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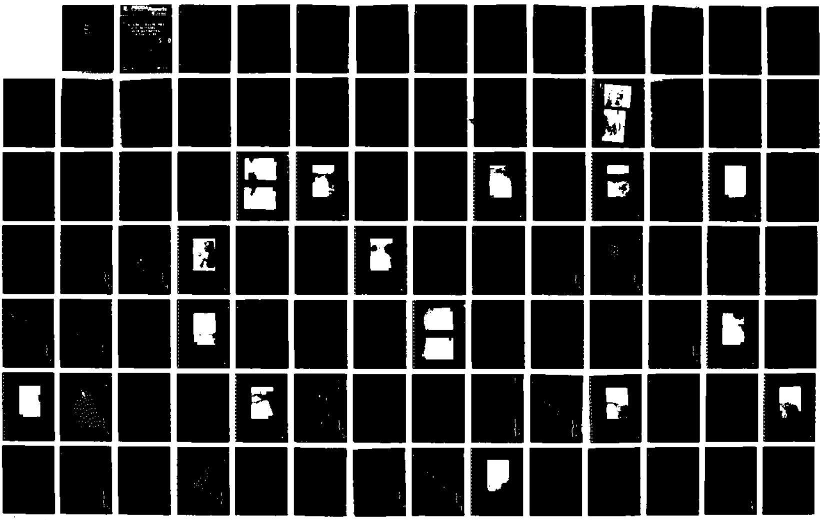

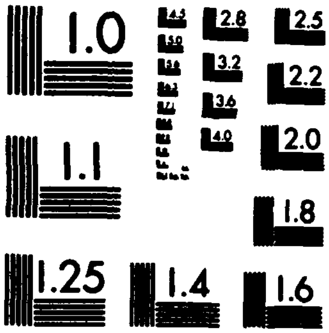

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

US Army Corps of Engineers
Seattle District

PSDDA Reports
Puget Sound Dredged Disposal Analysis

Washington State Dept. of Natural Resources

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CHECKING STUDIES ON ZONES OF SITING FEASIBILITY FOR DREDGED MATERIAL IN PUGET SOUND

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EPA Region 10

ECOLOGY

REPORT

CHECKING STUDIES ON ZONES OF SITING FEASIBILITY FOR DREDGED MATERIAL DISPOSAL IN PUGET SOUND

Submitted to:

U.S. ENVIRONMENTAL PROTECTION AGENCY

Region 10

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Exhibits

* Attached to Principal Copy of Checking Studies Report Only

ACKNOWLEDGEMENTS

Cooper Consultants, Inc. wishes to acknowledge the contributions of the many individuals, organizations and agencies that participated in, guided and supported this effort. Mr. Brian Ross, project monitor for the United States Environmental Protection Agency (EPA) was responsible for overall management and coordination of the many groups and individuals involved. Mr. Frank Urabeck, PSDDA Study Director for the US Army Corps of Engineers (COE), provided valuable technical input and agency perspective. DSWG, composed of members of the supporting agencies*, provided guidance and direction. Without their support, this study could not have been undertaken. The Port of Seattle provided access to and use of their facilities for placement of navigational aids and the Port of Everett provided a boat without which such aids could not have been used in Port Gardner and Saratoga Passage. NORTEC provided sieving trays for preparation of Van Veen grab samples while The Municipality of Metropolitan Seattle (METRO) provided the dual Van Veen grab sampler. Our subconsultants SAIC, SEA-I and Williamson & Associates worked long, hard hours under some very difficult weather conditions and within an extremely tight schedule. Mr. Charlie Eaton, skipper of the RV Kittiwake, provided us with an excellent platform from which to deploy the REMOTS system and Van Veen grab sampler. His knowledge of Puget Sound, navigational skill and experience were a valuable complement to the project staff.

* DSWG Members

Warren Baxter, COE, Chairman

Kevin Anderson, Washington Department of Ecology

David Jamison, Washington Department of Natural Resources

Carl Kassebaum, EPA

PLATES

FIGURES

FIGURES (continued)

TABLES

1.0 INTRODUCTION

Dredged material from adjacent rivers and embayments have been placed in Puget Sound marine waters for nearly a century. ~~In recent years, a~~ concern for the potential impact of these materials on the biological resources of Puget Sound waters (and ultimately on public health) has encouraged the development of a government funded program to address this concern. ~~An integral part of this program is~~ the Puget Sound Dredged Disposal Analysis (PSDDA), an interagency consortium charged with the responsibility of selecting the best approach to dredged material disposal in Puget Sound.

1.1 Puget Sound Dredged Disposal Analysis (PSDDA).

As a cooperative of federal and state agencies, PSDDA is responsible for developing and implementing an acceptable approach to the disposal of dredged materials into Puget Sound waters. The US Army Corps of Engineers (COE) is the member agency with the lead role in the coordination of PSDDA activities. Other key agency members include the US Environmental Protection Agency (EPA), the Washington State Department of Ecology (DOE) and the Washington State Department of Natural Resources (DNR). The major objectives of PSDDA are to: 1) designate sites for long-term, unconfined, open-water disposal of dredged material in Puget Sound; 2) develop evaluation procedures for determining the suitability of dredged material for unconfined open-water disposal and for confined disposal options; and 3) develop management plans for the disposal sites. The environmental impacts of dredge material disposal at the designated sites and associated evaluation procedures will be addressed in two EISs; the first will cover the Central Sound, the second will cover the North and South Sound. Potential impacts at alternative open-water disposal sites and alternative evaluation procedures will also be assessed.

1.2 Disposal Site Work Group (DSWG).

Guidance for all studies related to disposal site location is provided by the Disposal Site Work Group (DSWG) of the PSDDA. The Work Group is composed of staff members from the principal agencies, in consultation with other invited individuals and thereby represents political, economic and scientific (environmental) concerns and interests. It determines the basis for site locations and studies, approves all work plans, and reviews all work.

1.3 Disposal Site Study Plan.

As developed by DSWG, the plan of study consisted of four steps for siting dredged materials disposal. The first step was to determine Zones of Siting Feasibility (ZSFs) which offered minimal conflict with valuable resources, human health, and present and future uses. The second step was the characterization of the ZSFs through a review of published and unpublished data from previous Puget Sound studies and the conduct of field studies to check existing data for confirmation of the ZSFs. The third step is the selection of preferred and alternative disposal sites within the ZSFs. The fourth step consists of characterization of preferred and alternative sites by assessing existing data and conducting appropriate supplemental field studies.

1.4 Zones of Siting Feasibility (ZSFs).

The ZSFs are areas which have been determined to have the minimum level of conflict practicable with human uses, and are not limited by known biological resources or physical restrictions such as currents, depth, and substrate types. By developing a series of overlay maps which present known characteristics and resources of Puget Sound, DSWG selected broad areas of the Puget Sound waters which had the potential of containing an appropriate unconfined, open-water disposal site. This process identified more than one dozen ZSFs between Elger Bay in Saratoga Passage and Commencement Bay. Many of these ZSFs were eliminated from further consideration by imposing additional evaluation criteria such as limiting haul distance to 10 nautical miles from the potential dredge site and limiting the disposal areas to water depths of between 120 and 600 feet. Six ZSFs were ultimately selected for the Checking Studies to be conducted by Cooper Consultants, Inc. (CCI) between October and December 1985: one in Saratoga Passage, one in Port Gardner Bay, two in Elliott Bay and two in Commencement Bay.

1.5 Checking Studies.

The second step of the DSWG plan of study was to conduct a field checking study of the physical and biological characteristics of the six priority ZSFs. Prior to initiating the field activities, a review of published and unpublished data from previous studies of Puget Sound was completed to aid in the development of a clearer focus for the field program. Two vessel-deployed data acquisition systems were utilized during the field efforts. The SEA-I MANTA ROV System (video and 35mm stereo cameras; side-scan sonar; x-y-z positioning) was deployed to record gross physical and biological characteristics of the substrate along selected transects within the study ZSFs. The SAIC REMOTS Benthic Data Collection System was used to provide sediment profiles at 111 stations within the ZSFs. These profiles characterized grain size, redox potential and several other important attributes of the sediment. A number of 0.1m^2 Van Veen grabs were also taken for ground-truthing at 33 selected REMOTS stations.

1.6 Checking Studies Report.

This report contains a summary of the review of previously collected published and unpublished data on Puget Sound which are relevant to the ZSFs studied, and presents the results of the field checking studies.

2. ENVIRONMENTAL STUDIES REVIEW

As part of the process of evaluating the selected Zones of Siting Feasibility (ZSFs) for use as dredged material disposal sites, a review of existing information which might help characterize these zones was undertaken. This review consisted of an evaluation of published literature as well as unpublished data. The effort was initiated with and guided by discussions with individuals representing city, state and federal agencies, academic institutions and private consulting organizations known to have knowledge of the literature or involvement in ongoing or past studies in Puget Sound and expertise in Puget Sound biology, chemistry and physical oceanography.

Bibliographies from two major sources (Evans Hamilton, 1985 and Chapman et al, 1984; see Appendix A) were surveyed for citations to published literature which might contain information about the ZSFs. Screening of these sources was aided by discussions with the individuals listed in Table 2.1. These persons also helped to suggest other published sources, as well as unpublished data and draft reports, which might be applicable to the ZSFs. A complete listing of the documents and sources considered in the review are listed in Appendix A-2. Several of these sources contained data useful for further characterization of the ZSFs. An annotated bibliography of the sources considered in the review is contained in Appendix A-1. A summary of the review findings is given below.

TABLE 2.1

PERSONAL CONTACTS PROVIDING ASSISTANCE
IN SELECTION OF LITERATURE AND DATA SOURCES

Name	Organization
John Armstrong	EPA Region 10
Herbert Curl	Pacific Marine Env. Lab
Elizabeth Day	Evans Hamilton, Inc.
Libby Goldstein	EVS Consultants, Inc.
Lynn Goodwin	WA Department of Fisheries
Bert Hamner	COE, Seattle District
Robert Harman	Shoreline Community College
John Hughes	National Marine Fish. Service
James Hileman	EPA Region 10
Edward Long	NOAA
John Malek	COE, Seattle District
Donald Malins	NOAA
Robert Matsuda	Seattle METRO
Gary Mauseth	Nortec, Inc.
Bruce McCain	NOAA
Bruce Miller	UW Department of Fisheries
Frederick Nichols	USGS, Menlo Park
Robert Pastorek	Tetra Tech, Inc.
Patrick Romberg	Seattle METRO
David Schuldt	COE, Seattle District
Jerry Stober	UW Fisheries Research Inst.
Ronald Thom	University of Washington
Barry Townes	EPA Region 10

2.1 Elliott Bay

There is a relatively large body of knowledge about Elliott Bay available from past as well as ongoing studies. Much of the available data has been collected in or near the two Elliott Bay ZSFs, although in many cases exact locations by geographic coordinates cannot be determined from published reports. Available information includes data on the following parameters:

- Sediment Chemistry: Including EPA priority pollutants, trace organics, pesticides, trace metals, bioassays, oil and grease, biochemical oxygen demand (BOD), total oraganic carbon (TOC), organic nitrogen.
- Benthic fauna: Including taxomony and community studies relative to sediment type.
- Fish: Including species present, pathology.
- Sediment Physical Characteristics: Including rate of sedimentation, grain size.
- Pollution Sources
- Currents

A major five year study, the Toxicant Pretreatment Planning Study (TPPS) sponsored by The Municipality of Metropolitan Seattle (METRO), involved intensive sampling of water, suspended particulates, benthic organisms and sediments in Elliott Bay for 126 substances, including metals and organic chemicals designated by EPA as priority pollutants. Complete results from the TPPS are contained in a summary report and eight technical reports (Galvin, et al., 1984). Sample locations are well documented and many are located in the two Elliott Bay ZSFs. Results of sample analyses showed generally fine textured sediments with high levels of several priority pollutants in the ZSFs including copper, lead, mercury, HPAH, LPAH, PCBs and DDT. The area around Fourmile Rock dump site was classified in a group (including the Denny Way CSO and Harbor Island areas) as having the highest overall levels of toxicants in the bay. Studies of benthic organisms were concentrated in areas known to be influenced by sewage treatment and CSO outfalls. In the Fourmile Rock area, macrofaunal assemblages corresponded to deep station sediment texture gradients. The number of family groups was relatively high, but the number of taxa and species diversity were low to moderate. Seasonal changes in benthic communities and abundances were evident in many samples, with highest numbers occurring during the dry season when inputs of toxic materials is reduced. One bioassay sample from the Fourmile Rock dredge disposal site showed no biological impacts, although this site was designated for further study. Extensive data and analyses of toxicants and benthos are available in Technical Reports C-1 (Romberg, et al., 1984) and C-2 (Comiskey, et al., 1984) respectively.

In another important study Stober and Chew (1984) began the process of development of a comprehensive and integrated understanding of the marine ecology of Elliott Bay, but the study was terminated after three months of field effort. Samples taken from stations in or near the Elliott Bay ZSFs were used to characterize physical oceanographic processes, water column chemistry, subtidal benthic ecology, fish ecology, marine chemistry and marine toxicology. Stober and Chew found that concentrations of volatile solids, organic nitrogen, BOD, TOC and percentage of water in sediments generally increased with increasing water depth. They also suggest that Elliott Bay is divisible into an inner and an outer bay based on these chemical characteristics. While the outer bay had elevated levels of these constituents, the inner bay (including the E-1 ZSF) had still higher levels. Although the outer bay is generally considered that area near Duwamish Head, in terms of organic enrichment the Fourmile Rock ZSF area showed detectable levels which were somewhat less than the outer bay. It was concluded that while elevated levels of organic materials in the outer bay were probably related to topography, the inner bay was more heavily influenced by slower circulation and greater input of materials from the Duwamish River.

This conclusion seems to be supported by the unpublished work of Harman (and Serwald). Their research shows that the distribution of diatom frustules and foraminifera skeletons in the sediments of the inner bay are more closely related to freshwater environments, while indicators in the outer bay sediments were more consistent with marine environments.

Based on results of bioassay studies, Stober and Chew (1984) found that sediments from the Fourmile Rock dredge disposal site contained a high proportion of toxic materials. Examination of benthic organisms revealed that the greatest number of individuals were found in shallow waters and in the inner bay. However, numbers of species was greater in shallow water and in the outer bay while the inner bay had only 50 to 70 percent of the species found at comparable depths outside the bay. Studies of the water column also suggested a difference between inner and outer bays, with the inner bay being strongly influenced by the Duwamish River. The inner bay was characterized by lower abundances of phytoplankton and zooplankton than the outer bay areas and long residence time for inner bay water.

In the Elliott Bay Toxics Action Program, Tetra Tech (1985), has classified the Fourmile Rock dump site area, as a "high priority interim action" area based on available information regarding sediment chemistry, toxicity bioassays and benthic infaunal community variables. They have recommended that this area should be investigated in terms of stability for future dredge disposal. They described the area as "heterogeneous" with respect to the following characteristics:

- Sediment Chemistry
  - LPAH concentrations high
  - HPAH concentrations high
  - PCB concentrations high
  - Heavy metals (Cu, Pb, Zn) high
  - Arsenic concentrations low
  - TOC concentrations range from 0-2%
- Benthic Communities
  - Modified slightly relative to corresponding communities found in clean areas near Seahurst
  - Limited data prevents determinative conclusions about biological conditions
- Bioassays
  - Amphipod mortality high

Tetra Tech (1985) described sediment chemistry and bioassay conditions in the inner bay ZSF area as significantly above Seahurst reference values, but less than the Fourmile Rock area. No immediate action is prescribed for the inner bay ZSF area.

2.2 Port Gardner

Compared to Elliott Bay, relatively little sampling and synthesis of information have been performed in Port Gardner, particularly in the ZSF. Sampling conducted for the environmental impact study associated with the homeporting of a carrier battle group in Everett was concentrated within inner Everett Harbor. The analysis of dredging alternatives considered the existing DNR dredge disposal site located in the southeast corner of the ZSF as well as the "Deep Delta Site" which borders on the eastern edge of the ZSF. The existing disposal site was characterized as having low current velocity regime. The substrate consisted of sand to sandy silt with a high percentage of clay. Chemical analyses of bottom sediment in this area indicated the site is "less contaminated than Puget Sound background levels." A DNR video surveying the site in 1984 observed a variety of fish as well as invertebrate species including Dungeness crab, shrimp, sea pens and similar deep water organisms. The predominant invertebrates observed were deposit feeders, scavengers or predators. The fact that few suspension feeders were found was attributed to low current velocities. Infaunal diversity was characterized as slightly higher than most areas sampled in the Port Gardner vicinity. The Deep Delta Site had a substrate characterized by sand and silty sand, indicating continual deposition from the Snohomish River. This site also had a significant amount of wood debris, but was otherwise similar to other dredge disposal site.

The Tetra Tech (1985) toxics action plan for Everett Harbor and outer harbor waters speaks to a general lack of data for this area. Limited data available for the disposal site were not adequate to characterize the benthic infaunal communities. It is stated that high levels of toxic substances are probably not a problem in the Everett Harbor and the area may be a depositional zone for the Snohomish River.

