occurs in Quartermaster Harbor, but during larger year classes, spawning extends out of the bay to the edge of the study area. In 1975 and 1995, spawning was documented in the study area, and spawning extended around Piner Point to near the study area during several other years. **Adult use of nearshore area** Prior to spawning, prespawning adults congregate along the mouth of the harbor and offshore areas around southern Maury Island. Prespawning fish are associated with deep water, generally residing between 27 m and 37 m (90 and 120 ft). During non-spawning periods, the Quartermaster Harbor herring stock is considered resident, but movement patterns are largely unknown. WDFW speculates that they move widely throughout Puget Sound. Given the proximity, it is likely that herring from several Puget Sound stocks may mingle with Quartermaster Harbor herring or be found in the study area.

Table 2-10, continued

5. Larval/Juvenile requirements	**Habitat** Eggs hatch in about 14 days producing yolk-sac larvae. The yolk-sac supplies nutrients for about a week, after which independent feeding begins. Larvae are largely distributed by local current patterns. No larval retention studies have been conducted in the study area. Larvae metamorphose into juveniles 2 to 3 months after hatching. After metamorphosis, juveniles do not appear to have substantial affinity for spawning areas. Young juvenile herring are often found near spawning areas in June, shortly after metamorphosis, but by August, they are usually shore to shore in south Puget Sound.
6. Likelihood of study area use	As reported, herring movements outside of spawning and prespawning adults are not well known in Puget Sound. It is likely that the Quartermaster Harbor herring stock spawns within the study area during larger year classes between January and mid-April. Pre-spawning herring have generally been found offshore in deep water residing between 27 to 37 m (90 and 120 ft). Site area affinity prior to or after spawning by Quartermaster Harbor adults does not appear to be high; however, the study area provides suitable habitat for both adult and juvenile herring. Comprehensive baseline studies conducted in north Puget Sound found that herring was the most abundant species (number and biomass) observed in nearshore beach seine samples. The study area is likely used to a degree similar to other suitable habitats in Puget Sound by several co-mingling herring stocks.

SOURCES: Lemberg et al. 1998; Miller et al. 1977; O'Toole pers. comm. 1999; Stick pers. comm. 1999; Stick 1995; Thornton 1995; WDFW Field Reports

Table 2-11. Endangered species evaluation – Pacific cod

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** • Three stocks of Pacific cod are present in Puget Sound: – North Puget Sound-Gulf/Bellingham/San Juan Islands. – West Puget Sound-Strait of Juan de Fuca/Port Townsend Bay. – South Puget Sound-South of Admiralty Inlet. **Study area** • The Study Area is within the range of the south Puget Sound cod stock. Cod production exceeded one million pounds per year in the 1970s. Recent surveys indicate that the stock is at a critical or near-extinct level. Critical stock conditions may be the result of warm water conditions in Puget Sound.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 500 ft long situated in the southwest corner of the study area about 500 ft southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Pacific cod have not been documented in the study area.

Table 2-11, continued

4. Spawning	**Spawning habitat** Pacific cod in Puget Sound have been documented to spawn in Agate Passage, located at the northwestern tip of Bainbridge Island and Port Townsend Bay. Other probable spawning locations within the Sound include Dalco Passage, located off the southern tip of Vashon Island, just south of the study area; and Eliza Island, off Bellingham. WDFW has observed spawning cod off the southern tip of Maury Island, near Rosehilla. Pacific cod are demersal spawners where bottom substrates consist of coarse sand and cobble. Eggs hatch from 8 to 17 days at temperatures between 5 and 11 degrees C (41 and 52 degrees F). Cod larvae in Port Townsend Bay orient toward the bottom in shallow water, moving to deeper water in early juvenile stages. **Spawning season** Pacific cod spawn during the winter in cool waters between 6 and 7 degrees C (43 and 45 degrees F). **Adult use of nearshore area** Adult cod use specific shallow areas and embayments during the winter spawning periods. During non-spawning periods, cod have been known to occupy deep offshore waters and nearshore areas.
5. Larval/Juvenile requirements	**Habitat** Cod larvae in Port Townsend Bay orient toward the bottom in shallow water during the winter and spring moving to deeper water in early juvenile stages by summer. No investigations have been conducted in or near the study area.
6. Likelihood of study area use	Adult Pacific cod can be associated with nearshore or offshore areas; they could occur near the study area. Specific spawning grounds are present in Puget Sound, the closest within Dalco Passage off the southern tip of Vashon and Maury Islands, between 3 and 8 km (2 and 5 mi) from the study area. Spawning adults, larvae, and juveniles appear associated with embayments and nearshore areas.

SOURCES: Palsson 1990; Palsson et al. 1997.

Table 2-12. Endangered species evaluation – Pacific hake

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** Separate stocks of hake are found on the Pacific coast, north Puget Sound, and south Puget Sound. **Study Area** The Pacific hake stock in south Puget Sound is probably distinct from the north Sound stock according to WDFW. The adult biomass was estimated at 40 million pounds during the 1970s, but declined to barely one million pounds in 1994. The stock status is considered critical. WDFW reported that high predation by marine mammals may be preventing recovery of the population.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium to fine grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Pacific hake have not been documented in the study area.

Table 2-12, continued

4. Spawning	**Spawning habitat and season** The south Puget Sound stock spawns in Port Susan during the spring (the embayment formed by Camano Island). Eggs and larvae are pelagic. **Adult use of nearshore area** Adults are associated with both offshore and nearshore waters of South Puget Sound.
5. Larval/Juvenile requirements	**Habitat** No information was found regarding the larval and juvenile lifestages of hake.
6. Likelihood of study area use	Hake are at critically low levels in south Puget Sound, and high predation by marine mammals may be preventing their recovery. Adult lifestages can be associated with the nearshore so may be found near the study area.

SOURCES: Palsson et al. 1997.

Table 2-13. Endangered species evaluation – Walleye pollock

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** Walleye pollock are a subarctic cod species that is on the extreme southern end of its Pacific coast distribution in Puget Sound. **Study Area** Growth and other biological data indicate the south Puget Sound pollock are a different biological stock than those in north Puget Sound. The south Puget Sound pollock stock was abundant in the late 1970s but then declined until the fishery collapsed in the late 1980s. Trawl surveys conducted in 1993 and 1994 (latest years of available data) indicate that the population is at a critical, possibly extinct status.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Walleye pollock have not been documented in the study area.

Table 2-13, continued

4. Spawning	**Spawning habitat and season** Little information is available on Puget Sound populations. WDFW reported that spawning has been observed in Dalco Passage, south of Maury and Vashon Island. **Adult use of nearshore area** Adults in Puget Sound have been observed in both nearshore and offshore waters.
5. Larval/Juvenile requirements	**Habitat** No information was found regarding the larval and juvenile lifestages of walleye pollock.
6. Likelihood of study area use	Little information on the life history of walleye pollock is available for Puget Sound populations. The species is at critically low levels in the south Sound and may be extinct. Adult lifestages are associated with both nearshore and offshore areas so may be found near the study area.

SOURCES: Palsson et al. 1997

Table 2-14. Endangered species evaluation – Brown rockfish, copper rockfish, quillback rockfish

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** Separate stocks of rockfish have not been delineated in Puget Sound. Rockfish populations in south Puget Sound have undergone long-term declines in abundance since 1977.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium to fine grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 150 to 200 ft to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (50 ft^2) are present on either side of the pier, and one other area about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Habitat surveys conducted in 1998 and 1999 documented copper and brown rockfish in the study area. Both species were observed around the dolphins. Brown rockfish were classified as common in abundance.
4. Spawning	**Spawning season and habitat** All rockfish species have internal fertilization and bear live young. Little is known of the spawning habits and early life history of individual species because the larvae and juveniles are difficult to distinguish. In Puget Sound, brown rockfish spawn once a year; embryos are released from April to July. Copper rockfish appear to release young in April. No information was found on the quillback rockfish.

Table 2-14, continued

4. Spawning, cont.	**Adult use of nearshore area** All three rockfish species are known to occur in fairly shallow bays as well as deeper offshore areas. Rockfish generally associate with rocky areas, crevices, and reefs. Large juvenile or adult rockfish have been observed by divers to occupy areas around the sunken barges near the existing pier facility in the study area (species unknown). Older fish may move to deeper offshore waters. Tagging studies of copper rockfish in northern Puget Sound suggest that mature fish do not move far from chosen locations.
5. Larval/Juvenile requirements	**Habitat** Larvae are pelagic for periods of several months to a year, drifting with currents. Juvenile brown and copper rockfish occur in shallow nearshore waters, often around piers, other natural and artificial structures, and in bays.
6. Likelihood of study area use	The habitat requirements of large juvenile and young adult rockfish reported in the scientific literature are consistent with habitats present in the study area and the observations of rockfish near the sunken barges. The sunken structures, rockpiles, and the pier facility likely provide attractive cover for juvenile and adult rockfish. The larval stages are not likely present in the area for other than very transient periods. Larger adults and spawning may occur in offshore areas.

SOURCES: Delacy et al. 1964; Hitz and Delacy 1965; Mathews and Barker 1983; Palsson et al. 1997; Stein and Hassler 1989

2.3.5 Conclusions

The habitats and fish community observed or expected in the study area are typical of those found in south central Puget Sound. The study area is nearshore and thus has a preponderance of fish species, such as sea perch, greenlings, rockfish, sculpins, and demersal forage species, that characterize nearshore areas. Preponderantly offshore species such as the cods, sharks, and rays have not been documented or are rare in the study area. The sunken barges and dolphins, while anthropogenic in origin, attract structure-oriented demersal species such as rockfish, lingcod, and cabezon.

The study area does not provide critical habitat as defined under the Endangered Species Act for fish in Puget Sound. The study area is not associated with an estuary of a natal salmonid stream where high densities of juvenile salmonids are found. The study area is outside of the preferred Quartermaster Harbor herring spawning area in all but the largest year classes. Other species that rely heavily on nearshore areas do not have specific habitat requirements, and the study area is typical of those found in south central Puget Sound.

A number of marine mammal species may occur in south central Puget Sound, and these could potentially feed on occasion in the Maury Island nearshore area. The most common marine mammal is the harbor seal, which may use the area for feeding but does not have any haulouts in the vicinity of the nearshore area. Dall's porpoises are also seen frequently in this part of Puget Sound.

One fish species listed as threatened by the federal government and seven candidates for federal listing under ESA are present in Puget Sound. The study area is not likely to provide a critical habitat for ESA species. The study area is not associated with a natal stream and so Puget Sound chinook salmon, listed as threatened, would not be expected to use it as an extensive juvenile nursery or adult staging area. The area is primarily a migratory corridor for juvenile out-migrants and adults on spawning runs to natal streams. The study area lies adjacent to the spawning grounds of the Quartermaster Harbor Pacific herring stock. Annual spawning has been documented within the study area on two occasions and in areas just south of the study area on several occasions since 1975, generally in association with the largest populations of spawning fish. Spawning herring would likely use the study area only during the largest year classes. The brown and copper rockfish likely use the study area, possibly associating with structures such as the sunken barges and dolphins. However, these habitats are not unique in Puget Sound. The cod species—Pacific cod, walleye pollock, and Pacific hake—are associated with both nearshore and offshore areas. Major spawning areas for the three species are offshore and not nearby, but secondary spawning areas for cod and pollock have been documented at Dalco Passage, just south of the study area.

3.0
IMPACT ASSESSMENT

An impact assessment was conducted to identify the various potential environmental impacts to marine mammals and fish that would result from the proposed project. These potential impacts include noise (generated by both dock reconstruction and barge operations); turbidity; habitat loss due to dock reconstruction; chemical contaminants (primarily petroleum input in the form of spills, leaks, or as exhaust); propeller wash; light shading and night lighting; sand and gravel spills at the dock; and the effect on longshore sediment transport. Also discussed are the levels of marine mammal and fish sensitivity to each impact. The level of discussion presented in this assessment is proportional to the potential significance of each environmental impact.

3.1 NOISE

The proposed project will increase noise levels during the short-term while construction activities are underway and have longer-term impacts resulting from vessel traffic and loading operations. A brief description of sound is presented below followed by discussions of the noise characteristics generated by three dock-related operations (pile driving, vessel traffic, and barge loading), the sensitivity of animals to noise, and the impacts of increased noise levels on species.

Sound is a wave of energy traveling through a medium and is described by its pressure and frequency. Pressure is measured in micropascals (μPa), and frequency is measured in hertz (Hz). Frequency can be reported as either a pure tone or as sound spectra (bandwidth) (Richardson et al. 1995). In order to compare sounds, a log scale was developed, and this scale is reported in decibels (dB)(Richardson et al. 1995). An increase of 20 dBs results in a 10-fold increase in sound pressure (Feist 1991). The distance from a sound source affects sound levels; as distance increases, sound level decreases due to transmission loss.

3.1.1 Noise Generated from Project Activities

3.1.1.1 Pile Driving

Description of Project—Reconstruction activities are proposed for the existing Lone Star dock prior to its reuse. Repairs will include (Jones & Stokes and AR 1999):

- Reinstallation of the conveyor loading system
- Replacement of approximately 30 pilings

- Replacement of 25 percent of the existing dock's decking, stringers, and supports

The installation of the conveyor is expected to occur within a 15-day period, and piling replacement will take between 14 and 28 days. Pilings will be replaced using a pile-driving rig secured aboard a 36 m by 18 m (120 ft by 60 ft) barge-like vessel.

Timber piles will be installed using an air hammer. One existing dolphin of 10 pilings will be replaced, and two to three pilings will be added to each of the remaining nine dolphins (18 to 27 total pilings) for a sum total of 28 to 37 piles. Old piles will be left in place or cut at the sediment line. In addition, 10 fender pilings will be repaired by cutting away damaged wood. The fender pilings will be lifted 1 to 1.5 m (3 to 5 ft) so that the damaged portions can be removed.

Description of Noise—In air, the sound level of a pile driver has been measured at 101 dBA at a distance of 15 m (49 ft) (USEPA 1975). Based on limited underwater acoustical data, pile-driving sound levels have been recorded up to 25 dB (re 1 μPa) above ambient conditions at a distance of 593 m (approximately 0.5 mi) from the pile-driving rig (Feist 1991). In underwater acoustics, a reference (re) pressure is always associated with the dB so that comparisons between sound measurements may be made. the present standard for underwater measurements is 1 μPa (micropascal) at 1 m. If sound is measured at a different distance from the sound source, this distance should be reported. In this report, the reference distance is 1 m and the reference pressure is 1 μPa, unless otherwise noted. Peak sound pressure levels from pile driving have been recorded at frequencies of approximately 250 Hz to 750 Hz and again at 1250 to 2000 Hz; levels were not measured above 2000 Hz. Peak sound pressure levels generally ranged from 95 to 110 dB (re 1 μPa at 593 m) (see Figure 3-1) (Feist 1991).

3.1.1.2 Vessel Traffic

Description of Project—Vessel traffic will increase as tugs bring in empty barges for mining product and depart with full barges. Maximum daily mine production is estimated at 40,000 tons per day (Jones & Stokes and AR 1999). Though a range of barge sizes could be used, the most common would be the 10,000-ton-capacity barge (Table 3-1). Therefore, tugs would need to maneuver 10,000-ton barges eight times per day (to dock and undock). If 4,000- or 2,000-ton capacity barges were used, tugs would be docking and undocking 20 and 40 times per day, respectively. A combination of barge sizes could also be used. At lower production rates, the use of tugs is expected to decrease unless smaller barges are used.

This rate of activity would not be sustained for 365 days a year because the annual capacity of the mine is set at 7.5 million tons. Therefore, at the peak daily production rate of 40,000 tons per day, barging activities would be limited to 183 days per year.