2.3 Commencement Bay

Commencement Bay has been the focus of many studies conducted over the past several years by several agencies and academic institutions. Heavy industrial activity including coal transshipment, paper mills, copper smelting, chemical plants and sewage treatment has introduced contaminants into the bay from a variety of sources. The EPA has designated Commencement Bay as a priority Superfund site partly because of the high concentration of toxic chemicals in groundwater adjacent to the Bay. Several studies have reported elevated levels of chemical contaminants in suspended matter, sediments and marine animals collected in the bay, in and near the Priority One and Priority Two ZSFs designated by PSDDA. Most studies have concentrated on the shallower water near the shore and industrialized waterways.

Crecelius, et al. (1985) conducted an investigation of the contamination of sediments in Commencement Bay and related their work to earlier efforts. One sample core from this study was taken from the deepwater dredge disposal site on the boundary between the Priority One and Priority Two ZSFs. This study indicated contamination of sediments by heavy metals, aromatic hydrocarbons (AH) and chlorinated butadienes (CBD) has occurred during the past 80 years. Contaminant concentrations in the open bay were much lower than in the nearby industrial waterways, and toxic industrial waste has apparently not accumulated at the dump site. In general, contaminant concentrations were typical for an industrial harbor. Bay sediments contained smaller concentrations of heavy metals than sediments from central Puget Sound, possibly related to fast tidal currents and dilution by the Puyallup River. Concentrations of AH and CBD were 10 and 100 times higher, respectively, than in non-industrial sediments from outside the central Puget Sound area.

Hileman and Matta (1983) sampled deepwater (100+ feet) bottom sediments from several stations located in the Commencement Bay ZSFs. Their efforts were directed toward organic compounds, pesticides, PCBs, polychlorinated butadienes (PCDDS), metals, phenolics, cyanides and solids. Their report contains detailed maps showing concentrations of each contaminant at each sample station and compares results with other Puget Sound locations. Sediments ranged from sands at the outer limits of the Bay to "extra fine mud" at one point south of Brown's Point which is not in a ZSF. Most sediments were classified as "fine muds". The results of this study are generally in agreement with the findings of Crecelius, et al (1985), with low to relatively high enrichment of many of the organic compounds and metals in the vicinity of the disposal site and surrounding sample sites.

Word, et al. (1984) looked at subtidal benthic ecology for the area between Alki Point and Browns Point as part of the proposed Renton Sewage Treatment Plant Seahurst Baseline Study. Of the many sites they sampled, only two deep (600 feet) stations appear to have been located in the Priority Two ZSF. Data presented for these two stations indicated the area was inhabitated primarily by various polychaete and anthropod species. The northernmost station had relatively high numbers of taxa, while the southernmost was about average in number of taxa for all sampled stations. Sediments taken by grab sampling from these stations were generally sandy silts, with gravel and wood chips in some grabs. Colors ranged from gray-green to drab olive with a light brown surface layer and black coloration on the bottom of the grab present in some samples. There was no noticeable odor in most samples. Molpadids were noted in three of the grabs from this area.

2.4 Saratoga Passage

Little or no work that can be directly related to the Saratoga Passage ZSF is known. Washington Department of Ecology has sampled for many standard water quality parameters at one station located over a mile west of the northwest boundary of the ZSF. Unpublished maps of sites sampled by Harman (1985) suggest that he sampled one or two stations which may be in the Saratoga Passage ZSF, as well as several stations surrounding the Saratoga Passage ZSF sometime during the past several years. Harman's very general summary maps indicate that the ZSF lies within a retention (deposition?) zone influenced by outflow from the Skagit, Stilliguamish and Snohomish Rivers. This area was characterized by grey to green sediments. The species of foraminifera, polychaetes and pelecypods found indicated that there was little to no disturbance or environmental stress. No data were given on sediment grain size or chemistry.

3. FIELD STUDIES

This section describes the methods and materials used in the field sampling effort of the Checking Studies, discusses the parameters analyzed in terms of their general characteristics and use in study site definition and provides details on study results. The field effort was divided into two major tasks with separate data collection packages and support vessels for each.

3.1 Field Sampling Efforts

3.1.1 Navigational Control

Final boundaries for original Priority One ZSFs were set by PSDDA prior to the start of field sampling efforts. Parallel transects were then established at one-quarter mile intervals along the long axis of each ZSF to provide maximum sampling coverage and optimize navigational positioning and tracking.

State plane coordinates and appropriate offsets were determined for each established transect. Support vessel positioning was controlled by either a computer/Motorola Miniranger III or Falcon IV radio ranging system. These systems gave continuous updates of vessel position by reference to landbased transponders with an accuracy of three meters or less. Transponders were placed at known benchmarks and predetermined coordinates were then used to control positioning of the support vessels. In addition to the radio ranging systems, both support vessels also monitored Loran C channels and depth sounders for additional navigation information.

3.1.2 MANTA Operations

The first element of the field effort was characterization of broad scale bottom sediment attributes using sidescan sonar. The MANTA system (Plate 3.1.1), a submersible remote operational vehicle (ROV) owned and operated by SEA-I Research, Ltd. was selected for this effort. MANTA operations

Plate 3.1.1 - MANTA ROV. Shows deployment of vehicle from RV Marysville. Note television camera in upper forward

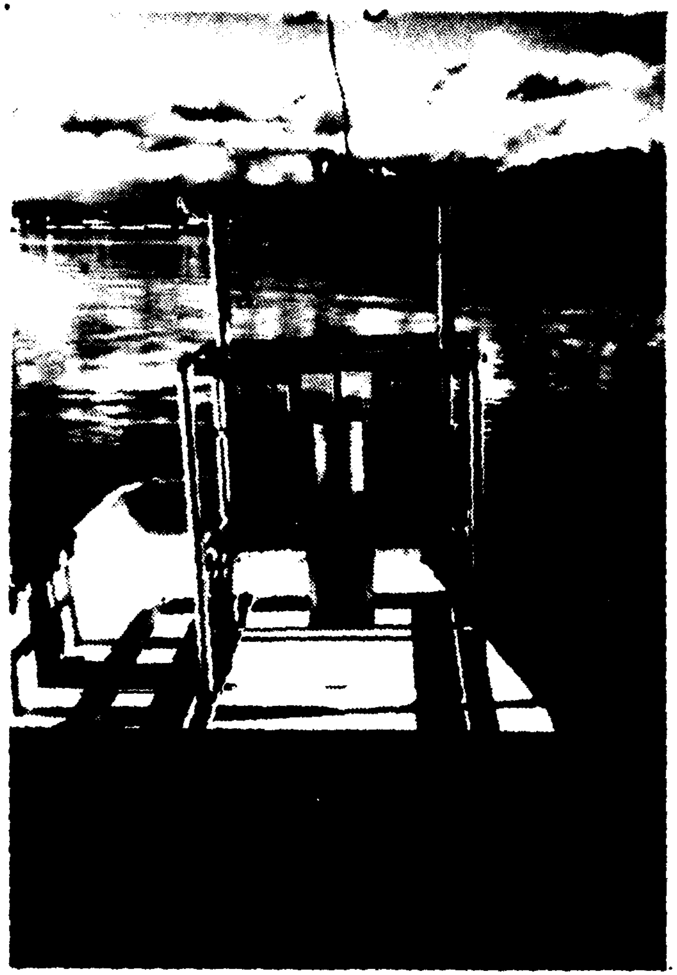


Plate 3.1.2 REMOTS Sediment Profiling Camera. Black area in the center is a shaded view into the prism. The camera is mounted inside the cylinder above the prism.

COOPER CONSULTANTS, INC.

took place between October 27 and November 2, 1985.

Deployed from the RV Marysville, the MANTA ROV carried precise geodedic micronavigation and telemetry systems, a 90 kHz sidescan sonar, a low incident light video camera and a 35mm stereo still camera. Under tow by the RV Marysville, the ROV was "flown" over established transects by computer systems at a selected depth or distance off the bottom. During sidescan operations, the typical off-bottom elevation was 10 meters, producing a sonograph swath of approximately 100 meters to either side of the line of travel. The navigational systems automatically entered "station" markers at 50 meter increments into the data/telemetry record being received from the ROV and onto the resulting sonograph. When visibility conditions permitted, the ROV was lowered to a distance of between 80 and 120cm off-bottom and the video and 35mm stereo still cameras were used for ground truthing of sidescan sonar data and to provide additional visual information about existing substrate characteristics. Additional information on the MANTA system may be found in Appendix B-1.

3.1.3 Remote Environmental Monitoring of the Seafloor (REMOTS System)

The REMOTS sediment profiling camera (Plate 3.1.2) and computer imaging analysis system was included in the study to provide baseline information on gradients of physical and biological characteristics of the bottom sediments. The REMOTS system was deployed from the RV Kittiwake at 121 stations located on or near the established transects. At each station, from one to six replicate 15x22cm photographic images were made of the sediment/water interface and underlying sediment. Sampling took place between October 28 and November 2, 1985. The specific sampling grids for each ZSF are described in Sections 3.3 through 3.6 which follow. Additional information on the REMOTS system may be found in Appendix B-2.

3.1.4 Van Veen Ground Truthing

After completion of REMOTS sampling, a dual array, $0.1m^2$ Van Veen grab sampler was used to obtain sediment samples for ground-truthing of REMOTS photographic images. This device was also deployed from the RV Kittiwake. The contents of one grab in each set were sieved through a 1mm screen. Infauna and other material retained on the sieve were preserved in Rose-Bengal stained formalin and archived for possible future study. One subsample of the top 1 to 7cm of material from the second grab was retained for particle size determination (PSD). A second similar subsample was archived for potential future analysis of metals and organics. Additional information on the Van Veen ground-truthing efforts may be found in Appendix B-2.

3.1.5 Study Areas

At 6.0 square nautical miles (nm^2), Port Gardner is the largest of the ZSFs (Figure 3.4.1). Approximately 23nm of transects, 70 REMOTS and 19 Van Veen grab sample stations were located in this ZSF. The Saratoga Passage ZSF (Figure 3.3.1), located north of Port Gardner, comprises an area of $1.8nm^2$. It contained 5nm of transects, 10 REMOTS and 3 grab ground-truthing stations. The remaining two ZSFs are located in Elliott Bay. The Fourmile Rock ZSF (Figure 3.5.1) in the outer bay is about $2.2nm^2$ in area. It had 5nm of transects with 21 REMOTS and 7 ground-truthing stations. The inner Elliott Bay ZSF (Figure 3.6.1) is located east of Duwamish Head. It is $2.75nm^2$ in area and contained 3nm of transects, 11 REMOTS stations and 4 grab sample stations.

3.1.6 Analytic Parameters

Annotated MANTA sonographs were produced for transects evaluated within each ZSF (Appendices C-1 through C-4 and Exhibit A-2). Prominant features such as apparent sediment type, discontinuities between sediment types, bottom relief, wrecks, concentrations of fish and other information of interest were marked on the traces.

Physical and biochemical parameters were determined directly from REMOTS negatives using a video digitizer and computer image analysis system. Negatives are analyzed to avoid false values due to changes in image density that can accompany the printing of a positive image. The system digitizes images by density slicing gray-scale values and can detect up to 256 different gray shades. System software enables measurement and storage of data for up to 22 different variables obtained from each REMOTS image. Some biological information such as presence of feeding structures, apparent successional stage and taxonomic identifications are made for each image on the basis of visual examination. See Appendix D for a listing of data obtained for each REMOTS image analyzed. Statistical parameters of number, mean, standard deviation and minimum and maximum values for selected attributes are reported for each ZSF, in Appendix D.

It is important to understand that the REMOTS analysis is based on photographs made during a highly dynamic period in Puget Sound, during and immediately following major storm events. Results reflect the physical conditions which existed at the time the photographs were taken. Without additional data, conclusions derived for physical processes are based on the principal investigators' best explanation for the observed conditions.

3.2 Parameters Analyzed

The following material considers the parameters observed and analyzed in this Checking Study. This discussion is intended to relate general results and conclusions in a manner which will provide a framework for better understanding of specific results and conclusions drawn for each ZSF and presented in Sections 3.3 through 3.6.

3.2.1 Sediment Characteristics

Sediment Grain Size

Sidescan sonar information was collected to portray large-scale sediment characteristics and changes in sediment type between locations along transects. Even to someone not skilled in sidescan sonogram interpretation, coarse materials and associated relief from dredge disposal activities are apparent in sonograms produced for the Fourmile Rock ZSF. In contrast, surface sediments within the other ZSFs appear essentially uniform in distribution and changes in sediment type are not abrupt. Thus, mapping of subtle differences in surface sediment characteristics (e.g., sandy silt versus silty sand, or medium sand versus fine sand) were more suitable tasks for the REMOTS effort and PSDs performed in ground-truthing efforts.

Poor near-bottom visibility conditions precluded collection of visual data for the Port Gardner and Fourmile Rock ZSFs. However, 35mm images taken by the MANTA in Saratoga Passage and inner Elliott Bay provided important ground-truthing for the interpretation of sonograms produced for the generally fine and rather unconsolidated sediments found throughout all study areas.

Sediment grain-size major mode and range were visually estimated from REMOTS photographic negatives by overlaying a calibrated grain-size comparator. The comparator was prepared and calibrated by taking REMOTS photographs of a series of seven Udden-Wentworth sediment size classes. One sediment size class was selected to coincide with a size value less than or equal to the lower limit of optical resolution of the photographic system (approximately 62 microns, or 4 phi). The others ranged up to 2 mm or -1.0 phi. This method therefore allows recognition of grain sizes equal to or greater than coarse silt. Its accuracy has been documented by comparing REMOTS estimates with grain-size statistics determined from laboratory sieve analysis. REMOTS sediment analysis integrates averge major modes of sediment size class or phi throughout the top 10cm of sediment in REMOTS photographic images.

PSD samples from the REMOTS ground-truthing effort were analyzed by a combination of wet-seiving and gravimetric pipetting methods (differential settling). The analysis utilized samples removed from the upper 1 to 2cm of sediments. The relative percentages of grainsize classes within a range of -1 phi through >9 phi (2mm down to 2 microns and smaller; i.e., small gravel to very fine clay) was determined. The range of particle sizes in these samples was similar to that found in previous studies conducted in Puget Sound (e.g., Seattle METRO Duwamish Head Study, Stober and Chew, 1984). Appendix E presents a correlation of particle size and phi sizes to broader sediment classes (e.g,, sand, silt and clay) and summarizes results of the PSD analysis.

REMOTS and PSD approach the distribution of sediments from considerably different sensitivities to definition of particle ranges and deal with significantly disparate reference points within the sediment column. At the very least, since PSD analysis evaluates the top 1 to 2cm of sediment and REMOTS integrates the top 10cm, some differences in results are realistically to be expected. The REMOTS is insensitive to gradations of silt-clay sediments, while the PSD analysis can produce distributional data for a range which includes extremely small particles. Despite these differences, the ground-truthing analysis generally agreed with the information developed by REMOTS.

Small-Scale Substrate Boundary Roughness and Other Physical Features.

Boundary Roughness. Stereo 35mm images collected by the MANTA for the Saratoga Passage and Inner Elliott Bay ZSFs show a network of small hills and valleys (micro-relief) with an amplitude or height of between 1 and 3cm and a length or frequency of 10 to 20cm (Exhibit A-3). Feeding burrows which could be attributed to large and small infauna are visible in these images. This type of biogenic micro-relief is typical of mature infaunal communities inhabiting fine, subtidal substrates. For example, larger deposit feeders (particularly head-down feeding forms such as maldanids or the caudate holothurian, Molpadia sp.) produce fecal cones and depressions as a result of feeding activities. In a low velocity current regime, sediment surface boundary roughness in excess of 3cm may be attributed to large conveyor-belt, head-down deposit feeders. Further discussion of generic biotic implications appears in Section 3.2.2.

The REMOTS system averages micro-relief within each image to produce a "mean boundary roughness" value for each replicate analyzed. Values in Figure 3.3.3 and similar figures reflect the means of replicates analyzed at each station.

Small-scale boundary roughness may occur as a result of erosion or deposition, activities of macrofauna, or a combination of these processes. Independent measurements of near-bottom current velocities and sediment transport dynamics would increase the power of REMOTS images to correlate boundary roughness with biological and physical processes. For those REMOTS images in which organisms or their burrows or feeding structures are seen, it is reasonable to attribute such small-scale micro-relief at least in part to biogenic sources.

Almost all marine benthic invertebrates produce fecal pellets, which are deposited in the region of the sediment surface (Rhodes and Boyer, 1982). Head-down "conveyor-belt"deposit feeders such as Molpadia sp. ingest fine sediment at depth. They transport it upward, processing it in the gut and egesting it at the surface as fecal pellets, thereby producing typical fecal mounds. Molpadia sp. are probably responsible for biogenic relief (fecal mounds), seen in REMOTS images as boundary roughness in excess of 3cm, although burrowing shrimp may also contribute. In the absence of near-bottom current data, well developed micro-relief may also be used to infer that little hydraulic energy is available to erode fecal cones or to transport sediments along bottom to fill depressions.

Some REMOTS images (e.g., Plates 3.2.1, Rep. G4-3b, and Exhibit B-2), however, show that although a well developed micro-relief was present, some localized sediment transport apprears to be occuring at least during the time the photograph was taken. Other photographs (Plate 3.2.2, Rep. SPC-3b) suggest that an underlying micro-relief may be masked by deposition of fine sediments.

Surficial Cohesion. A matrix of mucopolysaccharides binds and repackages biogenically processed silts and clays into fecal pellets the size of sand grains and larger (Rhodes and Boyer, 1982). Pelletal material may comprise a substantial portion of the substrate at the sediment/water interface in infaunal communities dominated by deposit feeders (See Plate 3.4.1). As the process of fecal pellet deposition continues in well-established macrofaunal communities, previously deposited material is buried and carried downward.

The increased surface to volume ratio of silt/clay-sized particles compared with particles the size of fine sand grains and larger provides an associated increase in surface area for microbial (food) attachment. For this reason, fine grained sediments appear to be actively selected over sands by most deposit feeders. As further suggested by Rhodes and Boyer (1982), fecal pellets may not be selected for ingestion by most deposit feeders. The tendency, then, is for pellets to be distributed throughout the zone of bioturbation and remain until broken down into their original particle sizes and recolonized by bacteria. The net result is that fecal pellet bound silts and clays deposited in the sediment column decreases sediment density and increases sediment water content by increasing interstitial (pore) space between particles.

The binding properties of the mucopolysaccharide matrix in the pellets may well act to increase the critical velocity required to place them in an "escape" suspension (Rhodes and Boyer, 1982). This resistence to erosional or resuspension currents may account for the apparent pelletal layer suspension seen in Plate 3.2.3.

Plate 3.2.1. Suggestion of localized transport of sediment in an area of well-developed micro-relief. (0.65X)

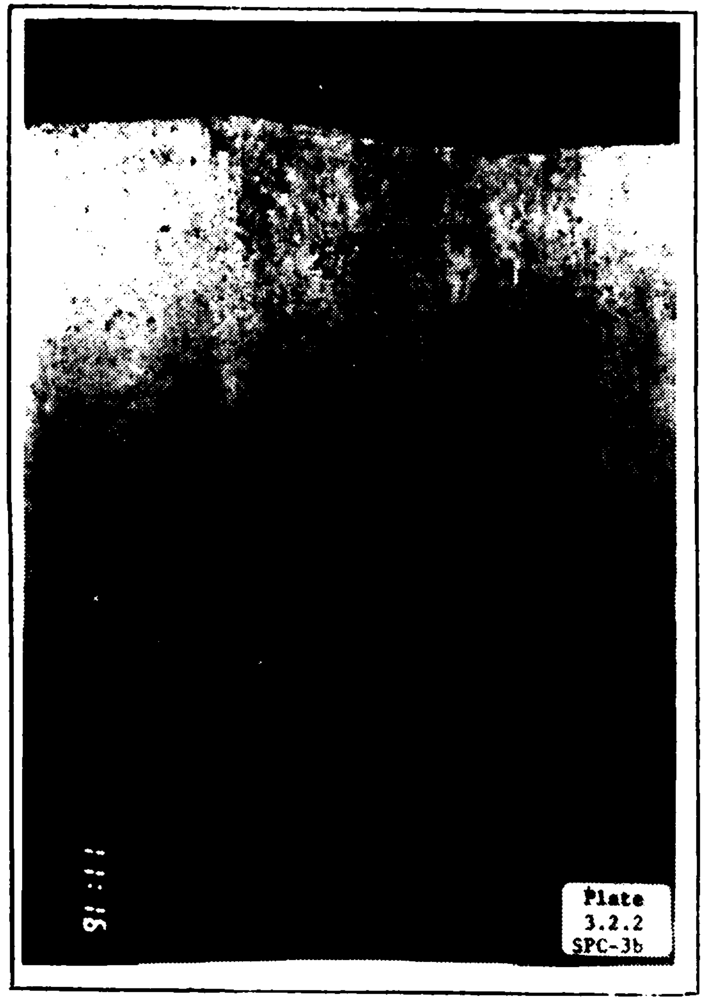


Plate 3.2.2. Micro-relief potentially masked by fine particle deposition. See original in Exhibit B-2a for detail. (0.65X)

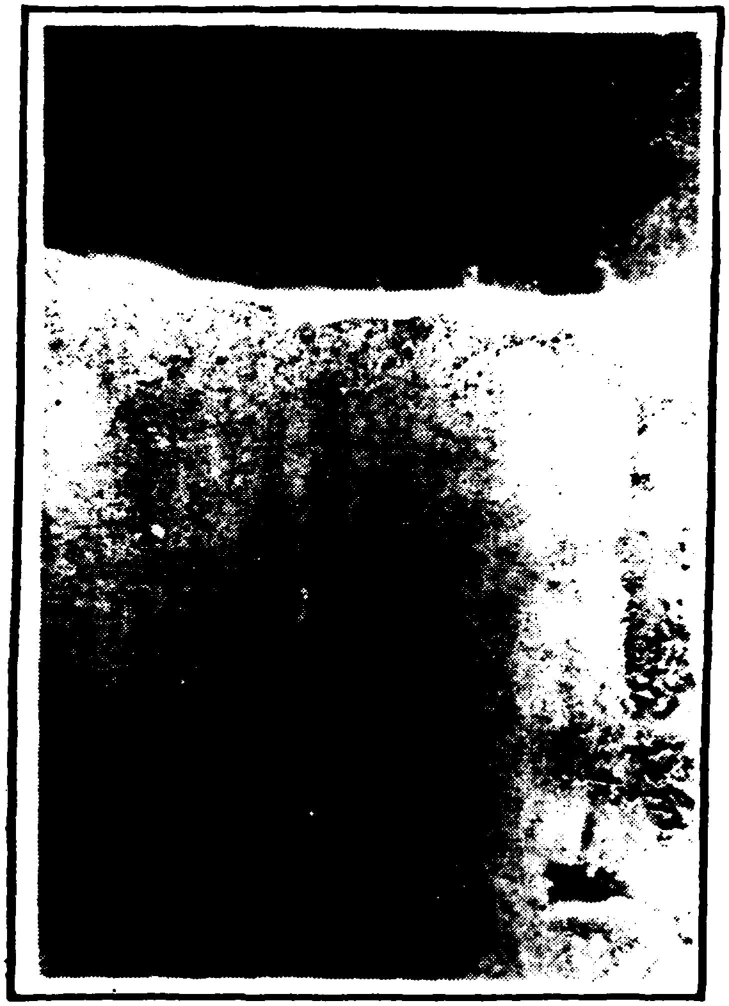


Plate 3.2.3. Pelletal layer in suspension. Note feeding burrow to the right, filled in with fecal pellets and clumps of fine grained material. (0.65X)

The suggested ability of these long-chain, complex organic compounds to bind fine sediments into cohesive matrices which resist erosional forces is of importance to a program considering the open-water containment of dredge material.

During REMOTS ground-truthing activities, 0.1m^2 Van Veen grab samples were recovered from various locations in each ZSF. Although some of these samples contained significant fractions of sediments with grain sizes coarser than silts, the majority appeared to be composed largely of highly cohesive silts to clays in an organic matrix. While sieving samples for archival of biota, the strongly cohesive character of these substrates was quite evident. Although no direct evidence is available, the observed cohesiveness of the substrates may be due to presence of biogenic mucopolysaccharides mixed into and binding the silts and clays.

Although the large clumps of sediment removed from the grab sampler were quite resistant to erosion, the immediate surface could be reduced with a gentle water spray, stripping fines away with the washwater. As the clump surface was being further reduced, these larger clumps tended to break into many smaller clumps. As the water spray was continued, the increased surface area to volume ratio of these small clumps then appeared to hasten their rate of reduction to a size small enough to pass through a 1mm mesh sieve. Those fine materials which washed through at that point still remained as very small clumps. They could be retrieved intact and smeared into a film between the thumb and forefinger, demonstrating their cohesive matrix and fine grained nature.

Preliminary studies of substrate surface resistance to erosive currents have been performed <u>in situ</u> in Puget Sound (Herbert Curl, personal communication). This effort utilized video to view responses of sediments to flume-controlled increases in along-bottom current velocity. The results suggest that for the types of cohesive, agglomerated sediments encountered in the PSDDA Checking Studies, the surface of the sediment forms a qualitative threshold "veneer" of resistance to erosion. Below that threshold, little or no erosion takes place. When the current velocity is increased to the threshold, erosion of the surface takes place explosively. It appears that in addition to rapid suspension of fines a significant component of the eroded sediment returns to the substrate as small clumps.

Germano (personal communication) citing previous work by D.C. Rhodes, also suggests that in areas with fine-grained cohesive sediments, a threshold along-bottom current is required to disrupt this cohesion. Once this disruption occurs, clumps or "mudclasts" are rolled along the bottom until continued erosion diminishes them to single grain dimensions.

Clumps of fine-grained sediment lying on the surface are apparent in many REMOTS images (cf. Plate 3.2.4, Rep. G7-6b). Occasional localized erosion of the small clumps may be seen as well. MANTA 35mm images also show these clumps, particularly in the Saratoga Passage ZSF. In this ZSF the clump sizes are generally smaller than found in other ZSFs surveyed, suggesting that a complementary source might be burrow management activities of large burrowing shrimp.

The significance of the presence of mudclasts in the majority of the REMOTS images is speculative and subject to further interpretation. The explanation which appears to best match the available evidence is that this phenomenon occurs in response to periodic current velocities strong enough to disrupt the cohesive sediment surface. Lower velocity current regimes may allow these sediment clumps to remain locally for a time. Continued higher velocities might erode them further to the point where the clumps are small enough for re-agglomeration with the substrate matrix. Bioturbation (biological reworking of sediments) may further aid in the reincorporation of small clumps into the matrix.

As site specific data and additional study results become available, these interpretations may well be modified.

Detrital Layers. Some REMOTS photographs show a layer of finely divided detritus or debris at the sediment/water interface. This suggests that along-bottom currents are low, allowing this easily transported material to remain in place.

Plate 3.2.4. Clumps of fine grained material ("mudclasts") at the surface and under the surface. (0.65x)

Bedforms. Wave formations in coarser grained sediments are referred to as bedforms. These regular surficial characters are generally attributed to along-bottom currents.

REMOTS Camera Prism Penetration Depth

The wedge-shaped REMOTS camera prism penetrates the substrate to allow a vertical profile image of the sediment to be taken. Falling at a constant rate and given a constant mass (weight), the camera prism and frame function as a penetrometer. Comparing penetration depth values amoung stations and replicates with similar grain size modes gives an indication of relative sidement shear strength and interstitial water content. The camera will penetrate to a greater depth in finer, unconsolidated sediments than it will in coarser, more compact substrates. For this study, penetration depths of less than 10cm generally corresponded to transition in grain size mode from silts to fine sands. Depths of 5cm and less corresponded to fine to medium and coarse sands. Where penetration depths for coarser sediment are greater than (or approximately equal to) depths for finer sediments (or where penetration depths are significantly greater for replicates or stations with similar size characteristics), a higher degree of sediment porosity is indicated. The most obvious source of unanticipated increased porosity or decreased sediment cohesiveness is bioturbation.

Redox Potential Discontinuity (RPD)

In fine-grained coastal areas when there is oxygen in the overlying water column, the near surface sediment may have a lighter color relative to hypoxic or anoxic sediment underlying it. The oxidized surface sediment contains ferric hydroxide (an olive color when associated with organic particles), while the reduced hydrogen sulphide sediments below this oxygenated layer are grey to black. The boundary between the oxidized surface sediment and underlying grey to black sediment is called the redox potential discontinuity (RPD). (See Plate 3.2.5, Rep. E1A-6c)

Plate 3.2.5. Redox Potential Discontinuity (RPD), shown by boundary between lighter aerobic sediment and underlying anaerobic grey to black sediment. Feeding void with head-down deposit feeder in place. (0.65X)

Within each REMOTS image, the area of the aerobic sediment is determined by computer, and calculations are performed to obtain a mean depth for the apparent RPD. The RPD depth is given special attention because it is that point in the sediment column with the highest bacterial productivity and, therefore, the principal site of feeding for head-down deposit feeders. Accordingly, it appears to be a sensitive indicator of infaunal succession, within-station biological community patchiness and bioturbation activity.

3.2.2 Biota

Infaunal Community Successional Stage

Assemblages of pioneering (Stage I) benthic organisms typically consist of dense aggregations of infaunal, tube-dwelling polychaetes living near the sediment surface. These functional types are usually associated with a shallow RPD. Bioturbation depths are shallow, particularly in the earliest stages of colonization.

Stage III organisms represent high-order successional stages typically found in mature, biologically stable regimes. Many of these Stage III infaunal invertebrates feed at depth in a head down orientation. Such localized feeding activity results in distinctive below surface excavations called feeding voids (Plates 3.2.2 and 3.2.6, Rep. G7-1c) and the production of fecal cones and burrow depressions. The bioturbation activities of these deposit-feeders are generally responsible for aerating the sediment and depressing the redox horizon at least several centimeters below the sediment/water interface.

No detailed information is available on local infaunal community structure based on collection of synoptic taxonomic data at Puget Sound basin REMOTS stations. An added difficulty is that community succession dynamics are not well understood for the range of deeper soft-bottom infaunal communities of Puget Sound (P. Jumars, personal communication).

Thus, successional stage analysis with REMOTS imagery is based on the

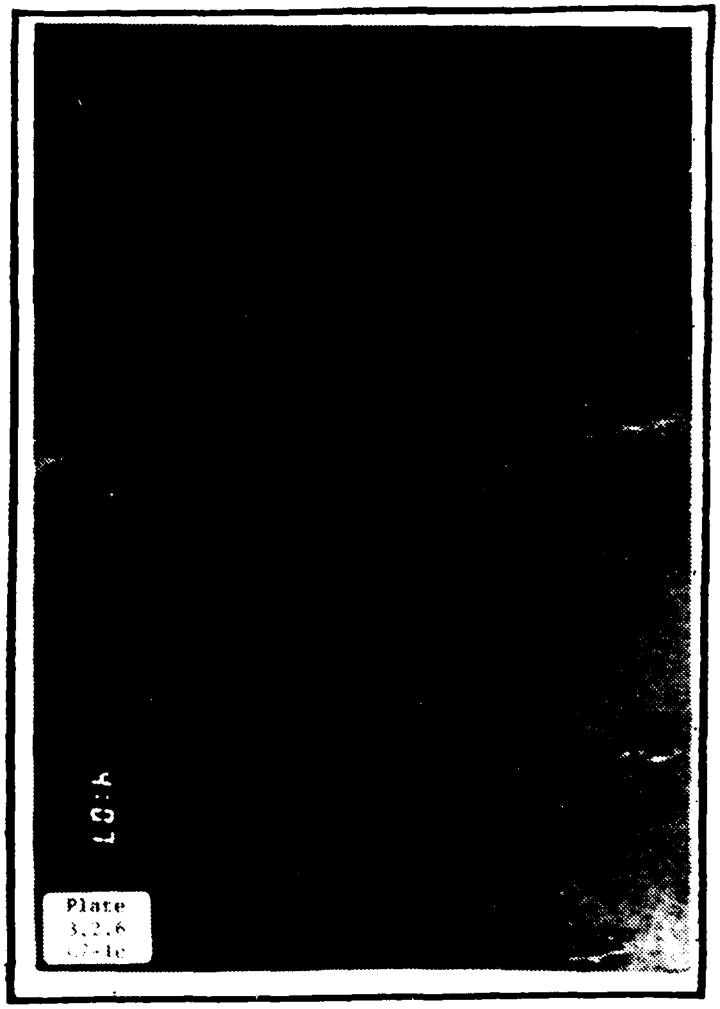


Plate 3.2.6. Feeding void below sediment surface, and apparent Stage I and Stage III organisms occurring together. (0.65X)

apparent end-members of the predominantly fine grained deposit-feeding community found throughout the ZSFs. Pioneering stage or opportunistic infauna (apparent Stage I) are typically small polychaete forms, whose tubes generally do not extend below 2 to 5cm. Based largely on work elsewhere, the assumed mature community components (Stage III) are burrowing shrimp and the group of large, head-down deposit feeders represented by the caudate holothurian Molpadia and maldanid polychaetes. Lack of direct taxonomic information for infaunal samples taken at REMOTS ground-truthing stations precludes discrimination of Stage II fauna from apparent structures in photographs. As a more complete picture of Puget Sound soft-bottomed assemblages and other similar communities in the ZSFs is developed, the community structural relationships of these groups may well be redefined.

The end-member stages (Stage I and Stage III) are recognized in REMOTS images by the presence of assemblages of near-surface polychaetes and/or subsurface feeding voids. Both types of assemblages are often present in the same image (Plate 3.2.6). A detailed explanation of REMOTS image interpretation can be found in Rhoads and Germano (1982).