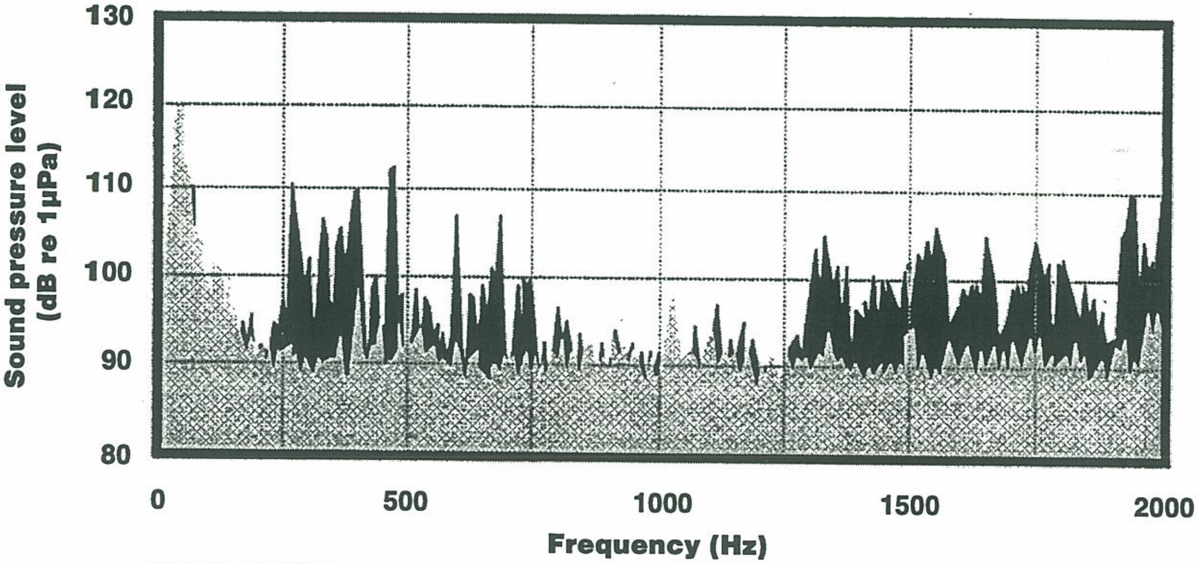

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Figure 3-1. Sound pressure level (dB re μPa) and frequency (Hz) of underwater environment 593 from pile driving activities. Black is pile driving noise and gray is ambient conditions

Table 3-1. Dimensions of barges to be used for shipping sand and gravel

BARGE CAPACITY (tons)	LENGTH (ft)	BREADTH (ft)	DEPTH (ft)	LIGHT BARGE DRAFT (ft)	LOADED BARGE DRAFT (ft)
10,000	330	80	19-20	4.5	16-17
4,000	240	62	16	4	12-14
2,000	200	54	11.5	1.5-2	9.5

SOURCE: Summers 1999a

Description of Noise—Table 3-2 shows the sound levels of barges and tugs recorded at a variety of frequencies. Vessel noise tends to dominate the 20 to 500 Hz frequency bandwidth and often reaches 1 kHz (Wenz 1962). Sound levels generated by a tug and barge combination range from 150 dB to 170 dB (re 1 μPa at 1 m) across a range of frequencies (37 to 12,500 Hz). Loaded barges were 6 to 16 dB louder than empty barges.

Table 3-2. Recorded or estimated sound levels and frequencies of various tugboat and barge scenarios

SOURCE	SOURCE LEVEL (dB re 1 µPa at 1 m)	FREQUENCY (Hz)
Supply barge	171	100-12,500
Small barge	168[a]	315-16,000[a]
Tug pulling empty barge[b]	166	37
Tug pulling empty barge[c]	164	1000[d]
Tug pulling empty barge[c]	145	5000[d]
Tug pulling loaded barge[c]	170	1000[d]
Tug pulling loaded barge[c]	161	5000[d]
Tug and barge	143	50[d]
Tug and barge	157	100[d]
Tug and barge	157	200[d]
Tug and barge	161	500[d]
Tug and barge	156	1000[d]
Tug and barge	157	2000[d]

SOURCE: Malme et al. 1989, except where noted

[a] Estimated.
[b] Buck and Chalfant 1972.
[c] Miles et al. 1987.
[d] 1/3 octave band center frequencies.

A tug and barge travelling at a constant speed will have a signature different from that of a tug maneuvering a barge at the dock. Both activities are likely to overlap in frequency and pressure levels. However, the sound levels of maneuvering activities at the dock are expected to be erratic, pulsed noise signatures with rapid changes in frequency and pressure because of abrupt changes in tug speed and direction.

3.1.1.3 Loading Operations

Description of Project**—**Most of the mine product will be loaded onto barges with a conveyor and transported to market. Two motor drives will run the conveyor: one will be positioned 15 m (50 ft) from the seaward end of dock, and the other will be 23 m (75 ft) landward of the high water mark. To distribute gravel and sand in the barge, a tug will move the barge back and forth while material is being loaded from the conveyor. Alternatively, the conveyor may be moved (Summers 1999b).

Description of Noise**—**The underwater noise levels associated with barge filling have not been measured. It is likely that sound will be transmitted through the hull into the surrounding aquatic environment. Tugboat noise levels generated by moving a barge for loading are predicted to be similar to those levels generated by docking activities. Low-frequency, pulsed noise signatures will be generated as a result of the tug's abrupt changes in speed and direction.

3.1.2 Sensitivity of Species to Noise

3.1.2.1 Importance of Sound to Aquatic Life

Aquatic organisms have adapted to use sound for a variety of functions. Fish and marine mammals may rely on sound for schooling orientation and predator avoidance (Blaxter and Batty 1985b; FAO 1970), prey location (FAO 1970), competitive interactions and courtship (Hawkins 1993), homing mechanisms (Nikolaev 1982), and echolocation and long-distance communication (Malme et al. 1989).

Unwanted noise can 1) interfere with acoustic communication, 2) produce unpleasant sounds, and 3) damage hearing (Malme et al. 1989). In response to noise stimuli, an organism may avoid an area. While this decreases exposure to acoustic interference, the animal may also be excluded from important feeding, mating, or spawning grounds.

3.1.2.2 Potential Receptors

Twenty fish species were recently observed in the vicinity of the dock, including threatened and candidate species (Jones & Stokes and AR 1999). In addition, several other fish species are likely to utilize this nearshore habitat (Table 2-8). Marine mammals may also be exposed to noise from dock-area activities. Species that may be found in waters off Maury Island include harbor seals (*Phoca vitulina*); California and Steller sea lions (*Zaloplus californianus* and *Eumetopia jubatus*); killer (*Orcinus orca*), gray (*Eschrichtus robustus*), minke (*Balaenoptera acutorostrata*), and humpback whales

(*Megaptera novaengliae*); and Dall's (*Phocoenoides dalli*) and harbor porpoise (*Phocoena phocoena*) (Jones & Stokes and AR 1999; Calambokidis 1999).

3.1.2.3 Sensitivity of Species

The hearing sensitivity of an animal is represented by an audiogram. An audiogram graphically shows the relationship between pressure and frequency and depicts hearing threshold levels under conditions of low ambient noise. Figure 3-2 shows the audiograms for several fish species and marine mammals. Tables 3-3 and 3-4 present noise levels and behavioral responses of fish and marine mammals to various sounds. For marine mammals, it was assumed that vocalization frequencies translate into frequencies of sensitivity.

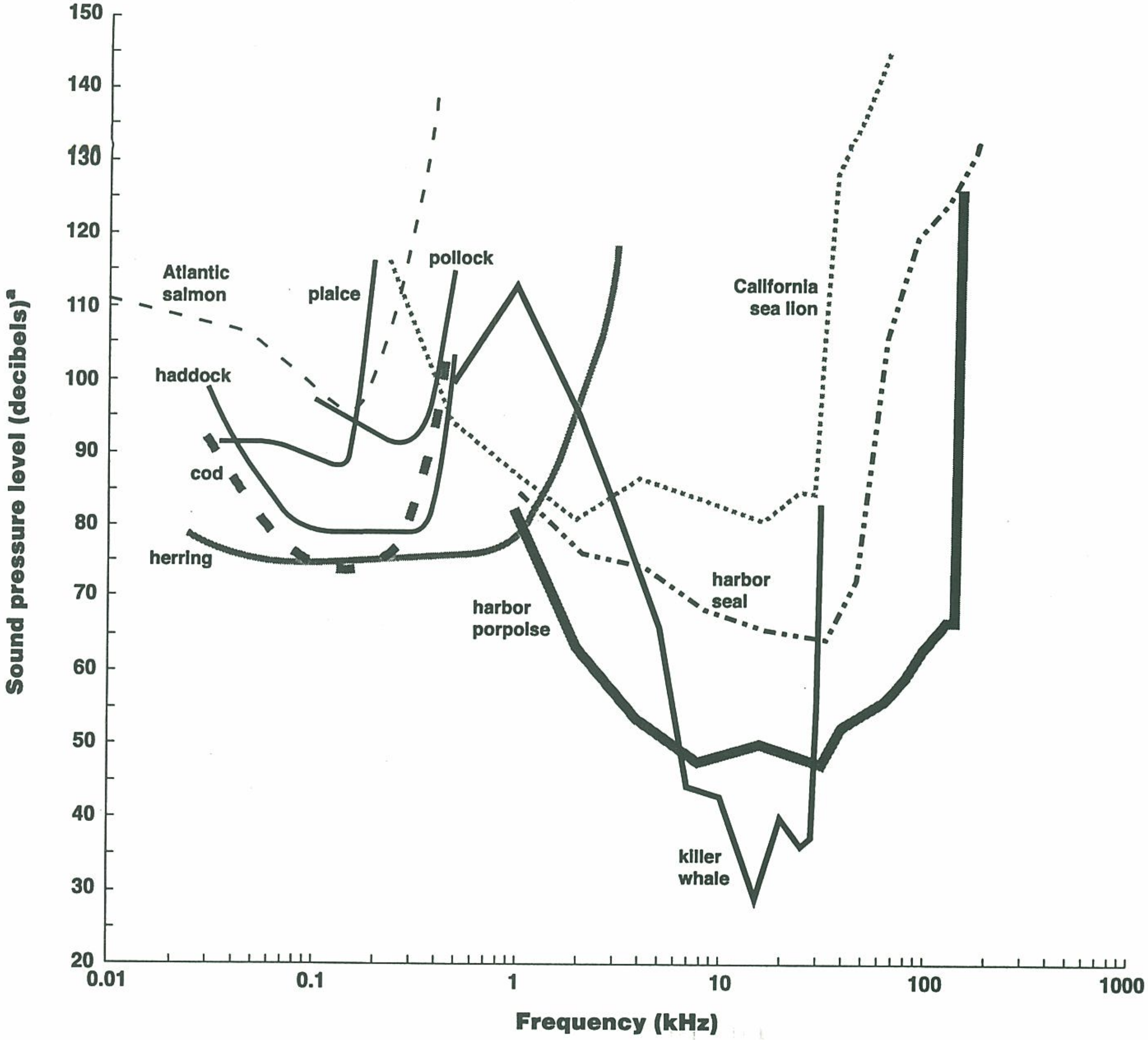
Table 3-3. Frequency of greatest sensitivity and vocalization characteristics of several marine mammals that may be found in south central Puget Sound

RECEIVER	FREQUENCY$_{\text{greatest sensitivity}}$ (kHz)	FREQUENCY RANGE OF VOCALIZATIONS (kHz)	DOMINANT FREQUENCY OF VOCALIZATIONS (kHz)
Gray whale *Eschrichtius robustus*	0.7[a]	20-2,000 (up to 20,000 for calves)	20-800 (up to 4,000 for calves)
Harbor seal *Phoca vitulina*	33	0.5-16	12
Harbor porpoise *Phocoena phocoena*	15	100-160	130
Steller sea lion *Eumetopias jubata*	15[a,b]	–	–
Killer whale *Orcinus orca*	15	0.1-35	1-25
Humpback whale *Megaptera novaeangliae*	–	10-4,000	144-192
Dall's porpoise *Phocoenoides dalli*	–	0.04-12	–

SOURCE: Malme et al. (1989)
NOTE: – - data not available

[a] Value is estimated.

[b] Hearing characteristics of California sea lion used to estimate Steller sea lion.



Note: Threshold stated as sound pressure (decibels with reference to 1μPa) for a frequency range of 0.02 – 1.2 kHz

[a] Relative to 1μPa

Figure 3-2. Audiograms of several fish and marine mammal species

Table 3-4. Sound levels and behavioral responses of several fish and marine mammal species

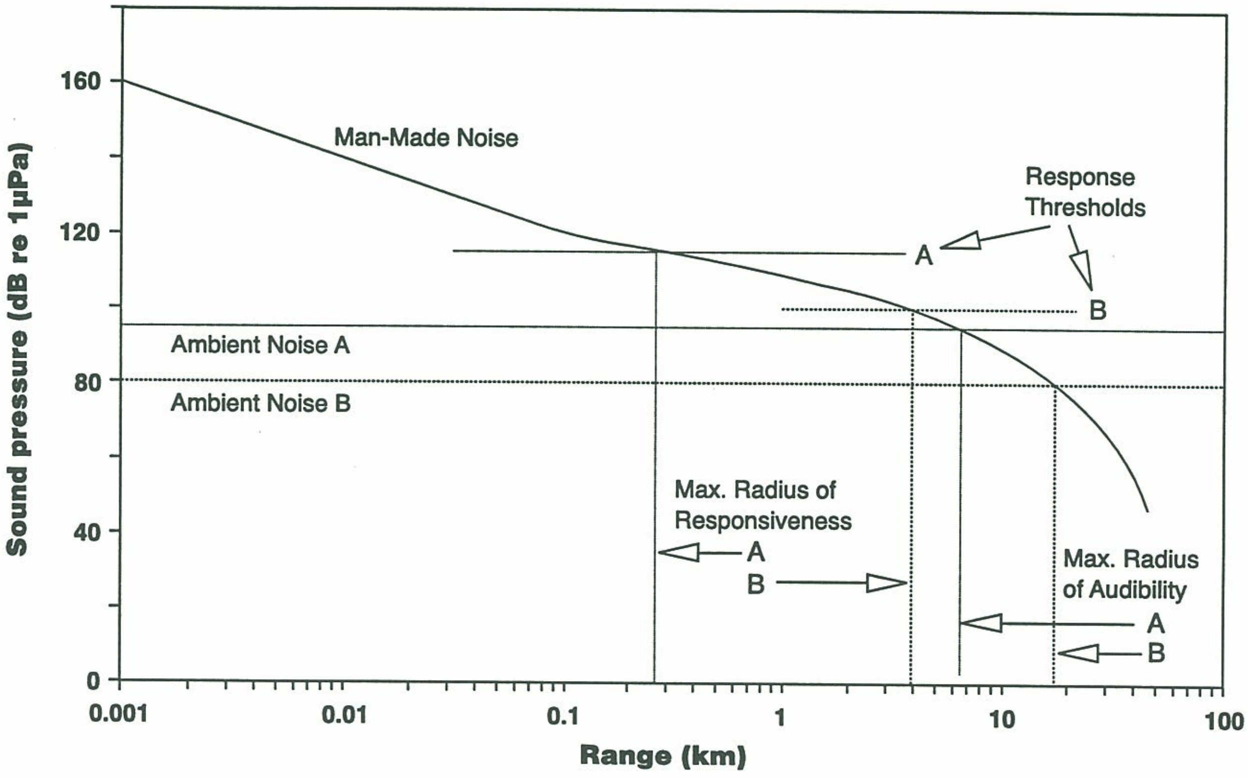
SPECIES	SOUND LEVEL	RESPONSE	REFERENCE
Herring	Approx. 28-34 dB above hearing threshold at 40-250 Hz at ranges between 100 and 200 m	Herring 60-95 feet below echo sounder transducer moved from area	Olsen et al. 1983
	75 dB between 20 Hz and 1.2 kHz	Peak sensitivity of hearing	Mitson 1995
Juvenile spring chinook salmon	10 Hz (5 second duration)	Flight (startle response away from sound) or avoidance No habituation after 20 trials	Knudsen et al. 1997
	30, 60, 180 Hz	Loss of equilibrium, erratic swimming, fish run into one another	VanDerwalker 1967
	70-88 Hz	Escape action, rapid swimming around tank until exhausted	VanDerwalker 1967
	5-280 Hz (strongest response at 35-170 Hz)	Avoidance response; most fish resumed normal distribution after 5 seconds	VanDerwalker 1967
	281-500 Hz	No response	VanDerwalker 1967
Silver salmon (3-5 inches long)	5-20,000 Hz	Initial startle response or quick swimming; reaction more pronounced at lower frequencies	VanDerwalker 1967
	50 Hz-20,000 Hz at intensity levels up to 7200 ubar	No attraction or repulsion to sound; fish elicited startle responses; more pronounced at lower frequencies	Moore and Newman 1956
Atlantic salmon	4dB (125 Hz) and 16 dB (250 Hz) louder than control	In one of three strains of salmon, significantly greater fork length and percent smolting occurred	Terhune et al. 1990
	150-380 Hz	Upper limit of hearing frequencies	Hawkins and Johnstone 1978 as cited in Knudsen et al. 1994
Juvenile Atlantic salmon	5-10 Hz	Most efficient at producing an awareness reaction and avoidance response; may be related to low frequencies often produced by swimming predators	Knudsen et al. 1994
	150 Hz	No repelling effect	
Rockfish	154 dB	Change in movement behavior	Pearson et al. 1992
	168 dB	Change from directed movement to milling	Pearson et al. 1992
	178-207 dB	Alarm behavior; pre-exposure behavior returned within minutes after sound exposure ceased	Pearson et al. 1992
	180 dB	Threshold for avoidance	Pearson et al. 1992
	200-205 dB	Threshold for startle responses	Pearson et al. 1992
	186-191 dB	Elicited changes in swimming and schooling behavior	Skalski et al. 1992
	Fishing vessel	Avoidance reaction by fish 207-265 m deep	Kieser et al. 1992