3.3 Saratoga Passage ZSF

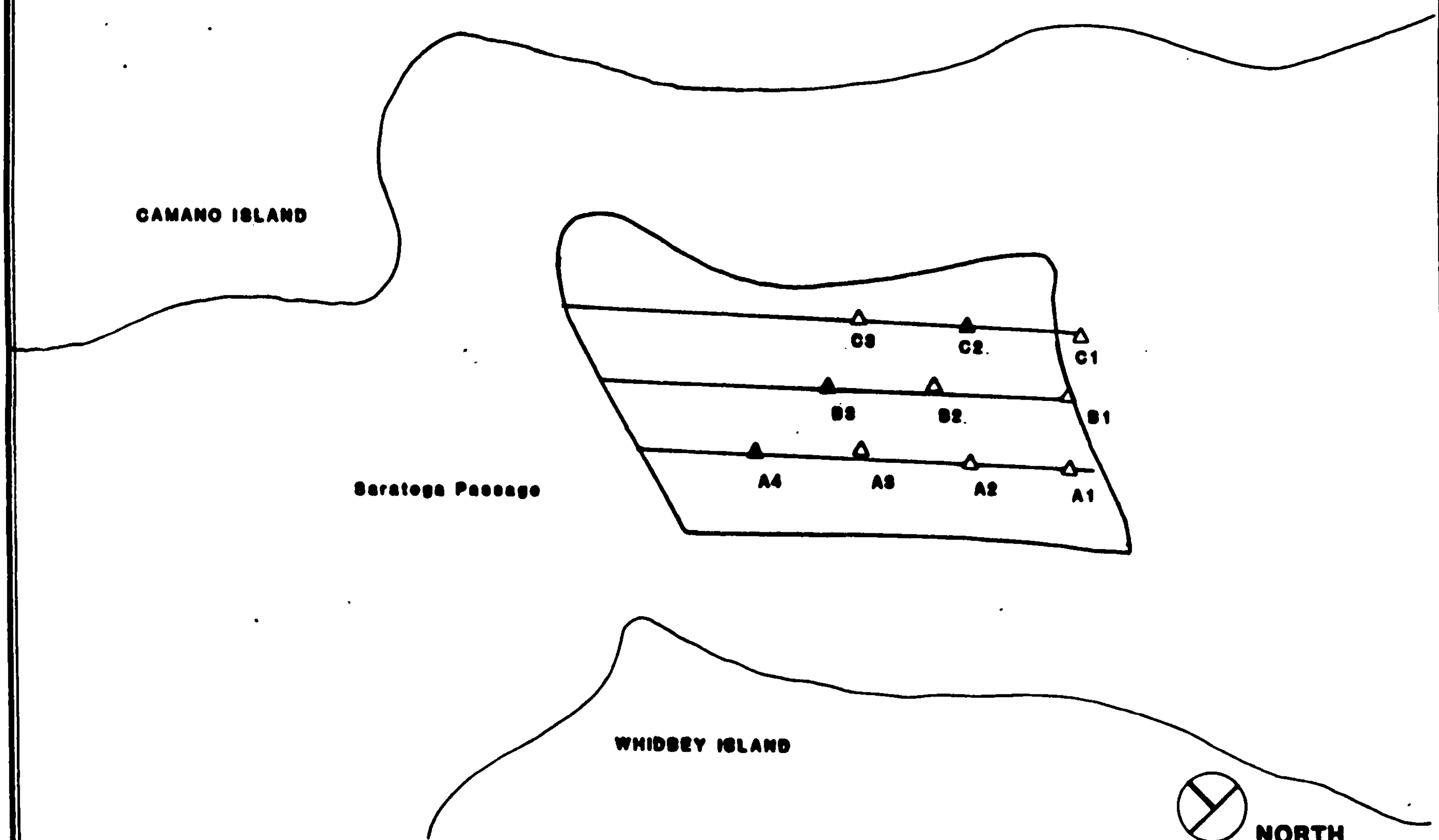
Field work was performed at the Saratoga Passage ZSF between October 30 and 31, 1985. Three parallel transects served as the basis for MANTA operations and REMOTS station location (Figure 3.3.1). Transects A and C received MANTA sidescan coverage and the middle transect (B) was covered by video and 35mm still cameras. High turbidity required that video and photographic data be collected at ROV heights off-bottom of less than 1 meter.

Poor navigational control associated with transponder triangulation geometry limited REMOTS operation to the southeast section of the ZSF. Heavy seas made it impossible to obtain REMOTS photographic replicates at some stations as well as to deploy REMOTS at one station for which navigation control was adequate. REMOTS was successfully deployed at three stations on each transect for a total of 9 stations. A total of 25 photographic replicates were obtained. For those portions of the ZSF not sampled by REMOTS, MANTA information was used as the primary data. Van Veen grabs were obtained at three REMOTS stations (Figure 3.3.1).

3.3.1 Geophysical Characteristics

Sediment Grain Size

The surveyed bottom of the Saratoga Passage ZSF graded from sands and silty fine sands in the northwestern third to less consolidated silty clays in the southeastern third (Figure 3.3.2). From MANTA stereo and single 35mm photographs taken along Transect B, sediments in the extreme northwestern portion of the transect appeared to be coarse sands [See Plate 3.3.1 (MANTA Station 0) and Exhibit A-3a]. On the basis of MANTA 35mm photos, proceeding from the northwest to the southeast along Transect B, sediments appeared to change from these coarse sands to fine sandy silts within less than 0.25nm. This sediment class transition corresonds with the deepest portion of a trench occurring southeast of a ridge line between East Point and Lowell Point.



NAUTICAL MILE 0 1/2 1

Figure 3.3.1.
Transects & REMOTS Stations in the Saratoga Passage ZSF

▲ REMOTS & VAN VEEN
△ REMOTS ONLY

COOPER CONSULTANTS, INC.

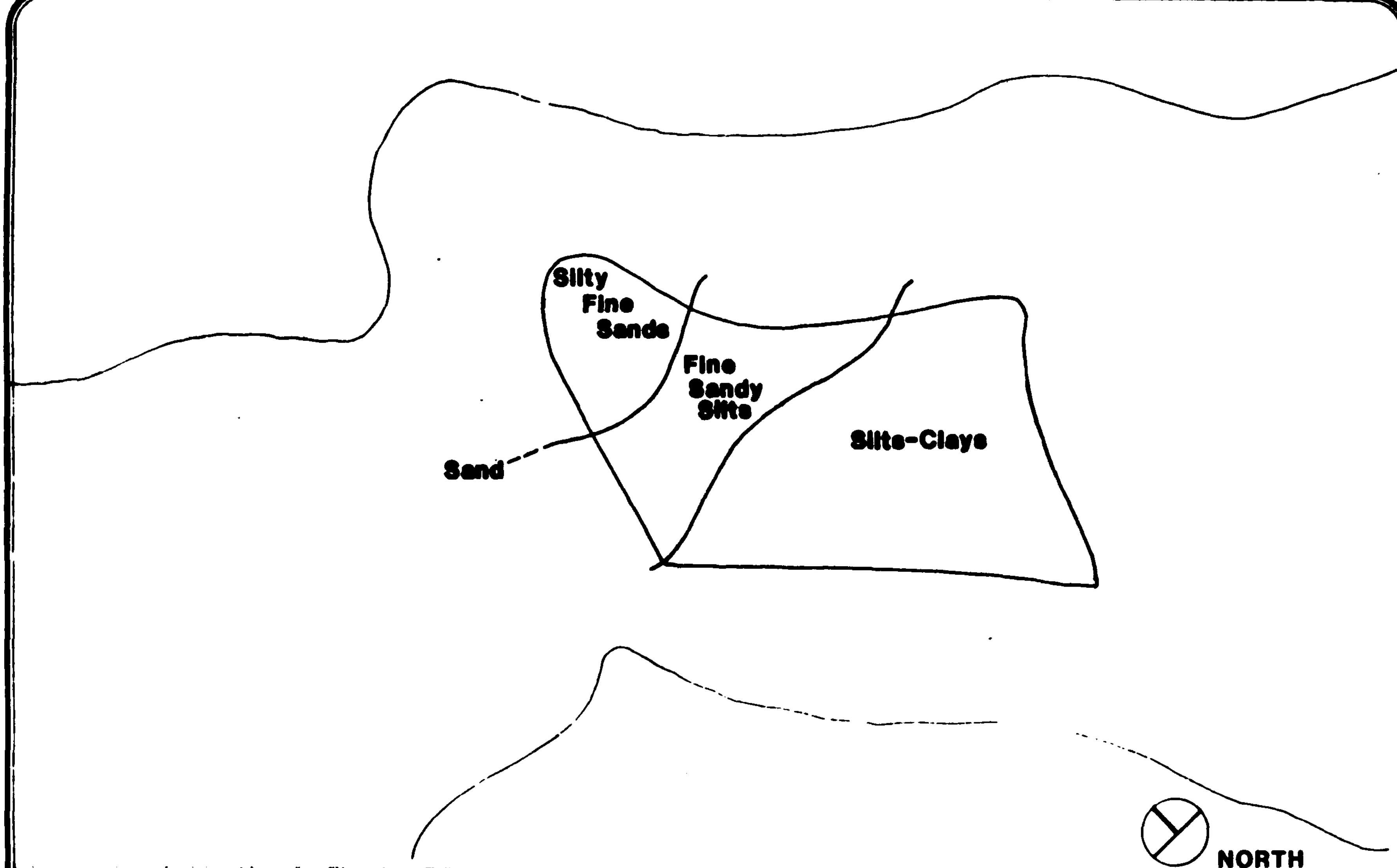


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Figure 3.3.2.
Sediment Characterization in the
Saratoga Passage ZSF

Plate 3.3.1. Coarse scoured sands at MANTA Station "0". Note large feeding burrow. (approximately 0.1X)

REMOTS Camera Prism Penetration Depth

REMOTS camera prism penetration depths were uniformly in excess of 14cm (Appendix D-1). The mean of values was 17.09cm, with a standard deviation of 2.37cm. This indicates that sediments in the southeastern two thirds of the Saratoga Passage ZSF had relatively low shear strength and were highly porous. These characteristics reflect of a high degree of bioturbation and sediment repackaging.

Small-Scale Substrate Boundary Roughness and Other Physical Features

Boundary Roughness. From MANTA 35mm photographs and REMOTS analysis, apparent mean small-scale boundary roughness values exhibited a broad and even distribution throughout the surveyed portions of the Saratoga Passage ZSF (Figure 3.3.3 and Appendix D-1). Micro-relief height ranged between 0.0 and 3.4cm with major modes of distribution at 0.8 and 2.0cm. The mean of values was 1.93cm, and the standard deviation was 1.88cm. With the exception of the northwestern third of the ZSF where there was some evidence of surficial scour, MANTA photographs (Exhibit A-3a) indicated that the sediment surface layer (uppermost 1 to 2cm) was filled in with unconsolidated fine materials, partially obscuring some feeding and shrimp burrow excavations (cf. Plate 3.3.2). This condition may be temporary, and may obscure an otherwise more well defined micro-relief.

Surfical Cohesion. REMOTS images refine the MANTA portrayal of the upper 1 to 2 cm of sediment. This layer actually appeared to be composed largely of fecal pellets, with a smaller fraction of very fine sediments. Both photographic methods also revealed a sparse admixture of the type of clumps of consolidated fine material discussed in Section 3.2.1.

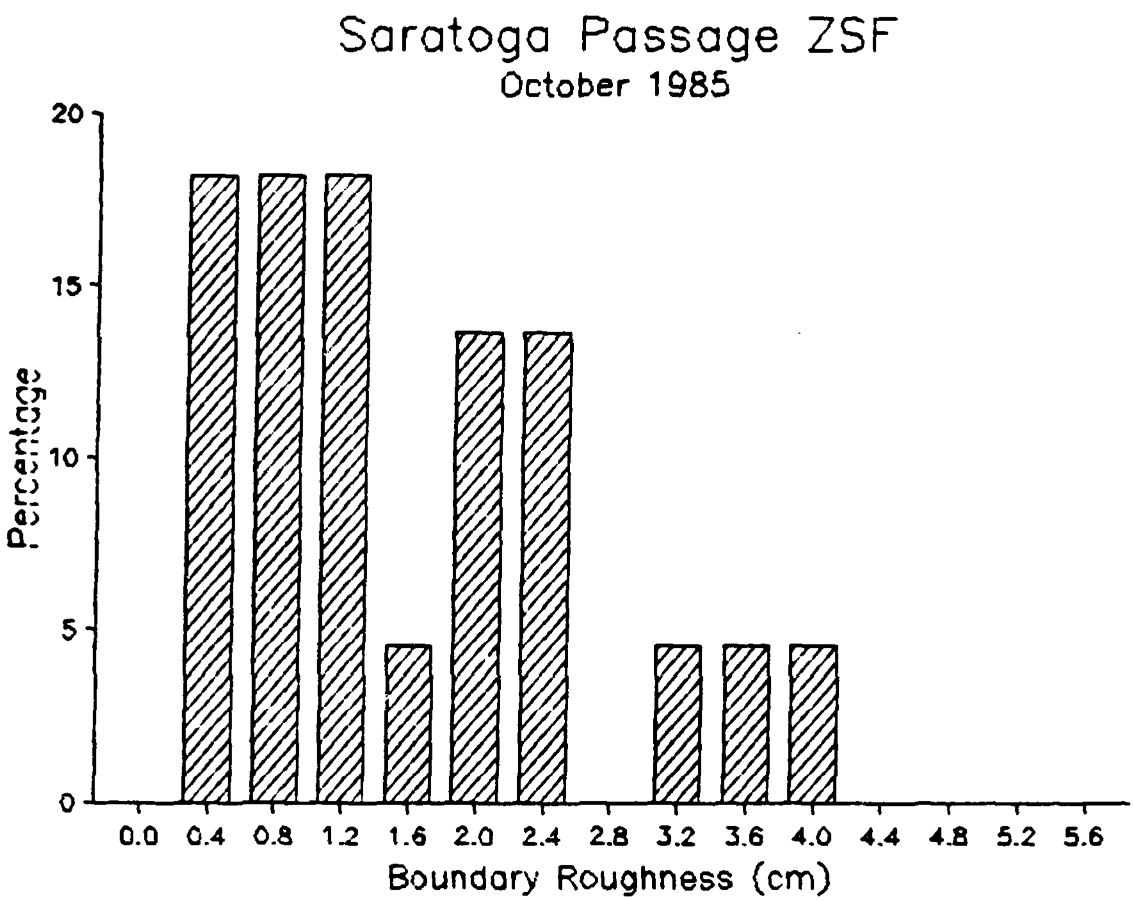

Figure 3.3.3.
Histogram of Small-scale Boundary Roughness in the Saratoga Passage ZSF

Plate 3.3.2. Appearance of sediment in limited suspension. Note filled in depression in center of photograph and suggestion of covering of micro-relief with fine materials. (0.65X)

Redox Potential Discontinuity (RPD)

From the percentage histogram presented in Figure 3.3.4 and Appendix D-1, apparent RPD depths in the REMOTS-surveyed stations of the Saratoga Passage ZSF were deeper than 8cm in all but 5 of the 25 replicates. The mean for the ZSF was 10.71cm, with a standard deviation of 2.82cm. Figure 3.3.5 characterizes spatial distribution of mean apparent RPD depths for REMOTS stations in the ZSF. SPB-3 was the only station for which the RPD was less than 10cm for all three photographic replicates.

3.3.2 Biota

Infaunal Community Successional Stage

As discussed in Section 3.2.2, there is presently no detailed information on infaunal community structure at Puget Sound basin REMOTS stations. Within those constraints, the following discussion utilizes end-members to characterize successional communities.

The distribution of apparent infaunal successional stages at Saratoga Passage is shown in Figure 3.3.6. Subsurface feeding voids, excavations and biogenic mounds indicated that head-down deposit feeders (assumed Stage III organisms) dominate the fauna within the ZSF. However, several REMOTS images and REMOTS station (SPA-1) lacked direct evidence of Stage III successional end-members. Pioneering successional stage members (Stage I infauna) were the dominant forms. Deep RPD and camera prism penetration depth values associated with these replicates suggest that this absence of more mature fauna may be a reflection of small-scale patchiness rather than a large scale distribution pattern. In all other stations, Stage I infaunal organisms were found as secondary successional community members associated with the Stage III species.