Table 3-4, continued

SPECIES	SOUND LEVEL	RESPONSE	REFERENCE
	180-191 dB at 6 pulses per min. from an air gun	Significant decline (52.4 percent) in catch-per-unit-effort of rockfish, decrease in aggregation height; assumed behavioral changes caused results	Skalski et al. 1992
Jack mackerel	Research vessel	Reaction distance ranged from 84 m to 341 m at different locations; large schools tended to break in two and pass either side of vessel	Mitson 1995
Sardine	Research vessel, 6.5-8.5 knots	Reaction distance 150-300 m	Diner and Masse 1987 as cited in Mitson 1995
Mackerel	Research vessel, 7 knots	Reaction distance 300-400 m	Diner and Masse 1987 as cited in Mitson 1995
Cod	20 Hz to 300 Hz	Critical frequency band of high sensitivity hearing; peak sensitivity is 75 dB at 100-300 Hz	Mitson 1995
	Threshold exceeded by 30 dB or more	Fish show avoidance reaction at distances 100-200 m up to 400 m	Mitson 1995
California sea lion	Most anthropogenic sounds in ocean	Best adapted to hear in air	Kastak and Schusterman 1998
	Peak sensitivity of 80 dB at about 2 and 16 kHz		Schusterman et al. 1972 as cited in Malme et al. 1989
Harbor seal	100 Hz	About 20 dB more sensitive to 100 Hz signals than California sea lion; more likely to hear low frequency sounds of ships	Kastak and Schusterman 1998
	Low frequency anthropogenic sounds	Potential for masking of intraspecific mating calls, which occur at low frequencies	Hanggi and Schusterman 1994 as cited in Kastak and Schusterman 1998

Effects of Ambient Noise on Sensitivity—Ambient noise represents the portion of the noise spectrum that is present as background levels. Ambient noise is important because it can influence hearing sensitivity to additional noise sources. Three types of underwater noise sources have been classified by Mitson (1995): physical, e.g., breaking waves; biological; and anthropogenic. Figure 3-3 illustrates how a 15-dB increase in ambient noise levels hypothetically decreases the range of responsiveness and audibility (detection) of an animal to anthropogenic noise stimuli. In general, as ambient noise levels increase, the maximum radius of audibility decreases.

Ambient noise conditions off Maury Island have not been measured. The nearshore habitat is a relatively high-energy zone, as indicated by the sandy substrate and open shoreline. Ambient conditions in this area may be estimated from the data presented in



Prepared from Richardson et al. 1995

Figure 3-3. Schematic illustration of a 15 dB change in ambient noise levels on maximum radius of responsiveness and audibility assuming a response occurs when man-made noise levels are at least 20 dB above ambient noise level

Table 3-5, which shows recorded noise levels from tidal action in sandy substrate. Similarly, Stober (1969) measured lake surf beats caused by wave action shifting coarse shore materials, small, loose "rubble," and sand. Frequencies above 5 kHz were attributed to surf beats, and frequencies below 4 kHz were generated by flow noise (from an outlet stream) and bubbles from surface waves. As distance from the shoreline increased, ambient noise levels decreased. Ambient noise levels also depend on propagation and absorption conditions (Mitson 1995). Greater levels of ambient noise are generated in shallow, hard-bottom substrates as compared to fine, silty substrates. Figure 3-4 combines hearing thresholds, ambient conditions, and noise from tugboat and barge combinations. It shows that tugboats and barges will be detected by fish and marine mammals, and noise levels will increase approximately 35 dB (almost 60 times).

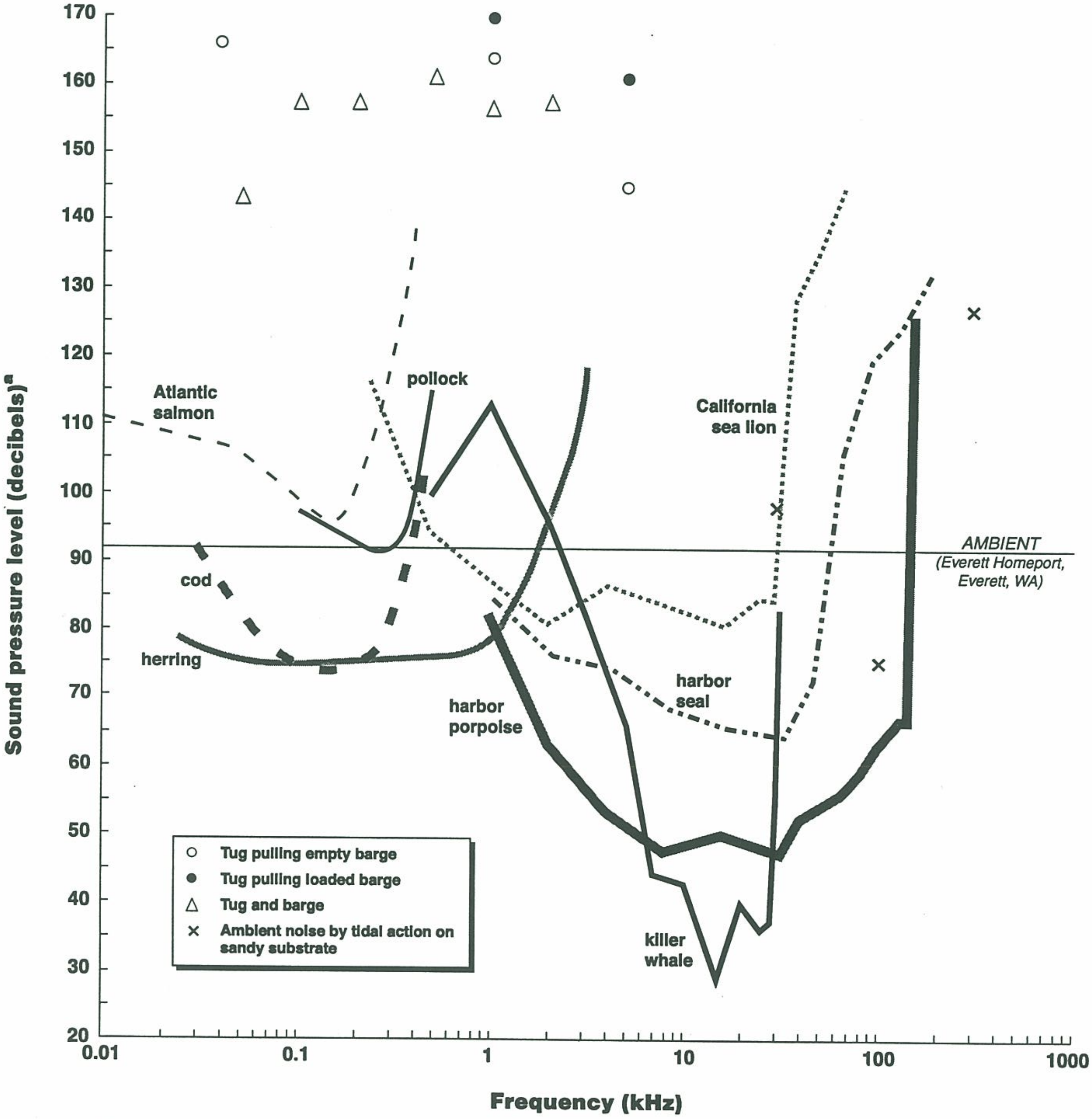
Table 3-5. Noise levels from tidal action on sand ridges

FREQUENCY (kHz)	SOUND PRESSURE (dB re 1μPa at 1 m)
30	98
100	75
300	127

SOURCE: Mitson 1995

Sensitivity of Fish—Industrial activities generate low-frequency noise (<1 kHz) (Malme et al. 1989), and this is within the hearing range of fish (Figure 3-2). In general, salmon are less sensitive to noise than clupeids, which have excellent hearing (Blaxter et al. 1981; Schwarz and Greer 1984; Feist 1991). Audiograms are not available for every fish species that inhabits the site. However, most commercially fished species respond to noise levels exceeding 30 dB (re 1 μPa) above hearing thresholds (Mitson 1995). In addition, fish with swimbladders tend to have better hearing because the organ functions as an amplifier (Mitson 1995). As the size of the swimbladder increases with age, hearing capabilities may also increase because amplification is proportional to the cube of the swimbladder's volume (Mitson 1995). Therefore, audiograms are different between species and possibly between various life stages or ages.

Sensitivity of Marine Mammals—The estimated auditory thresholds for marine mammals (Figure 3-2) in the low-frequency range (< 1 kHz) should be viewed with caution because of the potential interference of holding tanks during measurement (Malme et al. 1989). Frequencies below 1 kHz have not been tested in phocid seals, e.g., harbor seal (Malme et al. 1989). Within the range of frequencies tested, marine mammals are most sensitive above 1 kHz.



[a] Relative to 1μPa

Figure 3-4. Sound pressure level and frequency associated with hearing thresholds of fish and marine mammals, ambient noise levels, and tug and barge combinations.

3.1.3 Effects of Noise

3.1.3.1 Pile-Driving Activities

Hearing thresholds and responses to various noise stimuli are given in Figure 3-2 and Tables 3-4 and 3-5. Noise from pile driving encompasses a range of frequencies detectable by both fish and marine mammals, and broadband, pulsed sounds (such as pile driving) have been shown to be more effective at eliciting a response in fish as compared to continuous, pure tone sounds (reviewed by Feist 1991). Pile driving increased noise levels by 25 dB (re 1 μPa at 593 m [~.5 mi]) above ambient noise levels (Feist 1991). Because every 20 dB increase in sound pressure level increases actual sound pressure tenfold (Feist 1991), the pressure 593 m (1,946 ft)away from pile-driving activities is greater than 10 times the ambient condition. Noise levels closer to the activities are expected to be even greater. This suggests that pile-driving activities would affect fish, especially those with higher sensitivity such as herring.

Feist (1991) investigated the effects of pile driving on juvenile chum and pink salmon at the Everett Homeport, Everett, Washington. Based on behavioral observations, schools of juvenile pink and chum salmon did not show significant changes in behavior with or without pile driving, although fish tended to move toward an acoustically isolated cove. Feist predicted that pile driving would be audible to juvenile salmon more than 300 m (984 ft) from the source, although biological impacts were unclear. Based on salmon hearing thresholds, however, this response may not be indicative of other fish species utilizing the area, which are more sensitive (Figure 3-2). For example, herring spawning activities may be affected by pier reconstruction activities. The Quartermaster Harbor herring stock is one of 18 distinct herring populations in Puget Sound and spawns in Quartermaster Harbor in January through mid-April (Lemberg et al. 1997). A pre-spawning holding area is located approximately 4 km (2.5 mi) south of the mine site. Some research suggests that herring may be most sensitive to noise during the pre-spawning stage and alter their behavior in response to noise (Olsen 1981; Mohr 1964). If noise reaches sufficient levels in the pre-spawning holding area to cause disturbance or avoidance, the spawning success of the stock may decrease. In contrast, some evidence suggests post-spawners are most sensitive (Schwarz and Greer 1984). Post-spawning herring focus their efforts on feeding (O'Toole pers. comm. 1999). In areas with high noise levels, fitness may be decreased because of disruption in feeding activities. Rockfish are expected to avoid the area during pile-driving activities. Pearson et al. (1992) measured avoidance behavior by rockfish aggregated over 200 m (656 ft) deep from sound generated by air guns measured at 180 dB (re 1μPa). Other fish species also would be expected to avoid the area during pile driving.

Although marine mammals would be able to detect pile-driving noise, it is not expected that they would be affected by the temporary increase in noise. Pile-driving activities would likely affect harbor seals if haulout areas were located nearby (Calambokidis 1999). However, there are no harbor seal haulout areas near the Lone Star dock; the nearest haulout is on Gertrude Island several miles away (Jones & Stokes and AR 1999, Calambokidis pers. comm. 1999). Although low frequency sounds may mask intraspecific mating calls (Hanggi and Schusterman 1994), the pulsed short-term nature of pile-driving noise may not be sufficient for this to occur. Also, mating is not known to occur in the vicinity of Maury Island.

Harbor porpoises and killer, gray, minke, and humpback whales are rare in south central Puget Sound (Calambokidis 1999). Therefore, the probability that these marine mammals would be exposed to the pile-driving activity in the 2-to-4-week construction period is low. Even if they were to be exposed, the peak sensitivity and range of vocalization of marine mammals tend to be in the high-frequency range (>10 kHz) (see Table 3-4); and therefore, impacts are expected to be negligible based on available information. Unfortunately, pile-driving sound levels were not recorded in the high-frequency range; the upper limit of recorded frequency was 2 kHz.

Both Dall's porpoise and California sea lions frequent Puget Sound. However, they are not likely to be affected because of the short-term nature of the piling driving and the adaptability of these animals to anthropogenic sounds (Jones & Stokes and AR 1999; Calambokidis 1999).

3.1.3.2 Vessel Traffic and Loading Operations

Vessel activity has been shown to cause a variety of effects in fish and marine mammals, including altered embryonic development (Banner and Hyatt 1973), avoidance (Mohr 1964; FAO 1970; Olsen et al. 1983; Malme et al. 1989), changes in schooling behavior (Schwarz and Greer 1984), and varied respiratory patterns (Malme et al. 1989) (Table 3-4). Vessel noise dominates the 20- to 500-Hz frequency bandwidth and often reaches 1 kHz (Wenz 1962). This is within the hearing range of most fish but not necessarily within the range of marine mammals (Figure 3-2). Therefore, tugboat and barge operations are predicted to affect fish species more than marine mammals.

Docking and barge-loading activities are predicted to have a greater impact on fish and marine mammals as compared to a barge traveling through Puget Sound at a constant speed. This is because the noise from a vessel approaching at constant speed increases in amplitude while frequency remains constant; altering vessel speed changes frequencies (Schwarz and Greer 1984). It is usually abrupt changes in sound frequency or intensity, such as that associated with abrupt changes in vessel speed and direction, that elicit stronger behavioral responses (Schwarz and Greer 1984; Blaxter et al. 1981, Blaxter and Batty 1985). Abrupt changes in tugboat speed and direction are likely to occur during docking activities and possibly during loading. Docking could occur 8 to 40 times per day (see Section 3.1.1.2).

Species sensitivity to tugboat and barge traffic is expected to be ranked in a manner similar to their response to pile driving. For example, juvenile salmon in the area would be less likely than herring to react to the pulsed, changing noise signatures created by tugs maneuvering barges. Increased vessel traffic would increase noise levels at the pre-spawning holding area. It is possible that noise levels may be sufficient to cause disturbance or avoidance by herring and affect spawning success. Rockfish are found in industrial areas throughout Puget Sound. Whether these fish are not sensitive to vessel traffic or habituate to conditions is not clear. Tugboats and barges arriving or departing at constant speeds would be less likely to elicit a behavioral response.

A potential indirect effect of increased vessel traffic on fish and marine mammals is its effect on ambient conditions in Puget Sound. Increases in tugboat and barge traffic would likely increase ambient noise levels. At maximum production rates, 8 to 40 tugboat and barge trips could occur each day. It is not clear at what point ambient noise levels, comprised of natural and anthropogenic sources, reach an intensity that masks auditory functions. For example, vessel noise can mask vocal communication between harbor seal mothers and pups over the ocean surface and limit separation distances, thereby affecting feeding ability (Reiman and Terhune 1993), and the detection of low-frequency sounds is important for predator avoidance in fish (Knudsen et al. 1994).

3.1.4 Conclusions

Noise from pile driving, vessel traffic, and barge-loading activities are expected to be detected by both fish and marine mammals. Various levels of noise have been shown to alter embryonic development (Banner and Hyatt 1973), cause avoidance (Mohr 1964; FAO 1970; Olsen et al. 1983; Malme et al. 1989), change schooling behavior (Schwarz and Greer 1984), and vary respiratory patterns (Malme et al. 1989) (Table 3-2). Pile driving has been recorded at 200 to 2000 Hz, and vessel noise dominates at 20 to 500 Hz, often reaching up to 16 kHz (Wenz 1962). These frequencies are within the hearing range of fish but perhaps less so for marine mammals (Figure 3-2). Marine mammals are not expected to be affected by noise because peak sensitivity is in the high-frequency range (>1kHz). In addition, their presence is more rare in south central Puget Sound. Common species such as harbor seals have no sensitive haulout areas near the dock and, therefore, should not be affected.