Other Biotic Community Elements

Burrow excavations appearing in two MANTA photographs from the extreme northwestern segment of Saratoga Passage Transect B could possibly be

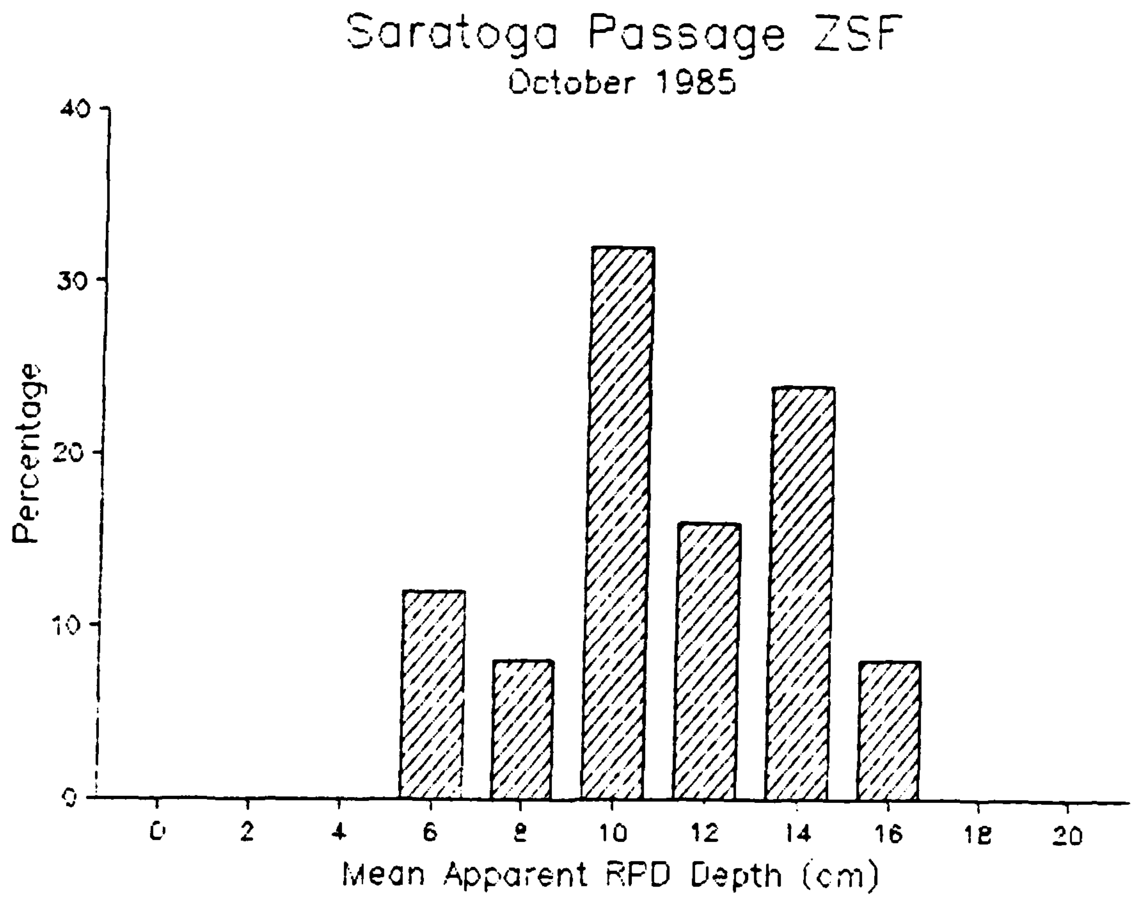

Figure 3.3.4.
Histogram of Apparent RPD Depths in the Saratoga Passage ZSF

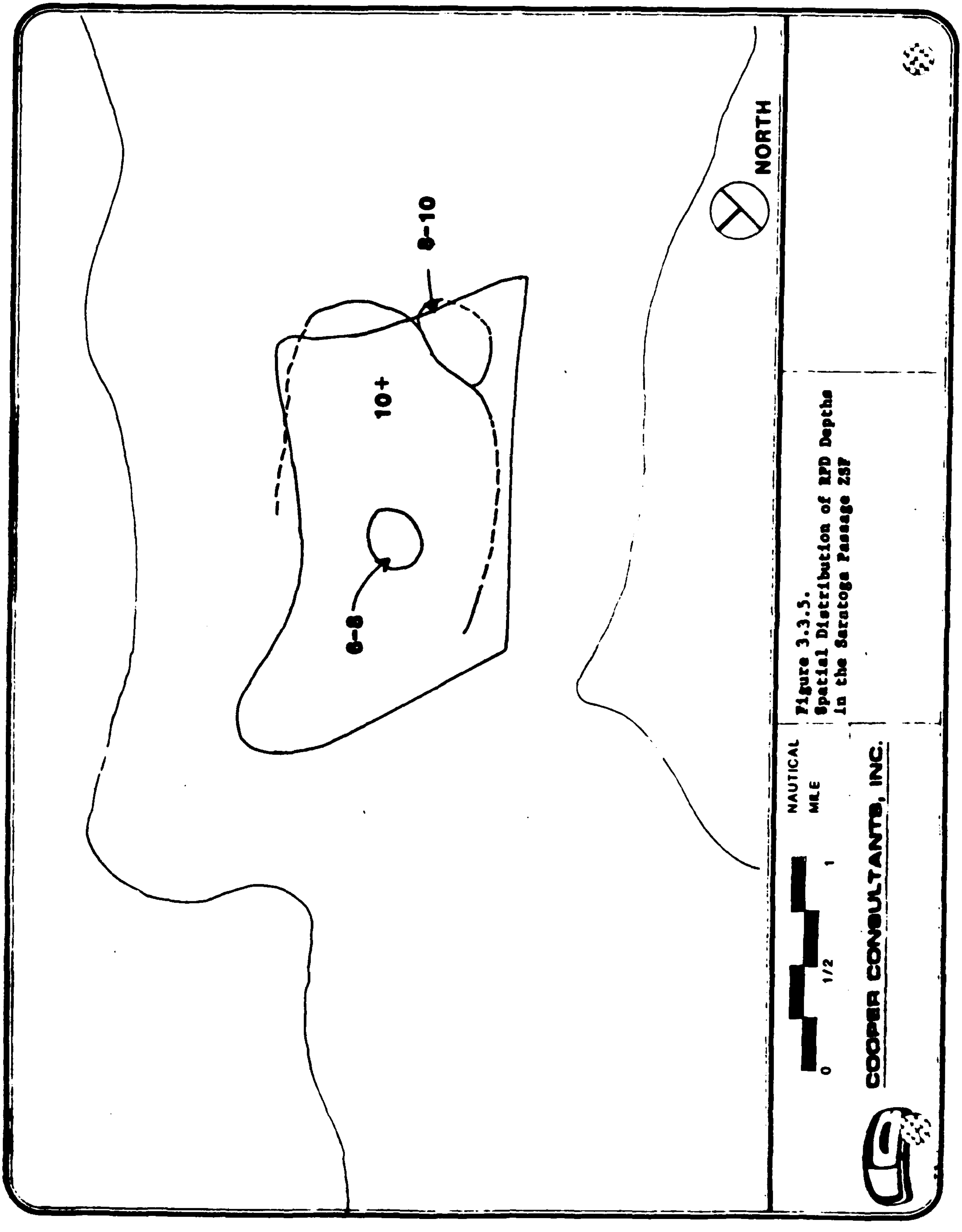

Figure 3.3.5.
Spatial Distribution of RPD Depths
in the Saratoga Passage ZSF

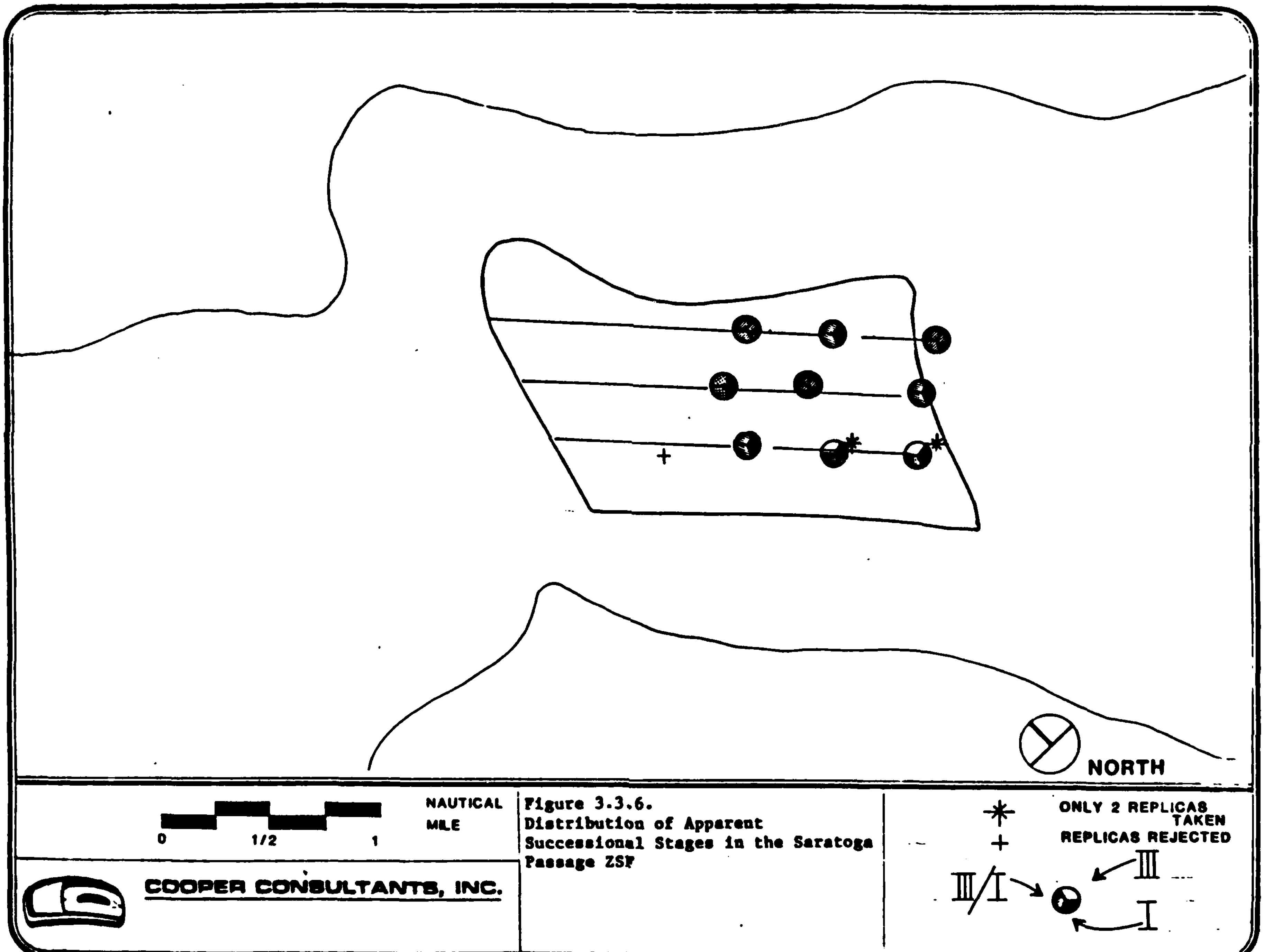

Figure 3.3.6.
Distribution of Apparent Successional Stages in the Saratoga Passage ZSF

attributed to a large bivalve such as Panope generosa (geoduck) or to large, deep burrowing shrimp. However, without further corroboration such as visible siphons or recovery of shrimp specimens, such identification is difficult. In one photograph from the extreme northwestern edge of the ZSF (MANTA Frame S-01, Exhibit A-3a), a small ophiuroid sea star may be seen. Occasional presence of these epifauna is in agreement with the informal findings of the ground-truthing effort.

Although no fish were seen in any of the still photographs for Saratoga Passage, sidescan sonograms (Appendix C-1 and Exhibit A-2a) and video footage (Exhibit A-3a) document fish in large numbers in midwater throughout the site. One or more traces on the sonograms from the northwest end of Transect C appear to be herring schools. No groundfish other than Chimeridae were specifically observed during the study. At no time during the field investigations were bottomfishing or seining activities observed in this ZSF.

3.3.3 Conclusions

Deep RPD and and uniformly deep camera prism penetration (i.e. highly porous sediments with a high water content) at the Saratoga Passage ZSF was almost certainly the result of extensive bioturbation. The overrriding conclusion is that this is a biologically stable area. On the basis of available information, the fauna appeared to be dominated by head-down deposit feeders and deep burrowing shrimp overlayed with a secondary assemblage of apparent Stage I fauna. Because Stage I organisms are an important groundfish food source additional visual examination and trawl data could well produce information on the presence of significant fish stocks in the Saratoga Passage ZSF.

Uniform distribution of fine, unconsolidated surface sediments and fecal pellets tends to support the conclusion that the majority of the surveyed area may be influenced by a low velocity bottom current regime, in which periodic sediment resuspension occurs. Presence of smaller clumps of silt/clay materials within the surface substrates may be due in part to burrow maintenance activities of shrimp. However, the surveyed area may experience periodic stronger erosive events required to generate larger "mudclasts".

In the extreme northwestern segment of the ZSF, coarse sediments and absence of significant amounts of fine material in the overlying surface suggest a more dynamic current regime than in the southeastern two-thirds. However, since this evaluation was performed during a period of intense mixing and rainfall, observed phenomena may or may not reflect typical ambient conditions.

3.4 Port Gardner ZSF

Field work was conducted at the Port Gardner ZSF on October 28 and 29, 1985. Eight parallel transects served as the basis for MANTA operations and locations of 58 REMOTS stations (Figure 3.4.1). An additional twelve REMOTS stations were located on two perpendicular transects (9 and 10) located in the southeastern segment of the ZSF. Transects 9 and 10 represented a perpendicular array of 8 stations, 250 and 500 feet from a central station, plus two stations along Transect 9 (1500 feet on either side of the center), and a twelfth station along Transect 9 (2500 feet from the center, to the southwest). (See detail in Figure 3.4.1)

The first eight transects received MANTA sidescan sonar coverage. Attempts were made to collect visual information on each MANTA transect, employing video and 35mm still cameras. The ROV was flown in terrain-following mode 80cm or less off-bottom. However, due to high turbidity conditions no useable visual images were obtained. Hard bottom conditions and steep bathymetric gradients due to an outcropping of Gedney Island prevented successful sampling with the REMOTS camera at station G8-4. No REMOTS photographic images were collected from station G9-6. At the 68 remaining stations, a total of 359 REMOTS replicate images were obtained. Of these, 198 replicates were analyzed (3 per station for Transects 1 through 8; 1 to 3 per station for Transects 9 and 10). The remainder of the replicates were archived. Twenty-five REMOTS stations were ground-truthed with Van Veen grab samples (noted on Figure 3.4.1).

3.4.1 Geophysical Characteristics

Sediment Grain Size

Based on REMOTS major mode grain size analysis (averaged to a depth of 10 cm), ground-truthing PSD analysis and MANTA sonograms, sediments in the Port Gardner ZSF are presented in Figure 3.4.2. The surveyed bottom of the western half of the ZSF was composed primarily of silts (4 phi) to finer silty clays (>4 phi). Corresponding with a bathymetric gradient of 125 to 140 meters in the eastern half of the ZSF, the major mode of