Fish species, however, tend to have the greatest sensitivity at low frequencies. Noise generated by dock operations is likely to be detected by fish in the region with varying degrees of sensitivity. For example, herring are much more sensitive to noise than salmon. In addition, herring spawning grounds are located south of the nearshore area of Maury Island. Increased vessel traffic may cause herring to temporarily avoid areas with noisy vessels during pre- or post-spawning activities (Olsen 1981; Mohr 1964; Schwarz and Greer 1984). Pulsed, abrupt noise signatures from changes in vessel speed and direction have been shown to have greater impacts on fish than continuous noise that might be generated by a tugboat and barge moving at constant speed. Docking activities are expected to generate pulsed signatures. Therefore, fish in the immediate vicinity of the dock will be affected by both pile driving and tugboat operations. The underwater sound level of a barge being filled has not been measured. However, this may represent a chronic exposure to noise and cause fish to leave the barge-loading area. The effect on population or ecological dynamics that may result from an individual animal avoiding an area is expected to be negligible. However, fitness of an individual fish is expected to decrease as startle responses and changes in normal activities, such as feeding, increase in association with noise levels from dock activities.

3.2 TURBIDITY

Replacement of dock and dolphin pilings could potentially generate turbidity if bottom sediments were resuspended during sediment disturbance. Driving new pilings into the bottom using an air hammer would disturb sediments in a small area around the piling, while fresh-heading, which involves pulling an existing piling up about 1 to 2 m (3 to 5 ft) and cutting away damaged wood, would also disturb bottom sediments immediately around the piling.

Based on grain sizes for the three sediment samples collected closest to the existing dock (SED-01, -02, and -05; Figure 2-6), sediments in the area are fairly coarse-grained, with some gravel (1 to 15 percent); high percentages of sand (80 to 96 percent); and very low silt and clay fractions (1 to 3 percent, and 1 to 2 percent, respectively). Based on the very low silt and clay content of these sediments, little fine material is available to be resuspended during pile driving and piling removal. As a result, turbidity generation would not be expected to be an adverse impact associated with dock reconstruction.

3.3 HABITAT LOSS

Because the plan for dock and dolphin reconstruction does not involve installation of any additional pilings, no permanent habitat loss would occur. However, positioning of the pile-driver vessel involves the use of two to four anchors. Anchoring in consolidated fine substrates can result in anchor scarring which may persist for several years, depending on resuspension and deposition rates. The sediments near the existing dock and dolphins are generally fine- to coarse-grained sands in which anchor scars would be less likely to persist.

The potential for anchoring to disturb eelgrass beds would depend on which pilings were replaced, and on how far away from the pile-driving vessel the anchors would be placed. Based on Figure 2-6, two eelgrass patches approximately 5 m^2 (54 ft^2) are located within 15 m (50 ft) of a dolphin.

3.4 OIL SPILLS AND LEAKS

No fueling activity would occur at the dock, so the potential for local sea water contamination by petroleum hydrocarbons is limited to spills and leaks of fuel, lubricating oil, or hydraulic oil. The tugboats proposed for use for the Lone Star project would be either 2,000 or 3,000 hp. The 3,000-hp tugboat has a fuel capacity of 80,000 gal, a lubricating oil capacity of 1,000 gal, and a hydraulic oil capacity of 200 gal (R. Summers 1999a).

A worst-case scenario, resulting in a full release of fuel (80,000 gal) as well as other engine fluids, might occur if a tugboat were to collide with the dock. It is beyond the scope of this assessment to provide a full review of the impacts of oil spills in the marine environment, which has been fully reviewed elsewhere (Jewett and Dean 1997; Wells et al. 1995; Rice et al. 1996; U.S. Coast Guard [USCG] et al. 1993). The impacts of oil spills include direct mortality and sublethal effects to fish, invertebrates, birds, and marine mammals.

3.4.1 Description of Tugboat and Barge Operation Impact

Barges would be towed to and from the dock by tugboats equipped with diesel engines of 2,000 or 3,000 hp. A maximum of 40 tugboat movements (20 incoming and 20 departing) would occur daily. Because this activity is not currently occurring at the dock, there are no site-specific measurements of petroleum hydrocarbons, which include PAHs, for marine waters in the project area. Our review of Puget Sound water quality monitoring studies did not produce appropriate measurements of total petroleum hydrocarbons or PAHs in seawater associated with commercial marine traffic. Nor were we able to find measurements of other contaminants, such as hydraulic fluids or lubricants, associated with tugboat operation.

It is likely that in the nearshore project area, which is open and exposed to wave action, longshore currents, and tidal advection, small inputs of petroleum hydrocarbons would be quickly advected from the site, and petroleum hydrocarbons would not be detectable in the water column. The validity of this assumption could be determined easily once project operations were underway by monitoring water quality at the dock. A critical issue related to the potential for adverse impacts to the local biological community would be the concentration and persistence (exposure period) of any contaminant inputs. That is, if petroleum hydrocarbons in project waters were not at high concentrations and remained only for short periods of time, then impacts to the biological community would be unlikely.

3.4.2 Potential Receptors

Potential receptors are benthic organisms listed in Section 2.1 and fish species listed in Section 2.3.1.

3.4.3 Sensitivity of Receptors

Rice et al. (1979) examined the sensitivity of 39 Alaska marine species to crude oil (measured as total aromatics) and determined that Pacific herring was the most sensitive of the species tested, with a 96-hour LC50 of 1 mg/L for herring adults and a 12-day LC50 of 1.5 mg/L for herring eggs. More recently, Carls et al. (1999) determined that herring eggs, exposed during a 16-day incubation period, showed a lowest-observed-effects level of 9.1 μg/L (total aqueous PAHs) for artificially weathered oil. In a study of the sensitivity of pink salmon embryos to weathered crude oil (Heintz et al. 1999), lethal effects were reported for exposure to total aqueous PAHs at 18 μg/L; this result was for a long-term exposure (during a several-month egg incubation period).

Although both studies suggest high sensitivity of salmon and herring embryos to aqueous PAHs, relating these results to marine traffic inputs of petroleum hydrocarbons would require the consideration of both the concentration and the persistence of such inputs in a high-energy environment. Also important would be the type of fuel used in the experiments and the degree of weathering, which may vary from potential fuel inputs resulting from the Lone Star mining operation. Both the Heintz study (Heintz et al. 1999) and the Carls study (Carls et al. 1999) showed that more-weathered oil had different PAH composition than less-weathered oil, resulting in higher toxicity. At the Lone Star dock, petroleum hydrocarbon inputs would likely be unweathered.

Constant water movement at the Lone Star dock would disperse any small inputs of petroleum hydrocarbons, and none would be expected to reach the sediments. Water quality measurements at the dock during operations could be made to confirm this assumption. Unless such measurements indicated that tugboat-related hydrocarbons were persistent at this location, effects due to μg/L concentrations of aqueous PAHs such as those reported by Carls et al. (1999) for herring and by Heintz et al. (1999) for pink salmon would not be expected at this site.

3.5 PROPELLER WASH EFFECTS

Approaching and departing tugboat and barge combinations will follow an arc-like path relative to the pier face. The depth at the pier face is approximately 7 m (24 ft) MLLW and increases offshore at a ratio of approximately 1 to 5. When lashed to the outer side of a barge at the pier, a tugboat would be in water 9 m (30 ft) deep.

A tugboat's propellers have the potential to resuspend bottom sediments as a result of the generation of propeller jets that locally increase the speed of the water near the bottom.

Maynard (1998) presents a relation between the maximum velocity of a propeller jet and the maximum bottom velocity:

$$V = \frac{CV_oD_p}{Hp}$$

where:

V = maximum induced bottom velocity

C = constant depending upon the propeller/rudder configuration (0.22 for open propeller and single rudder)

V_o = maximum speed of the propeller jet

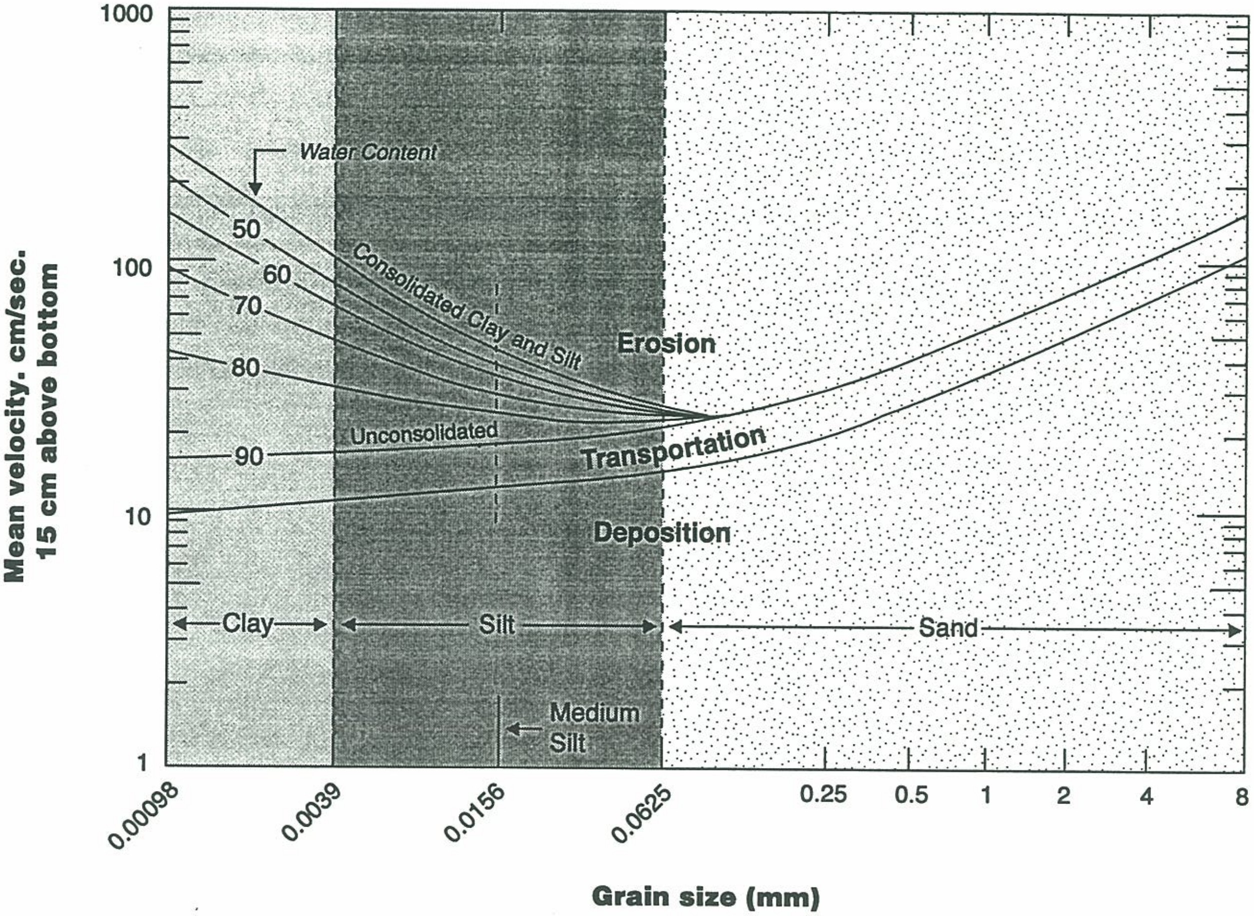
D_p = diameter of the propeller

H_p = distance from the propeller shaft to the bottom.

Assuming a value of V_o equal to 3 m/s (10 ft/s) relative to the current, a propeller diameter (D_p) of 2 m (7 ft), and a distance (H_p) of 6 m (20 ft) between the propeller shaft and the bottom, the predicted (albeit approximate) maximum bottom velocity would be 26 cm/sec (10 in/sec). Typically, an average speed of approximately 20 to 30 cm/sec (8 to 12 in/sec) near the bottom is necessary to resuspend unconsolidated particles of a size between fine sand and silt (Figure 3-5). According to this rough estimate, bottom velocities induced by the propeller jet would be capable of resuspending bottom sediments in waters immediately adjacent to the loading pier. The potential for propwash to resuspend sediments in deeper waters diminishes in proportion to the increase in depth.

Grain size data obtained from sediment samples obtained near the dock during a recent field survey show that a representative grain size distribution is 3 percent clay and silt, 89 percent sand, and 8 percent gravel and larger (Table 2-3). Bottom sediments near the dock do not contain much fine-fraction material, so little impact would result from its being resuspended by propwash. Once in the water column, the settling velocity of the fine-fraction material is so slow that advection would likely transport it and disperse it away from the resuspension site before any appreciable amount redeposited. Medium sand (settling velocity of approximately 3 cm/sec [0.1 ft/sec]) would likely fall out of the water column within a minute of being resuspended and would not contribute to any long-term turbidity. Fine sand would persist in the water column longer before settling out and would more likely be transported farther than the coarser sand fractions. Coarse sand and larger particles might be moved very locally as bedload along the bottom but would not be resuspended into the water column.

The existing pier lies on a bottom gradient of approximately 1 to 5. Currents tend to be along isobaths, which means that there is very little cross-isobath advection of water, and therefore of any water-borne properties such as suspended sediment. Therefore, even if sediment were resuspended by propeller jets, it would be transported primarily along shore rather than inshore.



Adapted from Paquegnat 1990

Figure 3-5. Current velocities required to transport particulate material

The frequency of tugboat and barge passages to the pier would be at least one barge per day, so there would not be enough time between passages for any additional unconsolidated sediment to accumulate and be available for resuspension. In short, vessel passage would keep the approach and departure corridor cleared of sediment down to the level of consolidated sediments not amenable to resuspension.

In addition to fine sediments, surface organic matter may be resuspended. This could influence the distribution of benthic organisms because it may provide a food source. However, it is assumed that benthos would relocate to areas of sufficient organic matter. A maximum increase in current speed of 26 cm/s (10 in/s) is not predicted to dislodge vegetation. The buffering capacity of vegetation was not included in the model and is likely to reduce resuspension. Eelgrass has been found in currents 1.5 to 2 m/s (10 to 13 ft/s) (Phillips 1994; Fonseca et al. 1983). This speed is two orders of magnitude greater than the predicted bottom current speed generated by a tugboat (26 cm/s or 10 in/s). Macroalgae are also predicted to withstand a bottom current of 26 cm/s.

Fish and marine mammals are not expected to be affected by propeller wash because they can move from the area and the area is not considered critical habitat.

3.6 SHADING AND NIGHT LIGHTING

Ambient light conditions around the dock may be altered by dock operations in two ways: 1) shading by barges, and 2) artificial night lighting and safety lighting. The ecological impact of shading produced by docks and piers on the nearshore community has only recently been investigated. Such structures have been shown to reduce light levels underneath and in the vicinity of the dock. After the light was reduced, alterations in the vegetative community were noted (Fresh et al. 1995; Burdick and Short 1998; Simenstad et al. 1997, 1999).

For this analysis, a barge docked at the Lone Star dock is assumed to function as a modified pier because barge loading may occur 24 hours a day, 7 days a week (Jones & Stokes et al. 1999). Alternatively, loading may occur only 12 hours a day, 5 days a week. However, the barge will still be docked when not being actively loaded; and upon departure, another barge may take its place (Summers 1999b). Table 3-1 shows the dimensions of barges over a range of barge load capacities.

The shade footprint created by a structure (the amount of area with reduced light levels) is important in determining the structure's impact on natural resources. Several parameters have been shown to affect the extent of the footprint: dock height, length, width, and orientation; the spacing between pilings; whether the dock has a floating or fixed structural design; tidal regime; and sun angle (Burdick and Short 1998; Fresh et al. 1995). Barge draft and depth (height above the water line) are characteristics of a barge not found in a dock model, but they are likely to be positively correlated with shading effects.

A light-shading model generated for the Clinton ferry terminal in Clinton, Washington, (Olson et al. 1997) showed shading effects primarily on the northern edges of the pier. The time of year affected the extent of the footprint such that a larger shade footprint was created in December as compared to March or June. In December, the shadow extended approximately 30 m (100 ft), nearly the width of the dock.

By comparison, a 10,000-ton-capacity barge docked at Lone Star has approximately the same width (24 m [80 ft]) and is also oriented in a similar direction. Based on these similarities, a shade footprint is predicted to occur along the northern edge of the barge. This northern edge encompasses nearshore habitat at approximately -6 m (-20 ft) MLLW.

3.6.1 Shading Effects on Eelgrass

Diver surveys (Jones & Stokes et al. 1999; Jones & Stokes and AR 1999) and side-scan sonar data (as detailed in Section 2.0) showed no eelgrass beds immediately below the area where a barge would be docked. Patchy eelgrass at the site was primarily located in depths of -1.5 to -4.5 m (-5 to -15 ft) MLLW, with the deepest eelgrass patch at approximately -5 m (-16 ft) MLLW. During a survey in July and August of 1999, eelgrass density ranged from single plants to 23 shoots per 0.25 sq m (3 sq ft) (Jones & Stokes and AR 1999). The closest eelgrass patches that would be affected by barge shading are two patches underneath the dock (<25 sq ft), surveyed in January 1998, and one patch located alongside the pier in -2 to -3 m (-7 to -10 ft) MLLW surveyed in July and August of 1999 (Jones & Stokes et al. 1999, and Jones & Stokes 1999). It is not clear whether all three patches occur concurrently or if they represent spatial variability over time. Individual shoots were also located just north of the dock in water approximately -20 ft MLLW and the SPI camera recorded the presence of eelgrass shoots at Stations 11 and 22 (Figure 2-6).

The extent of the shade footprint will determine the effect on existing eelgrass beds and individual shoots. The lack of eelgrass beds directly underneath a docked barge decreases the probability of lost eelgrass resources. However, the shadow may extend to the smaller patches of eelgrass plants previously mentioned (Jones & Stokes et al. 1999; Jones & Stokes and AR, 1999). Assuming the shade footprint extends several meters north of the barge, the shading effects produced by a barge may be large enough to alter photosynthetically active radiation (PAR) levels reaching the individual shoots or eelgrass patches located near the docked barge (see Figure 6-2 in Jones & Stokes et al. 1999; Figure 2 in Jones & Stokes and AR 1999; Figure 2-6). If shading to these plants were to be at levels below 300 micromoles per square meter per second (μM/m^2/sec), the eelgrass would likely become light limited and not survive (Thom and Shreffler 1996). Survivorship may also decrease if the presence of barges results in light levels that are chronically lower but still above the 300 μM/m^2/sec threshold. Under these conditions, plants may not be able to accumulate sufficient reserves during summer to use throughout the low-light conditions of winter (Olson et al. 1997; in Simenstad et al. 1997).

Shading effects are predicted to alter light conditions in the vicinity of a barge. Altered light regimes may affect the small eelgrass patches or individual shoots currently established. Shading may also prevent colonization of habitat that could be suitable for larger beds if the presence of eelgrass shoots is indicative of recolonization processes.

3.6.2 Shading Effects on Macroalgae

Although eelgrass was not present at the end of the dock, macroalgae have colonized the area. A diver survey recorded 6 algal taxa, 22 invertebrate species, and 20 fish species along transects in the dock vicinity (Jones & Stokes and AR 1999). At depths of -8 to -9 m (-25 ft to -30 ft) MLLW, *Laminaria, Ulva*, and red algae dominated. *Laminaria saccharina* was common from about -3 to -9 m (-10 to -30 ft) MLLW (the lower limit of the survey). The algal community in the barge loading area was also recorded with the SPI camera at Stations 16 and 17. These stations would be located underneath any of the barges used for loading. Light levels required for *Laminaria saccharina* have been recorded at 0.5 to 1 percent of surface irradiance in coastal water systems (Lüning 1981, in Lee 1989). A barge is predicted to lower light levels in the area and possibly limit the growth of currently distributed macroalgae. If light levels are sufficiently decreased, changes in species richness could occur by creating low-light conditions that would favor deep-water species adapted to these conditions (EVS 1999a).

Macroalgae provide habitat for nearshore organisms. Several species of fish were found to be abundant in *Laminaria*, including flatfish, rockfish, and pile perch (Jones & Stokes and AR 1999). In addition, zones of macroalgae may provide prey resources and refuge to juvenile salmon as they migrate to eelgrass patches in the vicinity. While no eelgrass was present under the barge area, it has been hypothesized that if sufficient prey resources were available under a dock, juvenile salmon might traverse the area between eelgrass beds (Simenstad et al. 1999). A 10,000-ton-capacity barge will cover approximately 2,450 sq m (26,400 sq ft); alteration of light levels is predicted in this area. Impacts to the macroalgal community may indirectly affect the functioning capacity of eelgrass beds by isolating the beds and removing the refuge and prey resources associated with the current habitat. A fundamental basis of landscape ecology is the role of spatial patterns, or proximity of habitat types, to an overall functioning system (Forman and Godron 1986).

3.6.3 Night Lighting Effects on Vegetation

At this time, the effects of artificial light on submerged vegetation cannot be analyzed without further information on the light intensity, placement, and duration of use.

3.6.4 Shading and Night Lighting Effects on Fish

In addition to vegetative impacts, changes in ambient light conditions may influence fish around the dock. Shading produced by barges could affect fish by changing the amount of light available for vision, creating shadow effects in the environment, and altering primary and secondary productivity.

Juvenile salmon have been shown to migrate along dock shadows and natural shadows such as edges of eelgrass beds (Simenstad et al. 1999). Feist (1991) observed juvenile pink and chum salmon swimming near the edges of docks but not going underneath. In a recent study investigating the affects of ferry terminals on salmon migration, chinook fry were released near a ferry dock and their movement was recorded. The migration pattern of the released school did not appear to be disrupted by the dock's shadow line. Fish were observed following the shadow line as it progressed over the course of the day and observed moving from the shadows into lighter areas to feed. Over time, the shadow essentially moved under the dock and the fish were assumed to have moved through to the other side with the shadow (Shreffler and Moursund 1999). It should be noted that this study was limited because of low replication and that general conclusions about the impacts of structures on chinook migration may be premature.

Based on limited information, it appears that for salmon migrating along the coast, the barge could provide a preferred migratory route by creating a shade contrast in the environment. It is not clear whether other species react to shade in the same manner. Marine mammals are not predicted to be influenced by shade, either directly or indirectly, because of the small area affected relative to their distribution.

Barge loading could also generate artificial night lighting through the use of work or safety lights. Little is known about the effects of night lighting on the nearshore community, and this has been identified as an area requiring future research (Simenstad et al. 1999). Chinook salmon typically show nocturnal activity and are negatively phototactic (Simenstad et al. 1999), and rockfish have been shown to be disturbed by artificial light at night (Kieser et al. 1992). Night lighting may deter chinook salmon and rockfish from using the area at night. Effects on other species are uncertain.

A fish's response to changes in light or dark conditions depends on numerous factors, including ambient light conditions, fish species, and fish age. Abrupt changes in light patterns, such as turning on lights in a dark setting or turning off lights abruptly, have greater impacts than do gradual light changes. For example, physiological adaptations in the eyes of chum and pink fry have been timed at 30 to 40 minutes when exposed to a change from light to dark, while for dark-adapted fry, adaptation to increased light requires 20 to 25 minutes (Brett and Ali 1958; Protasov 1970; Simenstad et al. 1999).

The age of a fish can also influence the amount of time required for adaptation to changing light levels. In adult fish, the time to adapt to brighter light stimuli decreases, whereas the time to adapt to darkness increases with age (Simenstad et al. 1999). Therefore, if night lighting were used for barge loading, which is a high probability because loading is proposed to occur 24 hours a day, it could affect fish in the immediate area around the Lone Star dock, especially if light conditions were changed quickly. Abrupt changes in lighting could temporarily hinder the ability of fish to avoid predation or locate prey.

3.7 SAND AND GRAVEL SPILLS AT THE DOCK

A meeting with Washington Department of Ecology, Pacific Groundwater Group, and EVS was held in December 1999 to determine the spill scenarios to be evaluated for the nearshore impact assessment. It was agreed that evaluating the following two scenarios would provide regulators with information about a range of potential impacts from loading operations:

1. A worst-case single event spill, with spillage of an entire load of the maximum size barge at the dock
2. A scenario in which minor spillage (approximately 1 percent) of each load would occur during loading; the evaluation of this scenario would provide insight into potential harm to the benthos of recurring spillage, which could prevent recolonization

3.7.1 Worst-Case Single Event Spill

The area of bottom sediment that potentially would be covered by mine product, primarily coarse sand and gravel, in the event of a spill of a fully loaded, maximum-size barge at the dock is presented in Figure 3-6. The stippled area shown in the figure represents a rough estimate of the spill footprint; this estimate was developed through the application of a computer model combined with best professional judgment (because of limitations associated with the model).

An initial analysis used the computer model STFATE to predict the mounding and spreading of material that would be released if a barge load of material spilled. STFATE is one of the models in the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) suite of computer programs for investigating impacts of dredging and dredged material disposal (see Appendix C of USEPA and ACOE 1998). STFATE accounts for factors such as current speed, depth to the seabed, and density of seawater at the location of dredge disposal in order to predict the dispersal of dredged material.

However, some limitations exist in the applicability of STFATE to a scenario in which relatively dry material is spilled into seawater from a barge. These limitations include the following:

- STFATE was designed for dredged material, which has a high water content and tends to act as a fluid when released into the sea
- STFATE does not model the larger-sized material, such as cobble, that may be included as part of a sand and gravel shipment from the Lone Star mine
- STFATE uses a single-point source of disposal (in this case, a single-point source of the spill)
- Because of the additional effort required to model the fate of material spilled onto a sloping seabed, the STFATE model was set up for a spill onto a level seabed

Details of the STFATE model as it was set up to predict the footprint of a potential Lone Star sand and gravel spill are provided in Appendix B. The appendix also provides a figure showing the results of the model's output. Briefly, the model predicts that the spill would cover an area of seabed approximately 90 m long by 90 m wide (300 ft long by 300 ft wide) to a depth of 15 cm (6 in.). The spill would be mounded in the center, with an area approximately 26 m (75 ft) in diameter covered to a height of 1 m (3.5 ft).

Best professional judgment was used in translating the STFATE model results to the footprint of the spill, as shown in Figure 3-6. The footprint is roughly oblong-shaped, approximately 122 m long by 91 m wide (400 ft long by 300 ft wide). Because STFATE did not include some of the larger-sized material, we cannot predict the height of the mound. However, it should be noted that, were a spill to result in a very high mound, Lone Star would need to consider recovering much of the material, at a minimum to prevent navigation hazards but also for the economic value of the material itself.

The footprint of the spill is longer (in the direction parallel to the dock and shoreline) than it is wide, corresponding to the shape and size of the barge. Because of the large particle size of most of the load, much of the material would rest immediately beneath the barge. The effect of the nearshore seabed slope would be to minimize the footprint shoreward of the dock, and the center of the footprint would be offset downslope to the southeast. Very little of the barge load is expected to be fine silt or clay (less than 7 percent of the load) which could generate turbidity in the event of a spill; any fine material released from the barge would be advected away.

The footprint of the spill, as shown in Figure 3-6, does not overlay any identified critical marine resources. It would not cover any of the areas of eelgrass that were mapped in

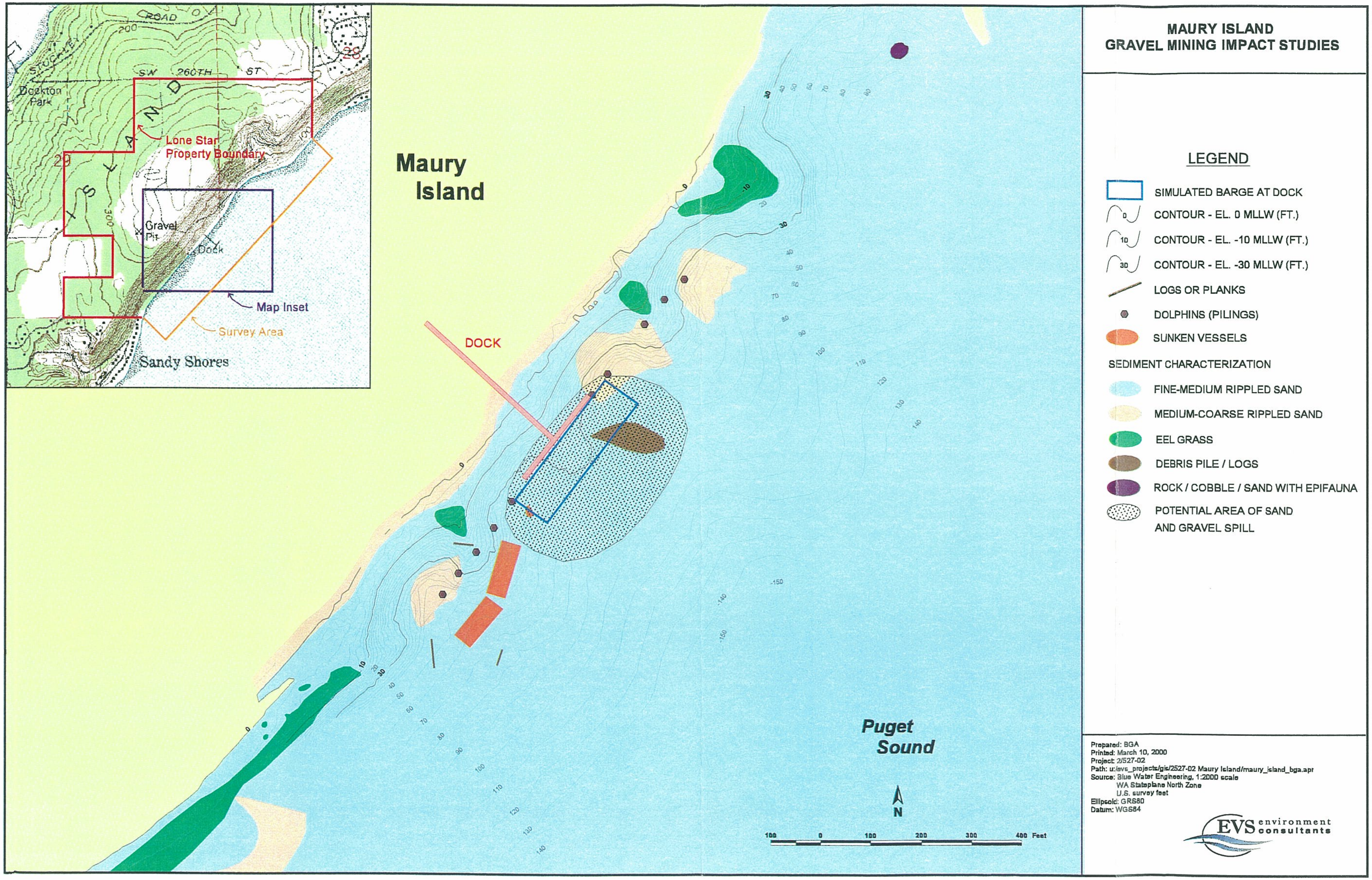


Figure 3-6. Potential area of bottom covered by coarse sand and gravel (worst case spill scenario). See text for explanation.

October 1999. It would cover the entire log and rock debris pile, a small corner of a patch of coarse-grained sediment and the small sunken boat.

The short-term effect of such a spill would be to eliminate the benthic community fish and vegetation in the spill footprint. The benthic organisms occupying this area represent prey for the fish community; therefore, some loss of prey organisms would occur. Because this type of habitat is not expected to be unique among Maury Island nearshore habitats (and it is not unique in the area surveyed), it is not likely that such a loss of prey organisms would have adverse effects on the fish community or even cause them to move away from the nearshore area.

The long-term impact of such a spill would be to shift the type of benthic community occupying this area in the direction of recolonizers appropriate to the grain size of the spill and possibly change vegetation from eelgrass to algae. Table 3-6 provides a comparison of the distribution of grain sizes that were found in the sediments collected near the dock versus the expected grain size distribution of a typical barge load of mine material. Although the size categories are not identical, the overall difference is that greater percentages of coarse sand, gravel, and cobble exist in the barge load than currently exist in the sediments at the dock; the sediments in the nearshore area are generally dominated by fine sand (see also comments in Appendix A, SPI photographs). Following a spill of a full barge load, there would be an overall change in substrate to an area of larger-sized material with more numerous and larger void spaces than currently exists near the dock. Such material could be expected to support a different benthic community, most likely one with greater diversity as a result of the additional cobble substrate. This new substrate could support an epifaunal community as well as small organisms that can hide in or inhabit void spaces. Recolonization of the spill by eelgrass is probably not likely because of the change from sand to coarse sediments. In sum, the long-term effect of a large spill of sand and gravel would likely be adverse for eelgrass but could be slightly beneficial for benthos by providing greater habitat diversity.

Table 3-6. Comparison of sediment grain sizes of nearshore sediments near dock versus gravel mine product

	Near-Dock Sediment Size Distribution		Gravel Mine Product[b] Grain Size Distribution		
Particle Type	Size Range	Percent[a]	Size Range	Screen	Percent
Gravel	2 mm – 256 mm	8	4.75 – 101 mm	#4- 4"	20
Coarse Sand			0.4 – 4.75 mm	<#4	57
Sand/Fine Sand	0.06 – 2 mm	89	0.07 – 0.4 mmg	<#40	23
Silt	0.004 – 0.06	2	<0.07 mm	<#200	7
Clay	< 0.004 mm	1			

[a] Based on mean of SED-01,SED-02, SED-05 (sediment samples collected near dock).