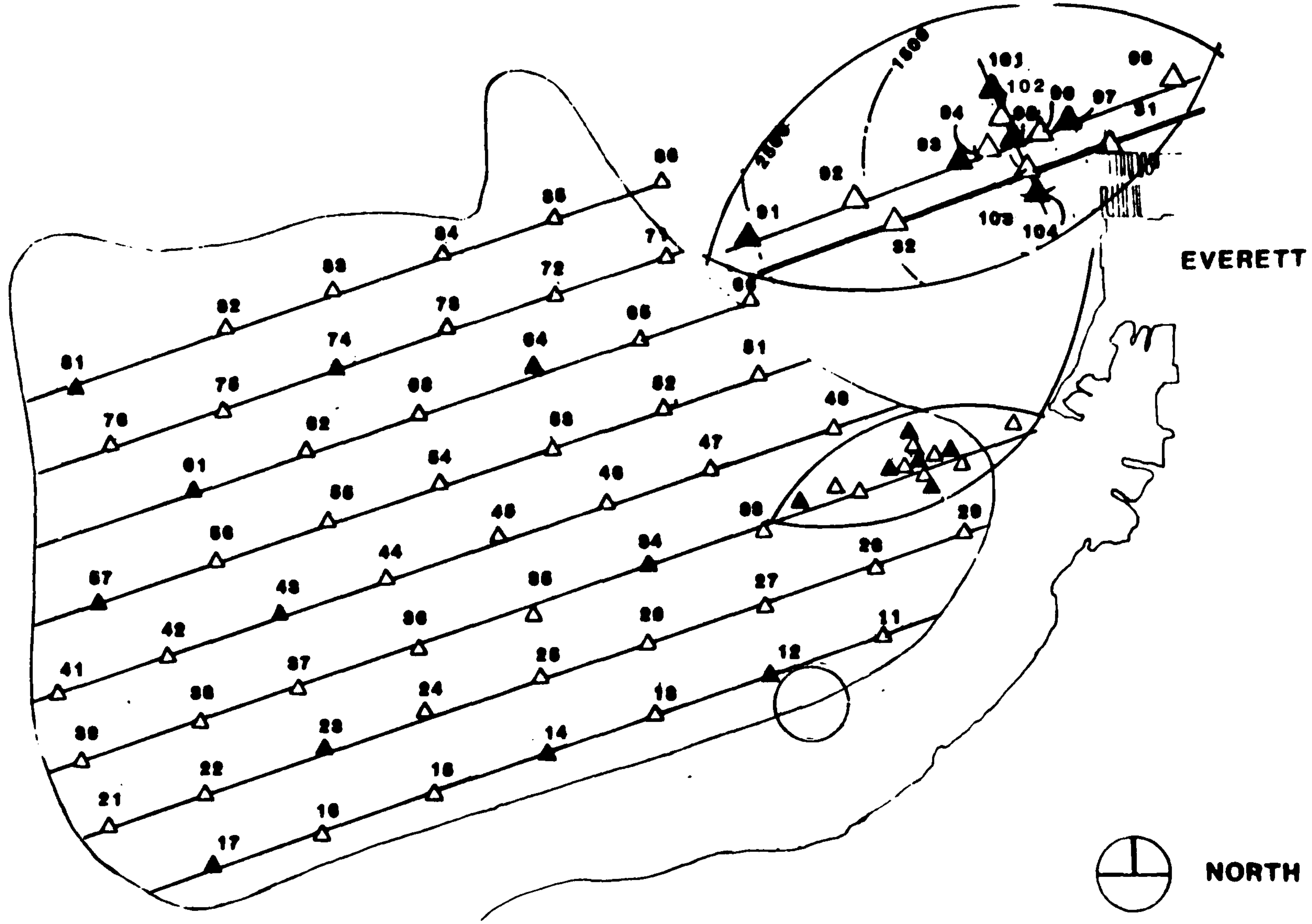

Figure 3.4.1.
Transects & REMOTS Stations in the Port Gardner ZSF

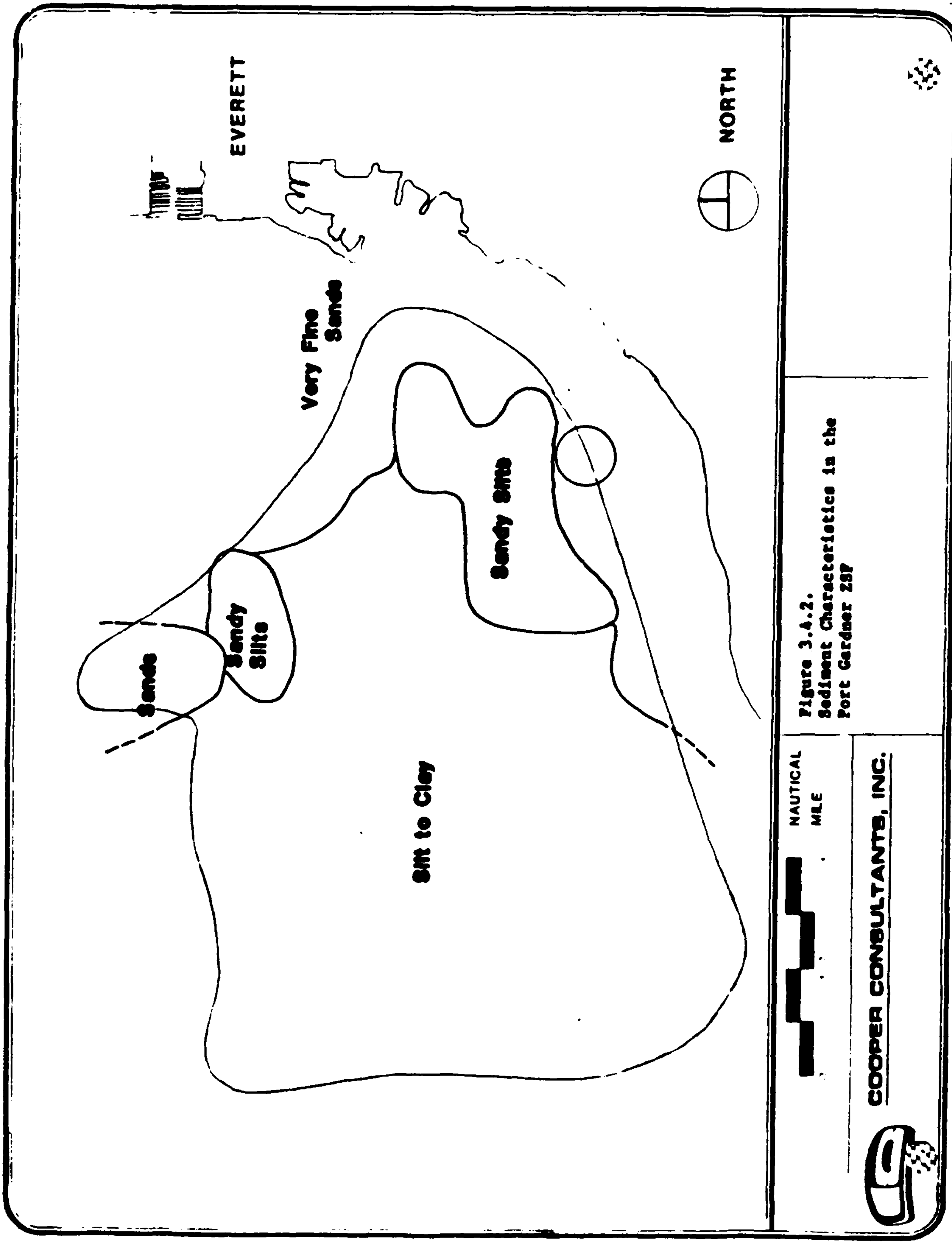

Figure 3.4.2.
Sediment Characteristics in the Port Gardner ZSF

sediment graded from very fine silty sand ($\geq$4 to 3 phi) at the deepest portion to very fine sand (4 to 3 phi) at the easternmost and shallowest segment of the site on the edge of the Snohomish River delta platform.

The uppermost 10 to 20cm of the floor of the western two-thirds of the Port Gardner ZSF consisted of silt-clay particles at water depths of 135 to 170 meters. Approaching the Snohomish River delta plateau to the east, water depth decreased to 38 meters. This bathymetric gradient was associated with a transition in sediment grain size from silts and clays to silty fine sands and sands.

The distribution of sediment size classes in Figure 3.4.2 was determined largely by REMOTS major mode analysis and MANTA data, with some incidental refinement from the PSD analysis. As such, it probably does not express the actual range of particle sizes for the stations evaluated. The greatest range of grain sizes was encountered in the extreme eastern portion of the ZSF, including coarser sediments (fine and medium sands). REMOTS data in Appendix D-2 indicate that for Stations G1-1, G1-2 (near the DNR disposal site), G6-6 and G8-6 (Plate 3.4.1), the range of grain size class extended to 1 phi or medium sands. Fine sand (2 phi) was present in the distribution of sediments for most station replicates along Transect 1 and for the eastern portion of the remaining transects.

The presence of these coarser materials may indicate refraction of currents along the southern shoreline of Port Gardner and the Snohmish River delta platform.

REMOTS Camera Prism Penetration Depth

The percentage histogram for the distribution of mean REMOTS camera penetration depths within the Port Gardner ZSF appears in Figure 3.4.3. The mean penetration value for all replicates analyzed was 14.19cm, with a standard deviation of 3.51cm. Penetration depths in excess of 10cm indicate that there was a high degree of sediment porosity in the majority of the site. Penetration depths less than 10 cm at some stations (Appendix D-2), generally corresponded with transitions in grain size

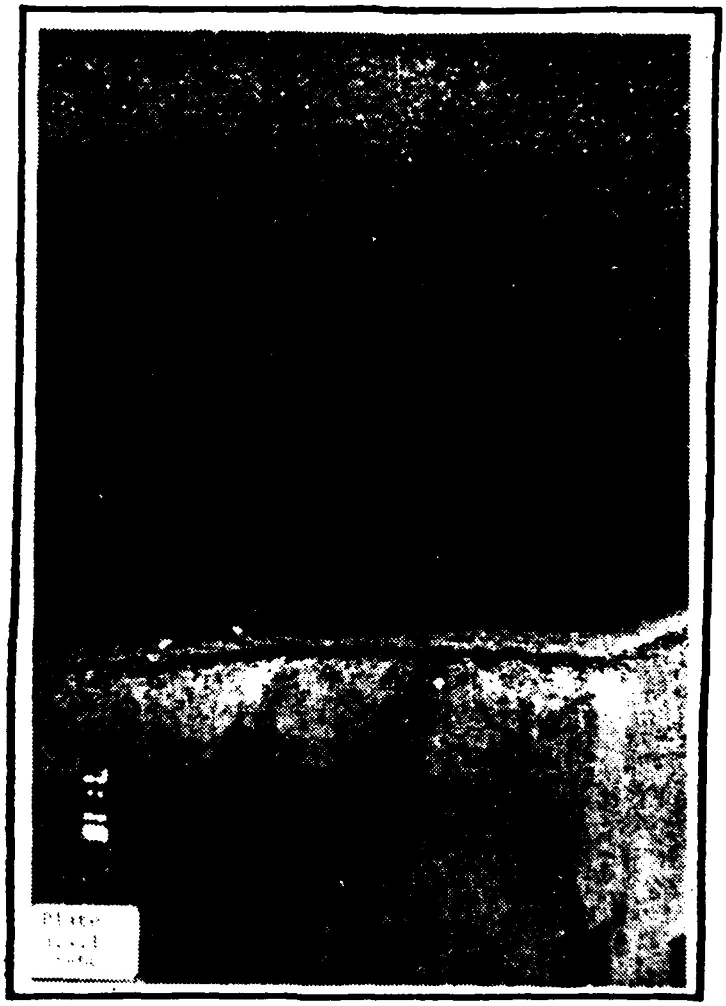

Plate 3.4.1. Sediment profile at G8-6. Layer of fine debris or detritus lies on the surface. Note material in suspension in the water column. (0.65X)

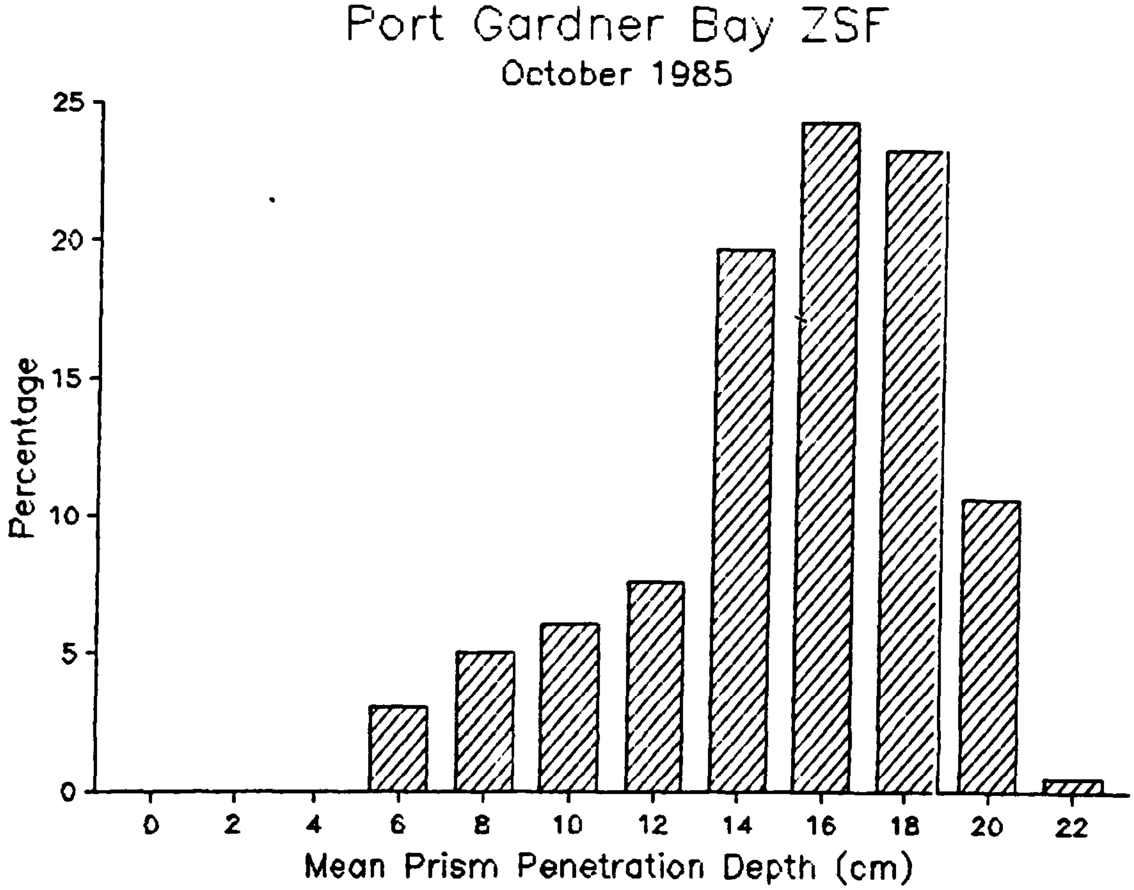

Figure 3.4.3.
Histogram of REMOTS Camera Penetration Depths in the Port Gardner ZSF

major mode toward coarser sediments. These values provide a further check on the qualitative accuracy of the REMOTS grain size analysis. Comparing values in Appendix D-2 for major sediment mode and penetration, it is also apparent that some stations with coarser sediment had prism penetration values equal to or greater than stations consisting of finer sediment. This greater than anticipated penetration suggests the effects of extensive biological reworking of the sediments within the ZSF and associated changes in sediment shear strength and total water content.

Small-Scale Substrate Boundary Roughness and Other Physical Features

Boundary Roughness. The percentage distribution of REMOTS sediment surface boundary roughness values for the Port Gardner ZSF is shown in Figure 3.4.4. With a major mode in the 1.2cm height class, and a replicate mean of 1.54cm, individual REMOTS replicate values ranged from 0.39 to 5.71cm. The standard deviation was 0.9cm. The majority of this small-scale roughness is was likely due to the activities of infauna (e.g., biogenic structures at the sediment surface). At stations G9-1 through G9-8, G10-3 and G10-4, reduction of obvious biogenic micro-relief, presence of coarser sediment grain sizes at the immidiate surface and high percentage of replicates with dense suspended matter above the sediment/water interface indicated stronger along-bottom currents in the extreme southwestern section of the ZSF.

Surficial Cohesion. Fecal pellets were apparent in a layer at the sediment/water interface, in feeding structures and in other depressions in the substrate surface for the majority of REMOTS images from the ZSF. In some images (cf. Plate 3.4.2, Rep. G7-4c), the pelletal layer appeared to be in suspension at the sediment/water interface.

Small clumps of cohesive fine sediment were also apparent in REMOTS images. These occurred at the sediment/water interface and just below the surface and can be seen at approximately half of the REMOTS stations in the Port Gardner ZSF. This condition was found particularly in the western half of the ZSF where fine, cohesive sediments were dominant (cf. Plate 3.4.3, Rep. G8-1c).

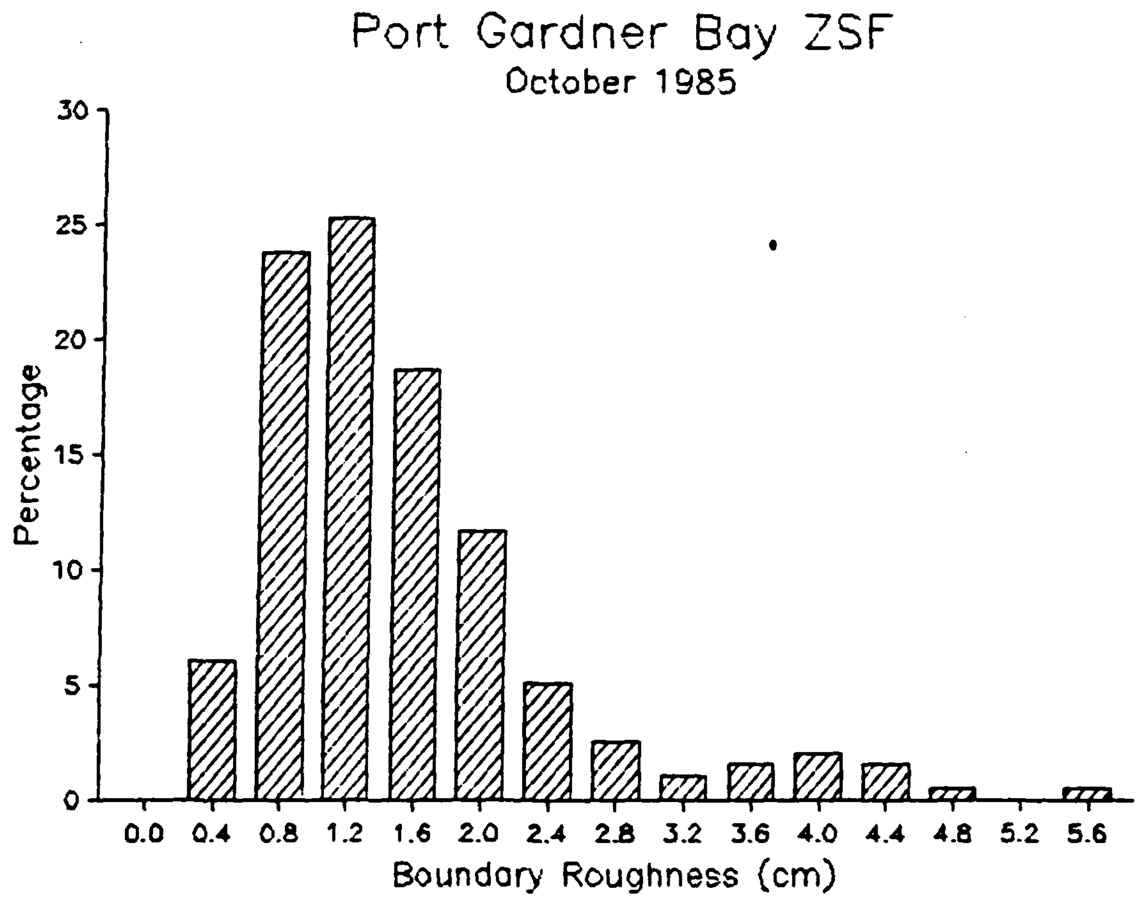

Figure 3.4.4.
Histogram of Small-scale Boundary Roughness in the Port Gardner ZSF