[b] Mine product would be sorted according to customer specifications. This set of specifications is Washington State Dept. of Transportation #9-03.14 (gravel borrow) (R. Summers 1999b).

3.7.2 Small Spills During Loading

Lone Star (Summers 1999b) considers the amount of material lost due to spillage at the dock so minor that they do not attempt to measure it. Windblown material is considered to be the main potential loss of product at the dock. Because such losses represent an economic loss, preventive measures have been taken. These include designing the conveyor so that the product is conveyed to the center of the barge and using barges with walls. In addition, a dock worker is stationed to observe loading, as is the tugboat crew, and personnel are trained to watch for situations in which the barge and conveyor are misaligned.

If small spills were to occur repeatedly during loading at the dock, the effect would be cumulative because the coarse fractions would remain where they fell. The bottom mound would increase in thickness as material accumulated and in breadth as the additional material rolled laterally away from the center of the mound until static stability was reached. If small spills were to occur frequently, finer material that reached the bottom could accumulate before being transported away by the influence of waves and currents. Conversely, infrequent spills would result in little accumulation because there would be sufficient time to transport material away. Whether or not there would be a net accumulation would depend on frequency, volume, and material grain size.

3.8 PILING INSTALLATION EFFECTS ON LONGSHORE TRANSPORT PROCESSES

According to Lone Star (R. Summers 1999a), the basic parameters (configuration) of the dock pilings and dolphins are not expected to change. Therefore, no changes should occur in the longshore transport of sediment as a result of the project.

4.0
CONCLUSIONS

This report provides a baseline characterization of benthic habitat conditions and sediment chemistry in the nearshore subtidal environment adjacent to the Lone Star mine located along the eastern edge of Maury Island. In addition, potential impacts to aquatic resources arising from Lone Star's proposed increase in gravel mining operations have been assessed. The major conclusions reached in this study are summarized below.

4.1 BASELINE CHARACTERIZATION

Several field studies were instigated in the fall of 1999 in order to characterize approximately 16 ha (39 acres) of nearshore environment along the shoreline of Maury Island. Characterizations were accomplished using a precision bathymetric survey, a side-scan sonar survey, a series of sediment profile images (SPI), and the results of chemical analyses from sediment samples.

Bathymetric results indicated that depth increased at a fairly steady rate from the shoreline and reached over 31 m (100 ft) at a distance of 84 m (275 ft) seaward from the center of the dock. A series of submerged beach cusps running perpendicular to the shoreline were detected. These represent a rhythmic shoreline feature common in sand and gravel substrates. The crests of these cusps are regularly spaced, and the Lone Star dock is situated upon a crest.

The side-scan sonar survey characterized a variety of seabed features in the area: several eelgrass beds, sunken barges, patches of coarse-grained sediment, and a patch of debris. Sediments off Maury Island are primarily fine- to coarse-grained sands with some concentrated patches of gravel and cobble or rocky bottom. Approximately 1.0 ha (2.5 ac) of eelgrass was observed. Two major eelgrass beds were located in water depths shallower than 6 m (20 ft), and smaller eelgrass patches were located on either side of the dock.

A total of 39 SPI stations were surveyed. The majority of bottom substrate was rippled medium sand. Penetration into the substrate was fairly shallow (less than 10 cm [4 in.]) because of the high shear strength of sandy sediments. A few isolated stations had deeper penetration, most likely due to bioturbation. Two SPI stations detected eelgrass not detected by side-scan sonar because of low shoot density. Six stations in the vicinity of the dock had surface layers of gravel, possibly indicative of historic gravel mining spills or bluff erosion. However, three stations located away from the dock also had a surface gravel layer.

Analysis of sediment samples revealed coarse-grained, sandy sediments with low organic carbon content (0.14 to 1.9 percent organic carbon). All pesticides, polychlorinated biphenyls (PCB), and three trace metals (arsenic, cadmium, and silver) had chemical concentrations reported as not detected. Concentrations of the remaining trace elements were below corresponding criteria in the Washington State Marine Sediment Quality Standards. Sediment polycyclic aromatic hydrocarbon (PAH) concentrations were low, except at one station where fluoranthene exceeded the marine sediment criterion.

4.2 ASSESSMENT OF POTENTIAL IMPACTS

Lone Star's proposal to expand the operations at the Maury Island gravel mine would involve reconstructing the existing dock and initiating shipping operations at the dock. Both types of activity could result in environmental impacts to the nearshore area.

The overall assessment of potential impacts to aquatic resources is summarized in Table 4-1. This table summarizes two types of information: first, a subjective assessment of the amount of information (denoted as limited, moderate, or sufficient) that was available for assessing potential impacts; and second, an assessment of potential population impacts (denoted as negligible, moderate, or substantial) to categories of aquatic resources within the study area. Both types of assessments were made for the stressors associated with pier reconstruction activities and barge operations.

The confidence with which potential impacts can be assessed is dependent upon the quantity and quality of information available. The determination of information sufficiency was a subjective decision that considered: 1) the specificity with which the changes in the nearshore environment associated with the proposed nearshore mining operations could be characterized, 2) the amount of site-specific information available to characterize the presence of aquatic species and their use of the habitat, and 3) the amount of information available in the scientific literature on threshold responses to stressors associated with dock and shipping operations. The information evaluated for assessing potential impacts included: 1) baseline habitat and sediment chemistry data collected during this study; 2) descriptions of proposed dock and shipping operations described in the draft environmental impact statement (DEIS) for Maury Island Lone Star Gravel Mine (Jones & Stokes et al. 1999) and provided by Lone Star representatives, 3) an eelgrass and macroalgae survey (Jones & Stokes and AR 1999), 4) information obtained through interviews with state and federal agency staff, and 5) a review of relevant scientific literature (EVS 1999b).

Table 4-1 shows that, for most stressors and aquatic resource categories, the amount of information for assessing impacts was deemed to be moderate or sufficient. The stressor categories for which limited information was available for assessing impacts were light shading and exposure to night lights. For both of these latter stressor categories, some uncertainty exists regarding exposure concentrations that would result from the dock and shipping operations, and, more importantly, very little scientific data exist on how populations of natural resources would react to these stressors.

Table 4-1. Assessment of potential impacts to aquatic resources

Activity/Stressor	Benthic Community		Vegetation		Salmonids (threatened/ endangered)		Herring (candidate species)		Rockfish (candidate species)		Cod-like Fish (candidate species)		Other Fish Species		Marine Mammals	
	Info	Impact	Info	Impact	Info	Impact	Info	Impact	Info	Impact	Info	Impact	Info	Impact	Info	Impact
Pier Reconstruction																
Noise	—	—	—	—	◍	△	◍	△–▲	◍	△	◍	△	○	△	◍	△
Turbidity	●	△	◍	△	●	△	●	△	●	△	●	△	●	△	◍	△
Habitat Loss	●	△	●	△	●	△	●	△	●	△	●	△	●	△	●	△
Barge Operations																
Noise	—	—	—	—	◍	△	◍	△–▲	◍	△	◍	△	◍	△	◍	△
Chemicals-chronic	◍	△	—	—	◍	△	◍	△	◍	△	◍	△	◍	△	◍	△
Propeller wash	◍	△	○	△	◍	△	◍	△	◍	△	◍	△	◍	△	●	△
Light shading	—	—	◍	◮	○	△	○	△	○	△	○	△	○	△	○	△
Gravel spills	●	◮	●	◮	◍	△	◍	△	◍	△	◍	△	◍	△	◍	△
Night lighting	—	—	—	—	○	△	○	△	○	△	○	△	○	△	—	—

Information available to support decision:

○ limited information
◍ moderate information
● sufficient information

— out of scope

Estimated population impact:

△ negligible impact
◮ moderate impact
▲ substantial impact

Table 4-1 (actually a figure; see Kimberly)

Three categories have been used to denote potential impacts to populations or communities of aquatic resources. A designation of negligible impact indicates that, based on the available information, it was the judgment of the authors that no long-term measurable change in the viability of the population resulting from exposure to a stressor would occur. A designation of moderate impact is provided where it is believed that measurable changes to the population may occur and that these changes may reduce the long-term abundance or spatial distribution, but not the population viability, of the aquatic resource in the study area adjacent to Maury Island. A designation of substantial impact is reserved for impacts that may threaten the viability of the aquatic resource in the study area. The permanent avoidance of the study area or elimination of a type of habitat are examples of impacts that would be classified as substantial.

4.2.1 Pier Reconstruction

The existing Lone Star dock would require repairs to support the proposed expansion of gravel mining and barge transport of product. These repairs would include:
1) reinstallation of the conveyor loading equipment; 2) replacement of approximately 30 pilings; and 3) replacement of approximately 25 percent of the existing dock's decking, stringers, and supports (Jones & Stokes 1999b). The installation of the conveyor equipment is estimated to take 15 days, while the replacement of pilings and decking is estimated to take between 14 and 28 days. Reconstruction activities would require use of a pile-driving vessel, which would be positioned with anchors. Timber pilings would be installed with an air hammer. These short-term reconstruction activities could result in impacts to nearshore marine resources due to:

- Increased noise associated with use of the air hammer
- Increased turbidity resulting from resuspension of sediments during installation and removal of piling
- Bottom habitat loss resulting from the installation of new pilings or associated with anchor scarring

Table 4-1 shows that, with the possible exception of impacts to the Quartermaster Harbor herring stock, the impacts resulting from these activities are not expected to result in any long-term measurable change in aquatic resources within the study area. The increased noise and activity during construction may result in some avoidance by marine species; however, the overall impact to aquatic populations is expected to be negligible.

Impacts to the herring population from noise associated with pier reconstruction were classified as negligible to substantial because the likelihood of construction impacts is dependant on the time of year. Herring are sensitive to noise, and evidence suggests that pre-spawning and post-spawning life history stages are most sensitive (Mohr 1964; Olsen 1981; Schwarz and Greer 1984). The Quartermaster Harbor herring stock, one of the

18 distinct herring populations in Puget Sound, spawns in Quartermaster Harbor between January and mid-April (Lemberg et al. 1997). Prior to the onset of spawning, adults congregate in holding areas off the mouth of Quartermaster Harbor to the southeastern portion of Maury Island. The distance from the mine site to the holding area is approximately 4 km (2.5 miles). If noise were to reach sufficient levels in the pre-spawning holding area to cause disturbance or avoidance, herring spawning success could decrease substantially. Although pier reconstruction represents a relatively short time frame, it could encompass approximately 30 percent of the spawning season for herring. Potential impacts to the Quartermaster Harbor herring stock could be mitigated by scheduling reconstruction activities to occur prior to or after the spawning season. If reconstruction activities did not occur during January through April, the impacts to this population would be judged to be negligible.

4.2.2 Barge Operations

The proposed expansion of gravel mining and the transport of product by barge would result in increased vessel traffic as tugboats brought in empty barges and departed with full barges. Shipping operations at the dock could potentially occur 365 days a year, 24 hours a day. Vessel traffic would include up to 40 docking and undocking movements of a tugboat and barge combination per day if small barges were used and up to 8 docking and undocking movements per day if large barges were used. Vessel and gravel loading operations could affect nearshore marine resources due to:

- Increased noise from vessels and dock loading operations
- Potential contamination of the water column resulting from spills or leaks of marine engine fuels, hydraulic fluids, or lubricants
- Propeller wash effects on bottom sediments
- Increased shading of the water column and bottom substrate by barges
- Use of dock lights at night
- Spills of sand and gravel

4.2.2.1 Noise

With the exception of herring, long-term impacts from noise that would occur with increased vessel traffic and dock loading operations are assumed to be negligible. Other species of fish and mammals are expected to be able to detect the noise generated from increased vessel traffic and dock-loading operations because the dominant frequencies of sound generated by vessels, 20 to 500 Hz, are within the hearing range of fish and mammals. Pulsed, abrupt noise signatures from abrupt changes in vessel speed and direction have been shown to have greater impacts on fish than continuous noise levels.

Docking activities are expected to generate pulsed signatures that could result in avoidance responses by fish and mammals in the vicinity of the dock. The effect of these responses on the long-term viability of fish and mammal populations along eastern Maury Island cannot be predicted with certainty; however, it is assumed that it would be negligible.

Herring are sensitive to noise, and evidence suggests that pre-spawning and post-spawning life history stages are most sensitive. The expansion of mining operations would substantially increase vessel traffic in the vicinity of Maury Island. Depending on the travel route and destination of the barges, noise levels could increase within the pre-spawning holding area or post-spawning feeding grounds, affecting spawning success and feeding success, respectively. Tugboat maneuvers at the dock would generate noise signatures with abrupt changes in frequency and intensity that are more likely to disrupt fish than continuous noise. Therefore, if herring spawn in the study area, noise levels could disrupt spawning activities. If spawning were limited to Quartermaster Harbor, noise levels could still affect herring in the northeast portion of the pre-spawning holding area.

4.2.2.2 Chronic Exposure to Chemical Contaminants

Occasional accidental spills and leaks of fuel, lubricating oil, and hydraulic oil in the vicinity of the dock could release petroleum hydrocarbons into receiving waters. It is likely that in the nearshore study area, which is open and exposed to wave action, longshore currents, and tidal advection, small inputs of petroleum hydrocarbons would be quickly advected from the site and diluted. Impacts on aquatic resources resulting from occasional small quantity releases of petroleum hydrocarbons are assumed to be negligible.

4.2.2.3 Propeller Wash

The maximum bottom current speed generated by a tugboat propeller in 6 m (20 ft) of water was estimated at 26 cm/s (10 in/s). While this velocity can resuspend fine sand and silt fractions, it is not likely to resuspend the coarser grain sizes dominating the study area. The organic matter within the upper boundary of substrate could also be resuspended. This is often a food source for benthic organisms. However, the impact of propeller wash on the benthic population within the study area was estimated as negligible because benthic organisms are assumed to relocate to areas with sufficient organic matter for food. Additionally, the influence of overlying vegetation, mucus tubes, etc. may decrease the actual amount of resuspension by protecting the benthic boundary layer and by consolidating grains. The impact on the vegetative community was also estimated as negligible. Eelgrass has been shown to survive in current speeds from 1.5 to 2 m/s (10-13 ft/s) (Phillips 1984; Fonseca et al. 1983). This is approximately two orders of magnitude greater than the current speed generated by the propeller. Macroalgae are also predicted to withstand currents of 26 cm/s (10 in/s), even if the velocity accelerated rapidly, which would be characteristic of propeller wash. Fish and marine mammals are predicted to avoid the propeller area, and therefore, impact to these populations is also estimated as negligible.

4.2.2.4 Light Shading

The estimated population impact of light shading by barges on eelgrass and macroalgae was predicted to be moderate. The extent of the shade footprint could reach currently distributed eelgrass patches as well as the macroalgae within the barge vicinity. Dock shading has been shown to change the vegetative community by favoring deeper-water species more tolerant of low-light conditions (EVS 1999a; Simenstad et al. 1997). Shading could also prevent colonization of sandy substrate by eelgrass. Individual shoots have been identified in the region estimated to be shaded by the barge. If the shoots are indicative of colonization processes, decreased light conditions may prevent further colonization. Overall, the spatial distribution of vegetation types around the barge-loading area could be altered, and, therefore, a moderate impact is estimated. Impacts on fish and marine mammals are estimated as negligible because the shaded area is not considered critical habitat and because the mobility of these organisms enables them to find other vegetated patches and avoid shaded environments.

4.2.2.5 Night Lighting

The estimated population impact on various fish species from night lighting is estimated as negligible. Because the area around the dock is not considered critical habitat for any fish species, fish that would be disturbed by artificial night lighting are predicted to leave the area. Abrupt changes in lighting conditions (turning lights on and off during the night) would be more likely to disturb local fish as compared to gradual changes in light levels. This is because ambient conditions influence lighting effects (Simenstad et al. 1999). Mitigation for localized impacts could include a gradual artificial lighting schedule and possibly low-lighting conditions when barges were not being loaded at night.

4.2.2.6 Gravel Spills

Gravel spills are estimated to moderately affect both the benthic and vegetative communities. A large, catastrophic spill comprised primarily of gravel and sand would smother benthos and vegetation within the spill footprint. Although the benthic community could recolonize the area, the short-term effect would be the mortality of benthos. If the spill were to occur over a vegetated patch, it would likely affect the spatial distribution of vegetation in the study area. Eelgrass is found in sandy substrate but is less likely to colonize a gravel area. A gravel spill could change the area from an eelgrass bed to one dominated by periphyton and algae.