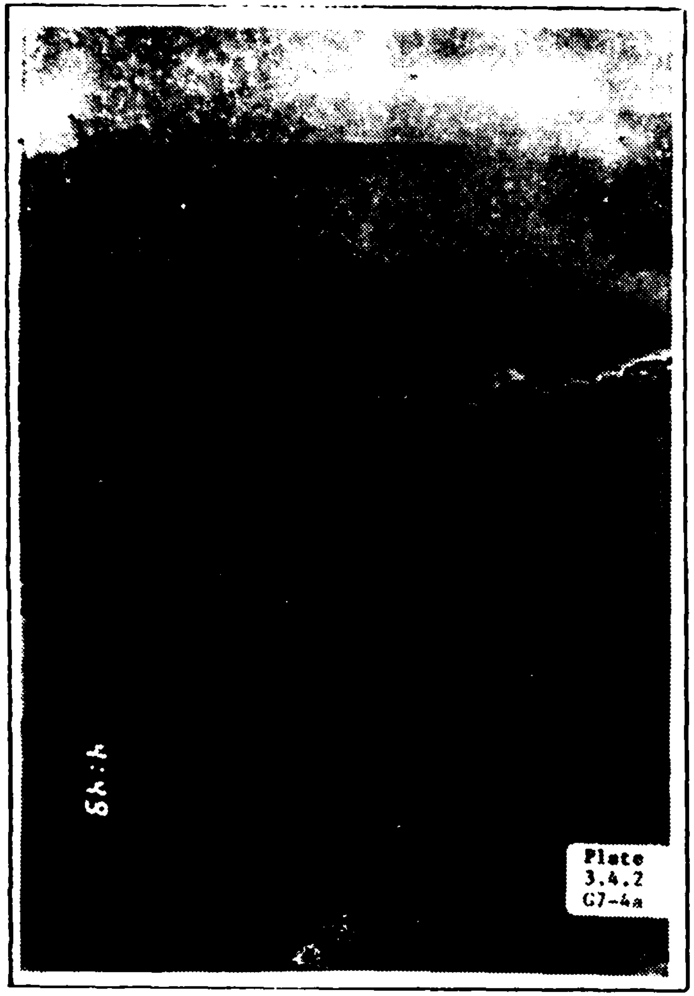

Plate 3.4.2. Pelletal layer in suspension at Station G7-4. (0.65X)

Plate 3.4.3. Small clumps of cohesive fine material on the sediment surface and just below the surface. (0.65X)

Independent current velocity measurements were not taken over the period during which the photographs were taken. However, in many of the photographs, eddy currents appeared to be lifting sediment into suspension from the surface of these clumps. One explanation proposed for the presence of these cohesive clumps at the Port Gardner site is that a previous erosive event freed them from the cohesive silt/clay matrix. It is also conceivable that sediment cohesive forces resisted errosive currents which might otherwise have resuspended and transported the fine particles. As the dynamics of the effects of erosive processes in cohesive, fine sediments are better understood and comprehensive current measurements are collected for this area, alternative explanations may be provided.

Detrital Layers. A finely divided layer of pelagic detritus or debris was noted at the sediment/water interface at the two shallowest REMOTS stations at the Port Gardner ZSF (G6-6 and G8-6, Plate 3.4.1). In a study performed in February and March of 1985, "a thin layer of [fine] wood waste debris" was found, principally in the extreme southeastern portion of the ZSF and in the shoaling area to the east of the ZSF (PSDDA, 1985). These findings suggest that at the time of both these evaluations, along-bottom current regimes were low enough to allow this easily transported material to be deposited and remain. During REMOTS and ground-truth sampling, no other evidence of a deposition of fine detritus was noted.

Bedforms. Apparent beforms for the ZSF were seen in one replicate at G9-5 and at G9-1. No other similar indications of current-induced wave forms were found in this area, despite significantly more intensive coverage. The conclusion is that these findings represent localized and spatially restricted higher current regimes. MANTA sonograms (Appendix C-2 and Exhibit A-2b) suggest presence of wave forms and bottom scour in the fine sediments between Stations G7-4 and G7-6.

Redox Potential Discontinuity (RPD).

The percentage distribution for mean apparent RPD in the REMOTS-surveyed stations of the Port Gardner ZSF is shown in Figure 3.4.5. Values ranged

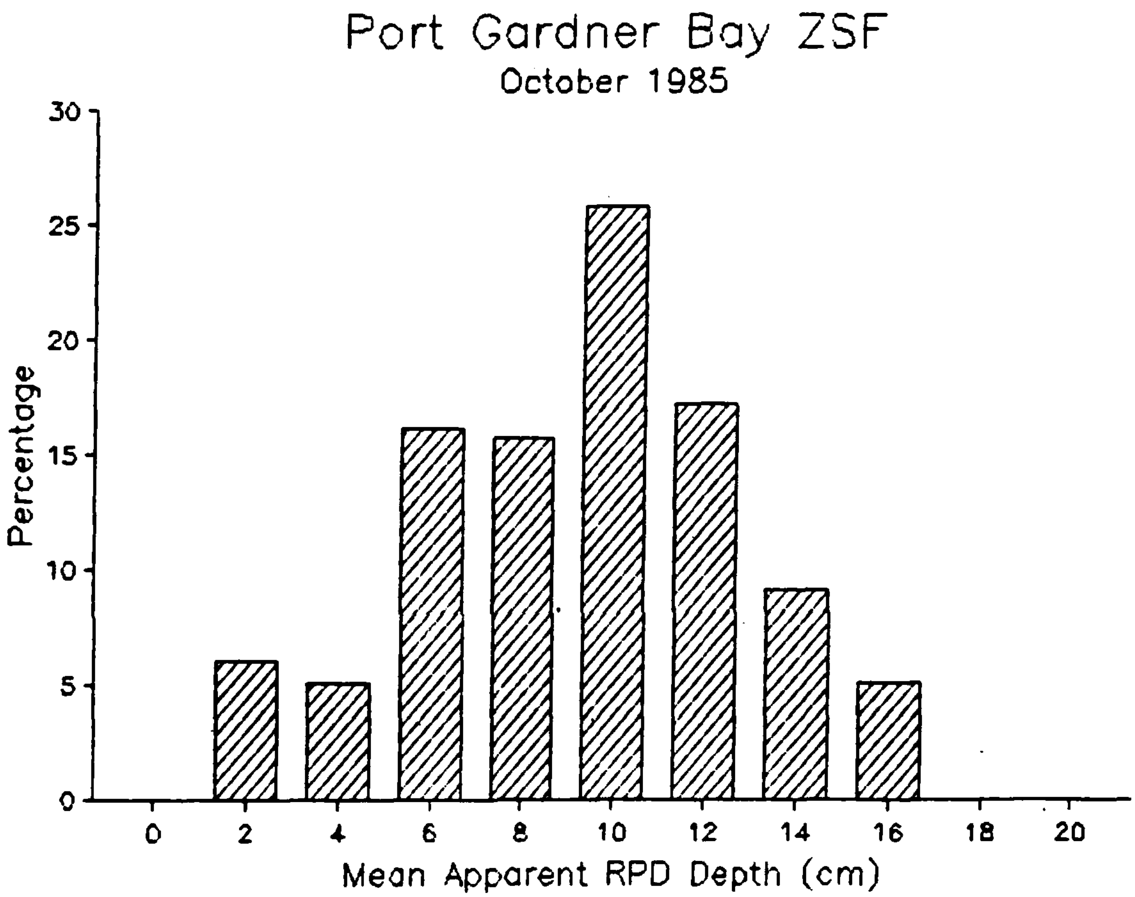

Figure 3.4.5.
Histogram of Mean Apparent RPD in the Port Gardner ZSF

between 0.0 and 16.2cm (with a mean of 8.74cm and a standard deviation of 3.54cm) and were close to or exceeded penetration depth in some cases. The major mode for RPD occurred with the 8 to 10cm class interval. Figure 3.4.6 portrays spatial distribution of RPD depths within the ZSF. The close correlation between depth of RPD and extent of bioturbation suggests that bioturbation effects are extensive in this ZSF.

One or more replicates in some stations showed deeper RPDs than would be anticipated based on values for surrounding stations. In these cases, the reflectance of the sediments underlying the RPD was significantly lower than the majority of replicates for all ZSFs. Stations G5-1, G5-4, G4-8, G3-3, G3-2 and all but the westernmost and easternmost stations of Transects 9 and 10 had a thick layer of this low reflectance material which exceeded the depths of penetration (cf. Plate 3.4.4, Rep. G10-3b). Their low reflectance suggests that these sediments were highly organic and strongly reduced. Undoubtedly associated with the observed degree of kinetic disturbance to the station (well-developed bedform) and its associated impacts on deep deposit feeders, Station G9-5 had a low mean apparent RPD (2.31cm).

REMOTS analysis indicates that the sediments at depths of between 0 and 10cm from these stations were relatively poorly sorted. Thus, they do not appear to have been deposited by currents or riverine inputs. In addition, stations G2-1, G2-9, G3-1 and G9-5 showed depressions in RPD depths in comparison with nearby stations. As contents of Van Veen grabs from the southeastern portion of the ZSF were informally inspected during ground-truthing efforts, it was apparent that pioneering infaunal species (principally Stage I: Capitella capitata) were the dominant organisms for these stations. Capitellids are often used as indicator species for organically enriched or polluted areas. (See Section 3.4.2 for additional discussion of the distribution of apparent infaunal community successional stages.)

Without further study, it is difficult to provide a definitive explanation for the observed characteristics. Poor within-replicate sediment sorting suggests an origin outside of natural systems. Dominant infauna for these

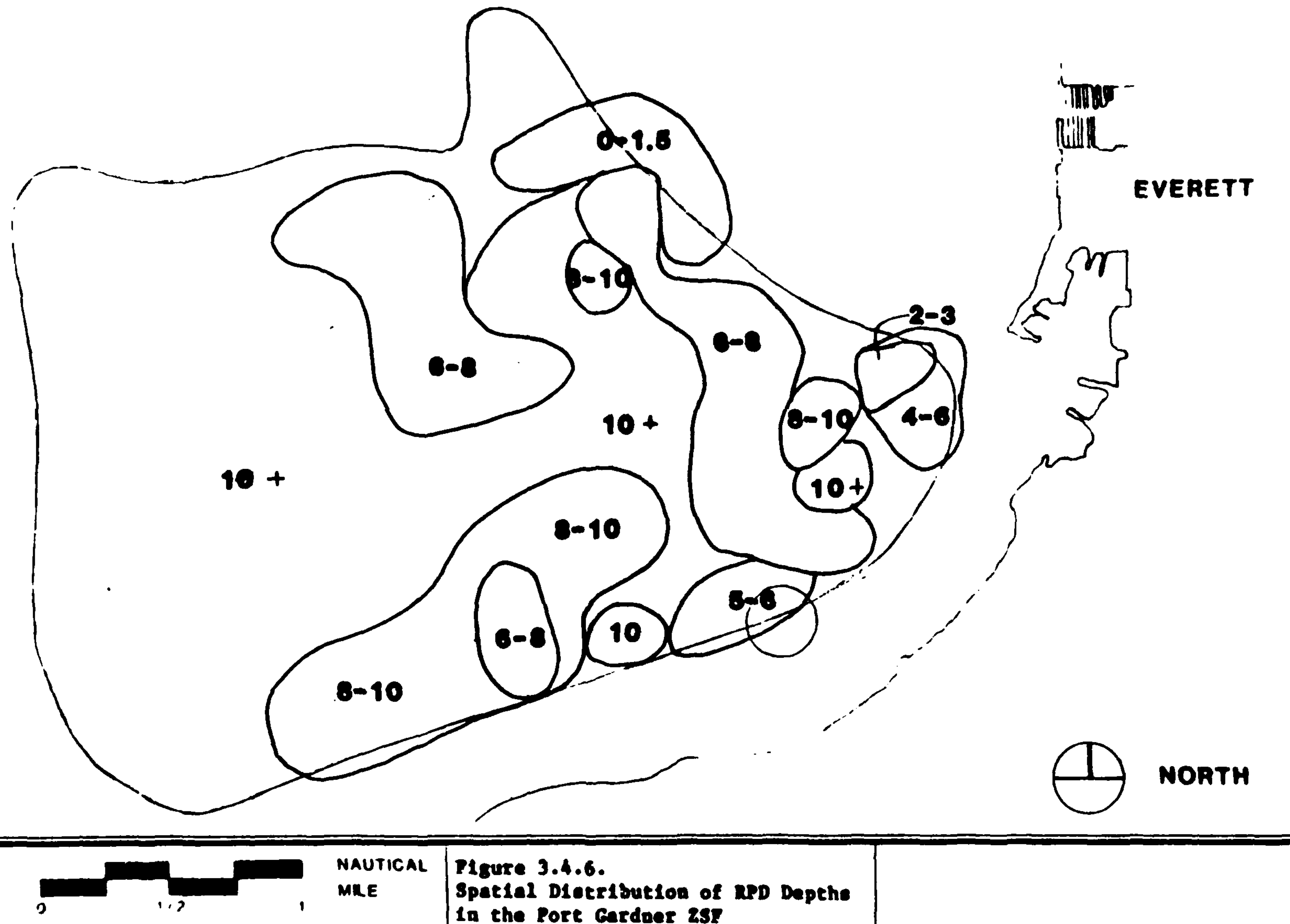

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Figure 3.4.6.
Spatial Distribution of RPD Depths
in the Port Gardner ZSF

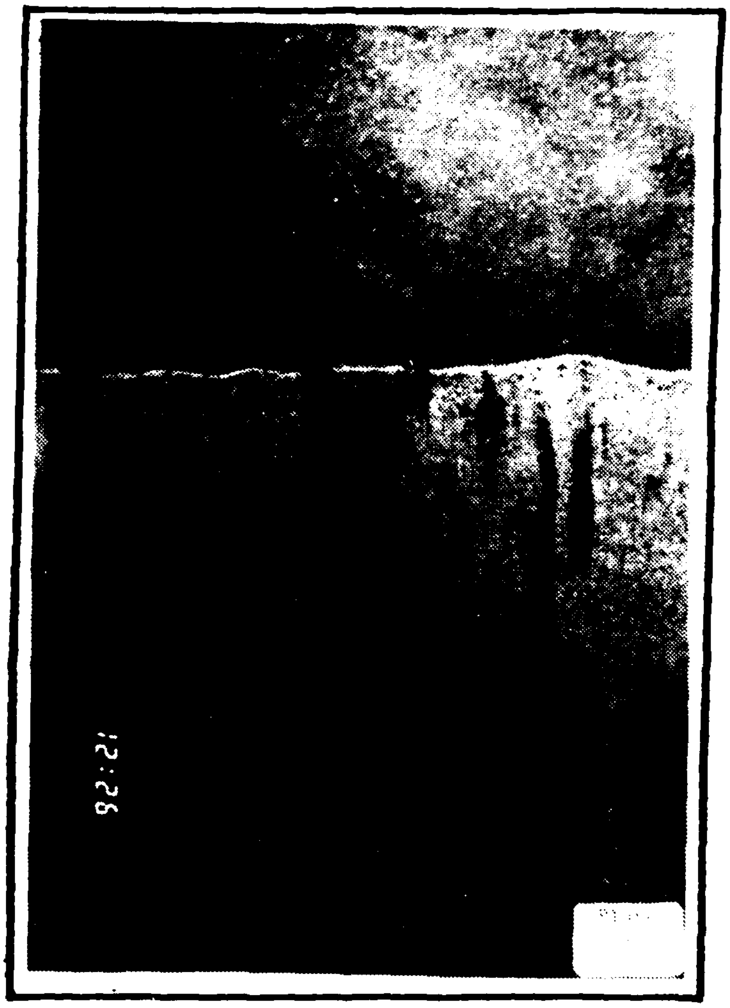

Plate 3.4.4. Highly organic sediments indicated by low reflectance (dark) character. (0.65X)

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low sediment reflectance areas are pioneering species. Relatively shallower apparent RPD depths (relative to surrounding stations with similar substrate characteristics) are undoubtedly related to minimal depths to which Stage I species are able to irrigate and rework sediments. Finally, reflectances of the substrate underlying the RPD are indicative of high sulfide and/or high organic levels.

Port of Everett marina dredge material disposal, conducted in the intertidal areas of Jetty Island in the fall of 1983 (John Malick, personal communication), may have been driven by currents to provide the source of coarser material seen in most of these stations. The wide range of sediment classes for Stations G1-1 and G1-2 and poor sediment sorting (Plate 3.4.5, Rep. G1-1c) reflect the presence of disposed materials. However, the observed highly non-reflective underlying material within these stations suggests two explanations. First, these sediments might contain compounds which have inhibited development of Stage III fauna which would have been able to rework the sediments to a greater depth and depress the RPD. Alternatively, the observed conditions may be the result of a recent and currently unexplained perturbation which has caused the loss of Stage III assemblages.

A good explanation is not available for source material causing conditions observed in the one replicate in Station G5-4. Based on the experience of the principal investigators in the monitoring of effects of the disposal of dredged materials and the available information, the observed characteristics for the above Stations appear to be the result of disposal activities. The apparent depression of the mean RPD at Station G1-2 may have resulted from disposal at the adjacent former permitted disposal Site.