Recolonization of a gravel spill area by benthic organisms would be expected to occur. Therefore, fish should be able to feed in the area, and the diversity of prey organisms could even increase because of increased substrate diversity. Marine mammals do not feed exclusively in the region and do not feed on benthos. Therefore, both fish and marine mammal populations would be expected to experience negligible impacts from gravel spills.

5.0
REFERENCES

AES. 1998. Existing conditions, impacts, and mitigations for marine fisheries. Maury Island pit barge loading facility, King County, Washington. Prepared for Lone Star Northwest, Inc. Prepared by Associated Earth Sciences, Inc., Kirkland, WA.

Banner, A. and M. Hyatt. 1973. Effects of noise on eggs and larvae of two estuarine fishes. Trans. Amer. Fish. Soc. 1:134-136.

Bargmann, G.G. 1984. Recreational diving in the State of Washington and the associated harvest of food fish and shellfish. Technical Report No. 82. Washington Department of Fisheries, Olympia, WA.

Blaxter, J.S., J.B. Gray, and E.J. Denton. 1981. Sound and startle responses in herring shoals. J. Mar. Biol. Ass. U.K. 61:851-869.

Blaxter, J.S. and R.S. Batty. 1985. The development of startle responses in herring larvae. J. Mar. Biol. Ass. U.K. 65:737-750.

Brett, J.R. and M.A. Ali. 1958. Some observations on the structure and photomechanical responses of the Pacific salmon retina. J. Fish. Res. Board Can. 15:815-829. In: Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of State of Knowledge. C.A. Simenstad, B.J. Nightingale, R.M. Thom, and D.K. Shreffler (eds). Research Report WA-RD 472.1. prepared for Washington State Transportation Commission, Department of Transportation, Olympia, Washington, June 1999.

Buck, B.M. and D.A. Chalfant. 1972. Deep water narrowband radiated noise measurement of merchant ships. Delco TR72-28. Report From Delco Electronics Santa Barbara, CA, for U.S. Navy Office of Naval Research., Arlington, VA. 30 pp. In: Marine mammals and noise. W.J. Richardson, C.R. Greene Jr., C.I Malme, and D.H. Thomson (eds). Academic Press, San Diego, CA.

Burdick, D.M. and F.T. Short. 1998. Dock design with the environment in mind: minimizing dock impacts to eelgrass habitats. An interactive CD-ROM published by the University of New Hampshire, Durham, NH.

Calambokidis, J. 1999. Personal communication (telephone conversation with J. Haddad, EVS Environment Consultants, Seattle, WA, on November 11, 1999, regarding marine mammals in lower Puget Sound). Senior Research Biologist, Cascadia Research, Olympia, WA.

Carls, M.G., S.D. Rice, and J.E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring *(Clupea pallasi).* Environ. Toxicol. Chem. 18 (3):481-493.

Diner, K. and J. Masse. 1987. Fish school behavior during echo survey observed by acoustic devices. ICES C.M. 1987/B:30, 41 pp.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America from the Gulf of Alaska to Baja California. Houghton Mifflin Co, Boston, MA.

Evans-Hamilton and D.R. Systems, Inc. 1987. Puget Sound Environmental Atlas. Prepared for U.S. Environmental Protection Agency, 1987-1992. Evans-Hamilton, Seattle, WA.

EVS. 1999a. Cherry Point screening level ecological risk assessment. Prepared for the State of Washington Department of Natural Resources, Olympia, WA. EVS Environment Consultants, Inc., Seattle, WA.

EVS. 1999b. Maury Island gravel mining project technical memorandum: Literature review for nearshore impact assessment. Prepared for Pacific Groundwater Group, Seattle, WA. EVS Environment Consultants, Inc., Seattle WA.

FAO. 1970. Report on a meeting for consultations on underwater noise. Rome, Italy, 17-19 Dec. 1968. FAO Fish. Rep 76. 32 pp.

Feist, B.E. 1991. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. Master of Science Thesis. University of Washington, Seattle, WA.

Fonseca, M.S., W.J. Kenworth, and G. W. Thayer. 1998. Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters. NOAA Coastal Ocean Program Decision Analysis Series No. 12. NOAA Coastal Ocean Office, Silver Spring, MD. 222 pp.

Fonseca, M.S., J.C. Zieman, G.W. Thayer, and J.S. Fisher. 1983. The role of current velocity in structuring eelgrass (*Zostera marina* L.) meadows. Est. Coastal Shelf Sci. 17:367-380.

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. John Wiley and Sons, New York, NY. 430 pp.

Fresh, K.L., B. Williams and D. Pentilla. 1995. Overwater structures and impacts on eelgrass (*Zostera marina*) in Puget Sound. pp 537-543. In: Puget Sound Water

Quality Authority, Puget Sound Research '95: Proceedings of conference held from January 12-14, 1995, in Bellevue, WA. Puget Sound Water Quality Authority, Olympia, WA.

Guza, R.T. and D.L. Inman. 1975. Edge waves and beach cusps. Journal of Geophysical Research 80: 2997-3012.

Hanggi, E.B., and R.J. Schusterman. 1994. Underwater acoustic displays and individual variation in male harbour seals, *Phoca vitulina*. Animal Beh. 48:1275-1283.

Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Ottawa, Ontario.

Hawkins, A.D. 1993. Underwater sound and fish behavior. P. 126-16. In: T.J. Pitcher (ed.), Behavior of teleost fishes. 2nd edition. Chapman and Hall.

Hawkins, A.D. and A.D.F. Johnstone. 1978. The hearing of the Atlantic salmon, *Salmo salar*. J. Fish Biol. 13:655-673.

Heintz, R.A., J.W. Short, and S.D. Rice. 1999. Sensitivity of fish embryos to weathered crude oil: Part II. Increased mortality of pink salmon *(Oncorhynchus gorbuscha)* embryos incubating downstream from weathered Exxon Valdez crude oil. Environ. Toxicol. Chem. 18(3):494-503.

Jewett, S.C. and T.A. Dean. 1997. Exxon Valdez oil spill restoration project final report: The effects of the Exxon Valdez oil spill on eelgrass communities in Prince William Sound, Alaska, 1990-1995. Restoration project 95106, final report, May 1997. Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, AK.

Jones & Stokes and AR. 1999. Eelgrass/macroalgae survey report. Lone Star Gravel Mine. Maury Island, Washington. August 31. (JSA 98-306-001). Prepared for King County Department of Development and Environmental Services, Renton, WA. Prepared by Jones & Stokes Associates, Inc. in association with Aquatic Research, Olympia, WA.

Jones & Stokes, Terra Associates, and M.R. Stearns. 1999. Draft environmental impact statement (DEIS). Maury Island Lone Star Gravel Mine. Prepared for King County Department of Development and Environmental Services, Renton, WA. Jones & Stokes Associates, Inc., Terra Associates, Inc., and M.R. Stearns Planning and Design, Bellevue, WA.

Kastak, D. and R.J. Schesterman. 1998. Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise, and ecology. J. Acoust. Soc. Am. 103(4):2216-2228.

Kieser, R., B.M. Leaman, P.K. Withler, and R.D. Stanley. 1992. W.E. RICKER and EASTWARD HO cruise to study the effect of trawling on rockfish behavior, October 15-27, 1990. Can. Manuscr. Rep. Fish. Aquat. Sci. 1261. 84 pp.

Knudsen, F.R., P.S. Enger, and O. Sand. 1994. Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, *Salmo salar*. J. Fish Biol. 45:227-233.

Knudsen, F.R., C.B. Schreck, S.M. Knapp, P.S. Enger, and O. Sand. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmon. J. Fish Biol. 51:824-829.

Komar, P.D. 1998. Beach processes and sedimentation. 2nd edition. Prentice-Hall, Inc., Upper Saddle River, NJ.

Lee, R.E. 1989. Phycology. 2nd edition. Cambridge University Press, New York, NY.

Lemberg, N.A., M.F. O'Toole, D.E. Penttila, and K.C. Stick. 1997. Washington Department of Fish and Wildlife, 1996 forage fish stock status report. Stock Status Report No. 98-1. Washington Department of Fish and Wildlife. Olympia, WA.

Lüning, K. 1981. Light. In: The biology of seaweeds. (C.S. Lobban and M.J. Wynne, eds). pp 326-355. University of California Press, Berkeley, CA.

Malme, C.I., P.R. Miles, G.S. Miller, W.J. Richardson, and D.G. Roseneau. 1989. Analysis and ranking of the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska. OCS/MMS-89/0006. 307 pp.

Mathews, S.B., and M.W. Barker. 1983. Movements of rockfish tagged in northern Puget Sound. Fish. Bull. 81(4):916-922.

Maynard, S.T. 1998. Bottom shear stress from propeller jets. Conference proceedings - Ports '98, Long Beach California, M.A. Kraman (ed.), American Society of Civil Engineers.

Meyer, J.H., T.A. Pierce, and S.B. Pathan. 1980. Distribution and food habits of juvenile salmonids in the Duwamish estuary, Washington. FAO Report. U.S. Fish and Wildlife Service, Olympia, WA.

Miles, P.R., C.I. Malme, and W.J. Richardson. 1987. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. BBN Rep. 6509; OCS Study MMS 87-0084. Report from BBN Labs Inc., Cambridge, MA, and LGL Ltd., King City, Ont., for U.S. Minerals

Manage. Service, Anchorage, AK. pp. 341. In: Marine mammals and noise. W.J. Richardson, C.R. Greene Jr., C.I Malme, and D.H. Thomson (eds). NTIS PB88-158498. Academic Press, San Diego, CA.

Mitson, R.B. (ed). 1995. Underwater Noise of Research Vessels: Review and Recommendations. Cooperative Research Report No. 209. International Council for the Exploration of the Sea, Copenhagen, Denmark.

Miyamoto, J., T. Deming, and D. Thayer. 1980. Estuarine residency and habitat utilization by juvenile anadromous salmonids within Commencement Bay, Tacoma, Washington. Technical Report No. 80-1. Puyallup Tribal Fisheries Division, Tacoma, WA.

Mohr, H. 1964. Reactions of herring to fishing gear reveled by echo-sounding. In: Modern Fishing Gear of the World. H. Kristjonsson (ed.). Fishing News (Books) Ltd. 2:253-257.

Moore, H.L. and H.W. Newman. 1956. Effects of sound waves on young salmon. U.S. Fish and Wildlife Service, Spec. Sci Rep. Fish. 172:1-19.

Nikolaev, A.S. 1982. Migration of adult pink salmon in Debroe Nacholo Bay. J. Ichthyol. 22(5):143-152.

Oliver, J.S. and P.N. Slattery. 1976. Effects of dredging and disposal on some benthos at Monterey Bay, California. Prepared for U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir VA. 83 pp.

Olsen, K. 1981. The significance of fish behavior in the evaluation of hydroacoustic survey data. Coun. Meet. Int. Coun. Explor. Sea (B:22):1-25. (Mimeo.)

Olsen, K., et al. 1983. Observed fish reactions to a surveying vessel with special reference to herring, cod, capelin and polar fish. In: O. Nakken and S.C. Venema. Symp. on Fisheries Acoustics, Bergen, Norway. FAO Fish Rep 300:131-138.

Olson, A.M., S. Visconty, B. Witherspoon III, K. Sweeny, R.M. Thom, and D.K. Shreffler. 1997. Light environment and eelgrass shading around three WSDOT ferry terminals. pp 71-101. In: Simenstad, C.A., R.M. Thom, and A.M. Olsen (eds). Mitigation between regional transportation needs and preservation of eelgrass beds, Volume. 1. Research Report WA-RD 421.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA.

O'Toole, M. 1999. Personal communication (telephone conversation with J. Starkes, EVS Environment Consultants, Inc., Seattle, WA, on April 6, 1999). Fisheries biologist, Washington State Department of Fish and Wildlife, Marine Resources Division, LaConner, WA.

Palsson, W.A. 1990. Pacific cod (*Gadus macrocephalus*) in Puget Sound and adjacent waters: biology and stock assessment. Technical Report No. 112 Washington Department of Fisheries, Olympia, WA.

Palsson, W.A., J.C. Hoeman, G.G. Bargmann, and D.E. Day. 1997. State of Washington, 1995 status of Puget Sound bottomfish stocks (revised). Report No. MRD97-03. Washington Department of Fish and Wildlife, Olympia, WA.

Pearson, W.H., J.R. Skalski, and C.I. Malme. 1992. Effects of sound from a geophysical survey device on behavior of captive rockfish (*Sebastes* spp.). Can. J. Fish Aquat. Sci 49:1343-1356.

Protasov, V.R. 1970. Vision and near orientation of fish. Israel program for scientific translations, Jerusalem. pp.175. In: Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of state of knowledge. Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. (eds). Research Report WA-RD 472.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA, June 1999.

Puget Sound Estuary Program. 1992. The 1992 Puget Sound environmental atlas update. Prepared for Puget Sound Estuary Program by Puget Sound Water Quality Authority and Department of Natural Resources, Division of Aquatic Lands, Seattle, WA

Reiman, A.J., and J.M. Terhune. 1993. The maximum range of vocal communication in air between a harbor seal (*Phoca vitulina*) pup and its mother. Mar. Mamm. Sci 9(2):182-189.

Rice, S.D., A. Moles, and J.F. Karinen. 1979. Sensitivity of 19 Alaska marine species to Cook Inlet crude oil and No. 2 fuel oil. In: Proceedings of the 1979 Oil Spill Conference (Prevention, Behavior, Control, Cleanup), March 19-21, 1979, Los Angeles, CA. American Petroleum Institute, Washington, DC. pp. 549-554.

Rice, S.D., R.B. Spies, D.A. Wolfe, and B.A. Wright. 1996. Proceedings of the Exxon Valdez oil spill symposium. American Fisheries Society Symposium 18, held at Anchorage Alaska, 2-5 February 1993. American Fisheries Society, Bethesda, MD.

Richardson, J.W., C.R. Green, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, New York, NY.

Schreffler, D.K. and R.A. Moursund. 1999. Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines. Phase II: Field studies at Port Townsend Ferry Terminal. Washington State Transportation Commission, Department of Transportation, Olympia, WA.

Schusterman, R.J., R.F. Balliet, and J. Nixon. 1972. Underwater audiogram of the California sea lion by the conditioned vocalization technique. J. Exp. Anal. Behav. 17:339-350.

Schwarz, A.L. and G.L. Greer. 1984. Responses of Pacific herring, *Clupea harengus pallasi*, to some underwater sounds. Can. J. Fish. Aquat. Sci. 41:1183-1192.

Shepard, M.F. 1981. Status and review of the knowledge pertaining to the estuarine habitat requirements and life history of chum and chinook salmon juveniles in Puget Sound. Final report. Washington Cooperative Fisheries Unit, University of Washington, Seattle, WA.

Simenstad, C.A., R.M. Thom, and A.M. Olson. 1997. Mitigation between regional transportation needs and preservation of eelgrass beds (Volume I). Final report prepared for Washington State Transportation Commission, Department of Transportation. WA-RD 421.1.

Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. 1999. Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of state of knowledge. Research Report WA-RD 472.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA.

Sizemore, B., A. Bradbury, and L. MacGregor. 1998. State of Washington 1998 geoduck atlas. Atlas of major geoduck tracts of Puget Sound. Washington Department of Fish and Wildlife. Olympia, WA.

Skalski, J.R., W.H. Pearson, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes* spp.). Can. J. Fish. Aquat. Sci 49:1357-1365.

Stober, Q.T. 1969. Underwater noise spectra, fish sounds and response to low frequencies of cutthroat trout (*Salmo clarki*) with reference to orientation and homing in Yellowstone Lake. Trans. Am. Fish Soc. 4:652-663.

Summers, R. 1999a. Personal communication (facsimile from Ronald E. Summers, General Manager Aggregates, to D. Garland, Department of Ecology, Bellevue, WA, Oct. 19, 1999, regarding changes in basic dock parameters; tugboat specifications; and barge specifications). Lone Star Northwest, Inc., Seattle, WA

Summers, R. 1999b. Personal communication (telephone call from Ronald E. Summers, General Manager Aggregates, to J. Haddad, environmental scientist, EVS Consultants, November 29, 1999, regarding potential for spillage of full loads of gravel and potential for small continuous spillage at the dock). Lone Star Northwest, Inc., Seattle, WA

Thom, R.M., and D.K. Shreffler. 1996. Eelgrass meadows near ferry terminals in Puget Sound. Characterization of assemblages and mitigation impacts. Battelle Marine Science Laboratory, Sequim, WA. In: Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of state of knowledge. Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. (eds). Research Report WA-RD 472.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA, June 1999.

Terhune, J.M., G.W. Friars, J.K. Bailey, and F.M. O'Flynn. 1990. Noise levels may influence Atlantic salmon smolting rates in tanks. Brief Communications. J. Fish Biol. 37:185-187.

USCG, API, and USEPA. 1993. Proceedings. 1993 International oil spill conference (prevention, preparedness, response). March 29-April 1, 1993, Tampa, FL. Sponsored by U.S. Coast Guard, American Petroleum Institute, and U.S. Environmental Protection Agency. American Petroleum Institute publication No. 4580. Port City Press, Baltimore, MD. 898 pp.

USEPA. 1975. Noise emission standards for construction equipment, background document for portable air compressors. EPA 550/9-76-004. U.S. Environmental Protection Agency, Washington, DC.

USEPA and ACOE. 1998. Evaluation of dredged material proposed for discharge in waters of the U.S. - testing manual. Inland Testing Manual. EPA-823-B-98-004 U.S. Environmental Protection Agency, Office of Water, Washington, DC, and U.S. Army Corps of Engineers, Washington, DC.

VanDerwalker, J.G. 1967. Response of salmonids to low frequency sound. pp. 45-58. Im: Marine Bio-Acoustics, Volume 2 (W.N. Tavolga, ed. Pergamon Press, Oxford.

WDFW. 2000. Personal communication (letter to D. Garland, Washington Department of Ecology dated February 15, 2000, comment letter regarding the Maury Island Gravel Mining Project; draft February 2000 impact assessment report prepared by EVS Environment Consultants). P. Erstad, Washington Department of Fish and Wildlife, Region 4 Office, Mill Creek, WA.

WDFW. WDFW Field Reports. Unpublished annual field reports. Herring spawn surveys, Quartermaster Harbor, WA.

Wells, P.G., J.N. Butler, and J.S. Hughes (eds). 1995. Exxon Valdez oil spill: Fate and effects in Alaskan waters. STP 1219. ASTM Publication Code No. 04-012190-16. American Society for Testing and Materials, Philadelphia, PA.

Wenz, G.M. 1962. Acoustic ambient noise in the ocean: spectra and sources. J. Acoust. Soc. Am. 34(12):1936-1956.

APPENDIX A

Interpretation of Maury Island Sediment Profile Images

Table A-1. Maury Island SPI

STATION	GRAIN SIZE MAJOR MODE	EELGRASS?	COMMENT
1	Medium Sand	no	Well-sorted medium to fine sands with low shear strength
2	Fine Sand	no	Small sand ripples present
3	Fine Sand	no	1 cm penetration, small twigs/debris on sed. surface
4	Medium Sand	no	Rippled sand bottom
5	Medium Sand	no	Rippled sand bottom, shallow water, biogenic BR
6	Fine Sand	no	8-10 cm layer of wood chips, twigs; sea lettuce present
7	Very Fine Sand	no	Shallow penetration, large starfish, some rocks, brittle star
8	Very Fine Sand	no	Large starfish, poorly sorted, fine sand, shell hash & pebbles, twigs, land-based debris
9	Fine Sand	no	Some evidence of fine-grained (silt-clay) present as minor mode
10	Very Fine Sand	YES	Errant macrofaunal burrow at depth
11	Fine Sand	YES	Eelgrass & sea lettuce present, high zooplankton density above boundary layer
12	Fine Sand	no	Sea lettuce & twigs on surface, and leaf litter mixed in sand at depth
13	Fine Sand	no	Shallow penetration, sea lettuce, twigs on surface
14	Very Fine Sand	no	Armored shell lag surface with twigs and some gravel pieces
15	Very Fine Sand	no	Large pieces of wood on sediment surface
16	IND	no	Hard bottom - large rock, macrophytes
17	Pebble/cobble	no	Hard bottom - gravel, barnacles & kelp
18	Medium Sand	no	15 cm penetration - dilated sands -- probably bivalve bed
19	Gravel layer over Very Fine Sand	no	Gravel layer on top of fine sands, barnacles/bryozoans on rocks
20	Gravel layer over Very Fine Sand	no	Pea gravel layer on top of fine sands
21	IND	no	Gravel, mussels, & shell lag with starfish feeding on bivalves
22	Fine Sand	YES	Sea lettuce present
23	Very Fine Sand	no	Hermit crab, squid eggs, Ulva, dead eelgrass in sand
24	Fine Sand	no	Ornamented tubes projecting out of surface (Diopatra?)
25	IND	no	Thick shell layer on surface
26	IND	no	Poorly sorted gravel, wood, & fine sand -- no

Table A-1, continued

STATION	GRAIN SIZE MAJOR MODE	EELGRASS?	COMMENT
			penetration
27	Very Fine Sand	YES	Well-sorted fine sand with dense eelgrass
28	Very Fine Sand	YES	Piece of rusting metal on surface, sparse eelgrass in background
29	Fine Sand	no	Well-sorted fine sand
30	Fine Sand	no	Well-sorted fine sand
31	Fine Sand	no	Well-sorted fine sand
32	Medium Sand	no	Medium sand, leaf litter & Ulva on surface, sands dilated
33	Gravel layer over Very Fine Sand	no	Gravel & twigs on surface
34	Very Fine Sand	no	Low penetration; tubes projecting above S/W interface
35	Very Fine Sand	YES	Dense eelgrass
36	IND	YES	Dense eelgrass, sea lettuce & leaf litter
37	Very Fine Sand	possibly	Dilated sands, sparse eelgrass possibly in background
38	Very Fine Sand	no	Some gravel with shells & sea lettuce on surface
39	Very Fine Sand	no	Mono-layer of gravel and shell valves - gravel looks like fairly recent deposit

APPENDIX B

STFATE Modeling of Sand and Gravel Spill

STFATE MODELING OF SAND AND GRAVEL SPILL

A computer program, STFATE, was used to model the mounding and spreading of material that would be released if a barge load of material spilled. STFATE is one of the models in the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) suite of computer programs for investigating impacts of dredging and dredged material disposal (Appendix C of USEPA/ACOE 1998). For this application, the event was modeled as a disposal event lasting 5 seconds for release of the entire barge load of material. As discussed elsewhere, there are some limitations in the applicability of STFATE to modeling a spill of dry sand and gravel into a nearshore area. These limitations are:

- STFATE was designed to be applied to dredged material, which because of its water content acts as a fluid when released from a barge into the sea; in contrast, a spill of dry sand and gravel has a lower water content
- STFATE does not model the larger-size (cobble) material that may be included in a load of sand and gravel
- Because of additional effort that would be required to model the fate of material onto a sloping seabed, the STFATE model was set up for a spill onto a level seabed

The model grid was a rectangle 550 m (1,800 ft) long and 180 m (600 ft) wide, and the grid cells were 15 m (50 ft) long and 6 m (20 ft) wide. For simplification in applying the model, the depth was assumed a constant 9 m (30 ft) over the entire grid.

STFATE incorporates site-specific oceanographic data into its simulation of movement and dispersion of discharged material. Because no direct current measurements were available for the area of operations, current speed over the majority of the water column was taken as approximately the maximum estimated tidal current obtained from a monitoring station in Colvos Passage on the west side of Vashon Island. The direction of the current was chosen to be aligned with the longer dimension of the model grid. Speed near the bottom was reduced by a factor of 6 to address bottom boundary layer effects. Choosing the maximum speed yields a scenario in which movement and dispersion can be expected to be greatest. A two-layer density profile reflecting typical values was also chosen, although this particular application of STFATE is not sensitive to the magnitude of the vertical density profile. Table B-1 lists depth, current speed, water column density, and bottom roughness height used for the modeling.

Table B-1. Input data for STFATE application to a gravel barge spill scenario

PARAMETER (Units)	VALUE	SOURCE
Water depth (ft)	30	Bathymetric survey
Roughness height (ft)	0.005	STFATE guidance manual[a]
Slope (degrees)	0	default
Density profile (g/cc)	1.014 at 0 ft 1.018 at 30 ft	representative values for the area
Current profile (fps)	3 at 0 ft 3 at 25 ft 0.5 at 29 ft	Max. tidal current, bottom boundary reduction
Length of barge (ft)	330	R. Summers, pers. comm. 1999a
Width of barge (ft)	80	R. Summers, pers. comm. 1999a
Pre-disposal draft of barge (ft)	16.5	R. Summers, pers. comm. 1999a
Post-disposal draft of barge (ft)	4.5	R. Summers, pers. comm. 1999a
Time required for dumping (s)	5	Assumption for modeling
Vessel velocity (fps)	1	R. Summers, pers. comm. 1999a
Volume of dredged material (cy)	7,500	R. Summers, pers. comm. 1999a
Types of material	silt, med. sand, gravel, void[b]	
Volume fraction for each type	0.04, 0.14, 0.42, 0.40	R. Summers, pers. comm.

[a] USEPA/ACOE 1998

[b] In the formulation of STFATE, void space is assumed to be filled by water.

Three different sizes of barges may be used to transport material: 2,000 ton, 4,000 ton, and 10,000 ton. To address a maximum-impact scenario, the largest barge size was chosen. Table B-1 also lists details of the barge and the discharge operation used in the model.

To address the differences between using STFATE to simulate the discharge of dry terrestrial material rather than wet, dredged material, several assumptions were made in characterizing the material. The typical size composition of the dry material is 7 percent material finer than 62.5 microns in size, 23 percent fine to medium sand, 50 percent medium sand to gravel, and 20 percent greater than approximately 5 mm in size (R. Summers, pers. comm. 1999b). The moisture content of the dry material, typically 5 percent, was ignored. STFATE requires grain-size information in terms of volume fraction rather than weight percent. The size fractions chosen to represent the material in STFATE for modeling purposes were silt, medium sand, and gravel. Particle settling speeds were chosen from the range offered by STFATE for each size class.

The estimated bulk density of the material is approximately 1,600 kg/cu m (2,700 lb per cubic yard [cy]), which translates into approximately 1.6 gm/cm^3 (Summers pers. comm.

1999b). The approximate density of the solid material is 2.7 gm/cm^3. As a rough approximation, the volume fraction of each model size category was assumed equal to the weight percent. To adjust the volume fraction of the combined size categories to yield a bulk density of 1.6 gm/cm^3 (i.e. 2,700 lb/cy), the weight percent of each was multiplied by 1.6/2.7. Void space in the combined material was then assumed to provide the additional volume necessary for 2,700 lb of combined material to occupy a total volume of 1 cy. Table B-1 lists the volume fractions of the material determined in this way.

MODEL RESULTS

Figure B-1 shows the thickness contours predicted by the model. The shape of the contours reflects an inherent feature of STFATE, namely that the program assumes discharge from a point source. Thus, the contours near the specified discharge point are nearly circular and concentric. If STFATE accounted for the shape of the barge, the contours near the discharge point would be elongated and oriented similar to the barge. For reference, if the barge were circular and had the same area as a 100 m × 24 m (330 ft × 80-ft) shape, the outer edge would nearly coincide with the 0.6-m (2.0-ft) thickness contour.

The model predicted a maximum thickness of 2 m (3.5 ft) of material at the discharge point specified in the simulation. The gravel fraction accounted for approximately 80 percent of this thickness. The maximum contribution of silt to total thickness is less than 0.02 ft over the entire simulation grid. In the downstream (along flow) direction, the thickness decreases to approximately 21 cm (0.7 ft) at a distance of 61 m (200 ft) and 6 cm (0.2 ft) at a distance of 91 m (300 ft) from the discharge point. Sand provides the largest contribution to thickness farther than approximately 61 m (200 ft) downstream of the discharge point, which is a reflection of the influence of advection. In the direction perpendicular to the flow, the thickness decreases to approximately 0.3 ft at a distance of 200 ft from the discharge point.

It is likely that the actual footprint from a spill would be smaller than predicted by STFATE. One reason is that predictions by STFATE incorporate a dynamic spreading algorithm that assumes gravitational forcing of sediment that is already fluidized in the barge. Discharged dry material would not be expected to spread in the same way because the frictional resistance of the dry material is greater than that of the discharged dense sediment and water mixture. Dry material would likely spread less upon encountering the bottom. It is also likely that much of the material contained in a barge that sank would remain confined by the barge rather than all being released to the water column.

After a spill event, natural processes will continue to redistribute the sand and finer material fractions just as those same processes work the existing bottom sediments of

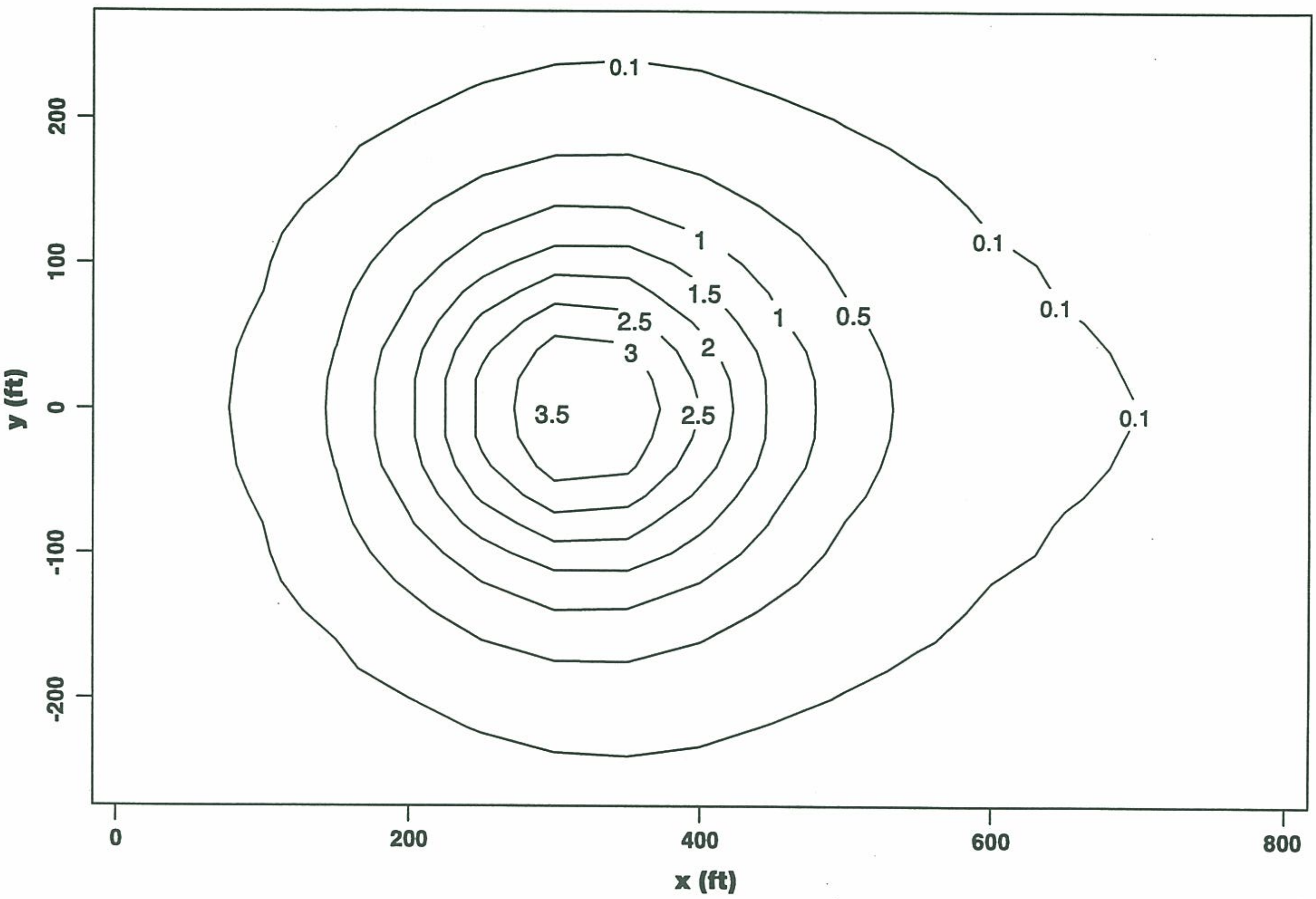


Figure B-1. Predicted footprint area and height of spill (units in feet) of coarse sand and gravel from full loaded, 10,0000-ton barge

comparable size. The coarser fractions that include granules, pebbles, cobbles and larger rocks will remain mounded at the spill site and may facilitate the retention of finer-grain material in the voids. Thus, little likelihood exists of the mound of coarse material dissipating after it has settled onto the bottom.

To maintain a simple scenario, the effects of sloping bottom were not modeled. Inserting a bottom slope greatly increases the amount of time to set up the model. The effect of a sloping bottom would be to direct spreading preferentially downhill, and the thickness distribution of spilled material would thus be skewed toward thicker values downhill of the discharge point.

According to model results, the most likely source of impact away from the immediate location of the spill will be the fine-to-medium sands that can be advected along in the water column before settling out downstream or be transported along the bottom as bedload. The coarser fractions remain near the discharge point, and the finer fractions (silt, clay) have insufficient volumes to have much effect.