3.4.2 Biota

Infaunal Community Successional Stage

Figure 3.4.7 characterizes the distribution of apparent infaunal successional stages at the Port Gardner ZSF. Of the 198 REMOTS images

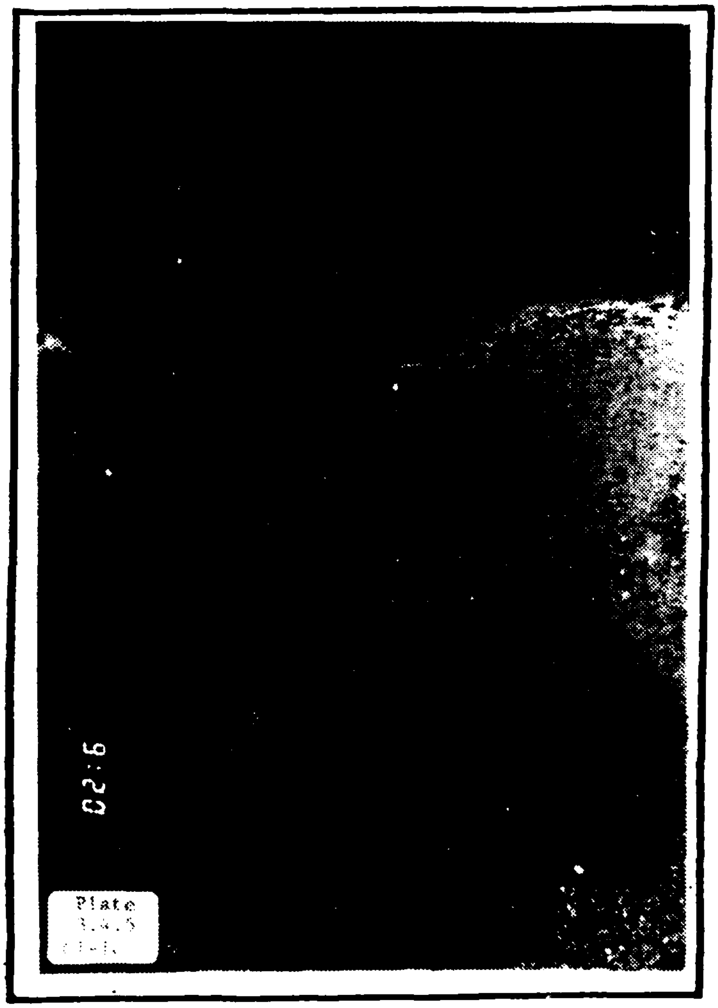

Plate 3.4.5. Poor sediment sorting, reflecting assumed presence of dredged materials near DNR Disposal Site. (0.65X)

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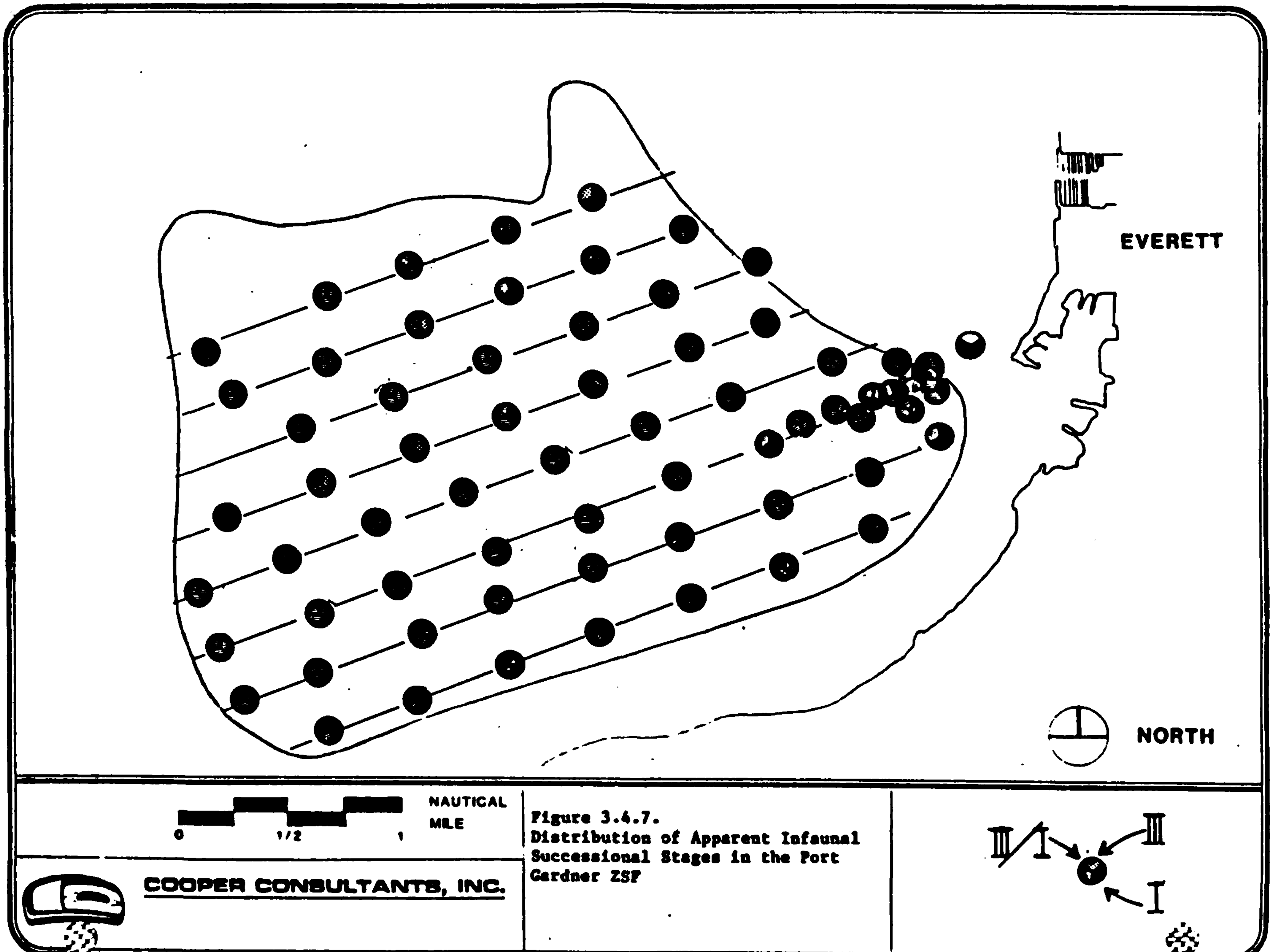


Figure 3.4.7.
Distribution of Apparent Infaunal Successional Stages in the Port Gardner ZSF

analyzed from the Port Gardner ZSF, 18 showed apparent Stage I organisms alone. (Appendix D-2) These photographs and incidental visual inspection of grab samples collected during ground-truthing activities, indicated that the dominant Stage I infaunal assemblage was composed of spionid and capitellid polychaetes. During ground-truthing field efforts, capitellids were noted to be particularly abundant on Transects 9 and 10, and at other stations in the southeastern portion of the ZSF where shallow RPDs and/or highly reduced sediments were noted.

Apparent Stage I polychaetes were represented in at least one replicate at each station. In 12 replicates, the sole representatives were apparent Stage III fauna (evident by the presence of such feeding structures as feeding voids and fecal mounds attributable to large deposit feeders and burrows probably produced by shrimp). In the remainder of the replicates or 85 percent of those analyzed, the apparent community structure was Stage III organisms with a subordinate or secondary occupation by Stage I benthic faunal assemblages. In the large majority of cases, an apparent mean RPD depth in excess of 10cm (Figure 3.4.6) coincided with the apparent presence of large, mature deposit feeders (Stage III) actively reworking the upper sediments.

Other Biotic Community Elements

MANTA sonograms (Appendix C-2 and Exhibit A-2b) indicate extensive fish populations were present in the area of G7-1, G8-5 and G8-6. Poor visibility (high turbidity) precluded successful recovery of either video or still camera images which were to have provided confirmation of megafauna (bottomfish and crabs) inhabiting the Port Gardner ZSF. Suspected use of the area by gravid Dungeness crabs (*Cancer magister*) and characteristics of distribution of bottomfish stocks will require further study prior to siting of disposal areas.

3.4.3 Conclusions

Figure 3.4.2 delineates a gradient in sediment class which roughly corresponds with the bathymetric gradient in the eastern portion of the

Port Gardner ZSF. In the absence of other data, presence of cohesive silt/clay clumps ("mudclasts") and evidence of bedload transport in REMOTS images suggest that a high energy bottom current regime can occur in the western half and a localized area in the southeastern corner of the site. A typical pattern may be the resuspension of particles up to 3mm in diameter apparent in Plate 3.4.6.

Limited information indicates that during the REMOTS evaluation a lower energy regime existed in the eastern half of the site with the exception of the southeastern corner. Stations in the northeastern and southeastern portion of the site showed evidence of deposition of finely divided debris and detritus. Based on an absence of mudclasts associated with the silt-clay sediments in the eastern central portion of the site (Stations G5-4 to G5-2 and G4-5 to G4-8) a low energy area may exist in this vicinity.

REMOTS images used for evaluation of conditions at the Port Gardner ZSF were collected during a period of high river runoff and stormy conditions. Without independent measurements of along-bottom currents, absolute characterization of the ZSF in terms of erosional/depositional environments is not possible. However, the available data allow interim judgements which respond to the best explanation for apparent substrate attributes. Figure 3.4.8 presents an interpretation of potential near-bottom current regimes, based on the presence of mudclasts, poorly sorted and coarser sediments and the presence of bedforms.

The majority of the site was dominated by apparently well-developed infaunal deposit-feeding assemblages. These organisms were actively reworking the upper 10 to 20cm of sediment and were responsible for most of the small-scale sediment surface topography. The bioturbation activities of this community are inferred to be responsible for increasing the porosity and water content of the silt-clay materials which dominate the site. The presence of these species may accordingly have significant impacts on the geotechnical properties and erodability of these substrates. All stations showed the presence of small, opportunistic

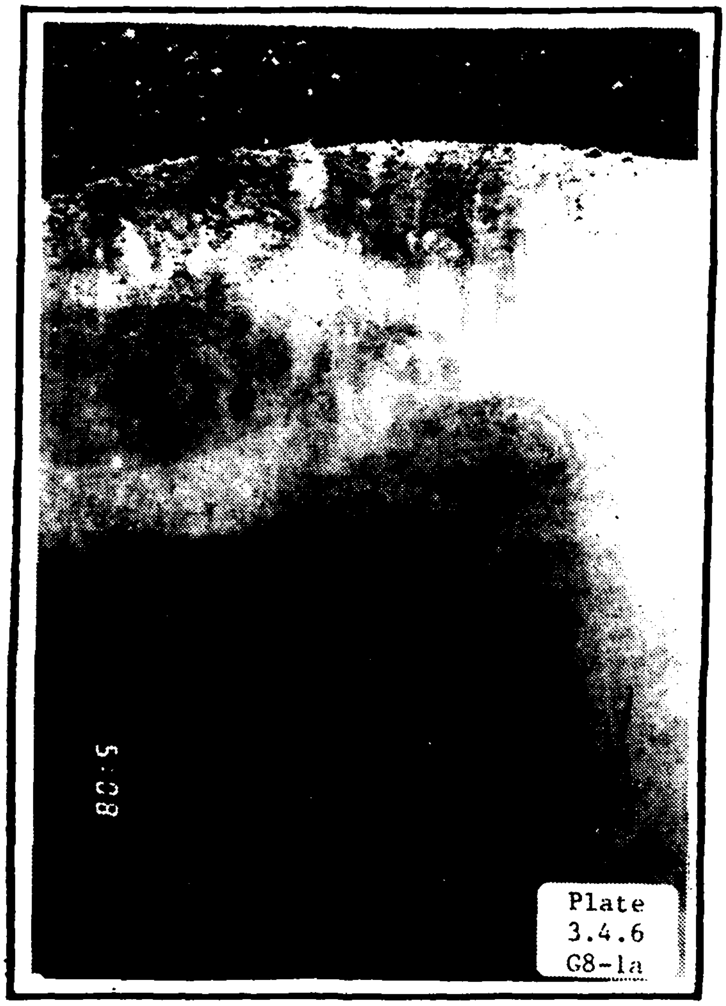
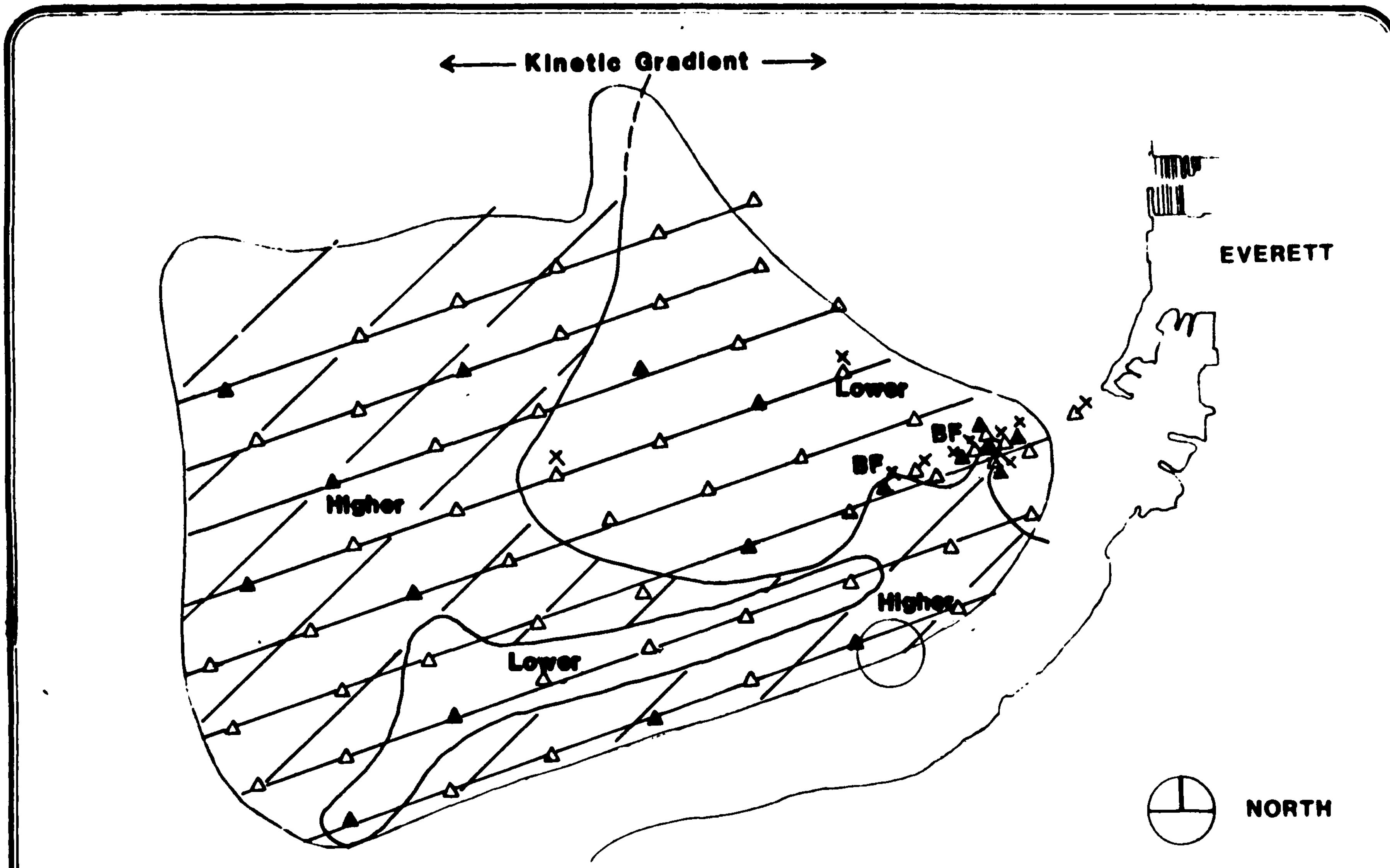


Plate 3.4.6 Resuspension of particles up to 3mm in diameter. (0.65X)



NAUTICAL MILE
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3.4.8.
Benthic Process Map for the Port Gardner ZSF, based on Apparent Indicators

▲ REMOTS & VAN VEEN
△ REMOTS ONLY
X POORLY SORTED MATERIAL
BF BEDFORM
MUDCLAST

near-surface polychaetes which are probably a good source of food items for fish.

The data suggest that there are periodic currents, particularly in the western half of the site, sufficient to disrupt the cohesive sediment surface and produce sediment clumps in the southeastern corner (where current scour seems to have produced surficial coarseness of sediment). The presence of well-developed micro-relief in the western half of the Port Gardner ZSF indicates that such events occur on a time scale long enough to allow re-establishment of observed small-scale boundary roughness. Some evidence suggests that quiescent periods occur in the eastern half of the site. The principal data need for this ZSF is an evaluation of apparently dynamic along-bottom current regimes and their effects on resuspension of sediments. Such studies should be concentrated in areas chosen for potential dredge material disposal sites.

Finally, basic information is needed regarding the successional structure of the soft bottom community in the ZSF and importance of the area as habitat for bottomfish and crabs (specifically Dungeness crab).

3.5 Fourmile Rock ZSF

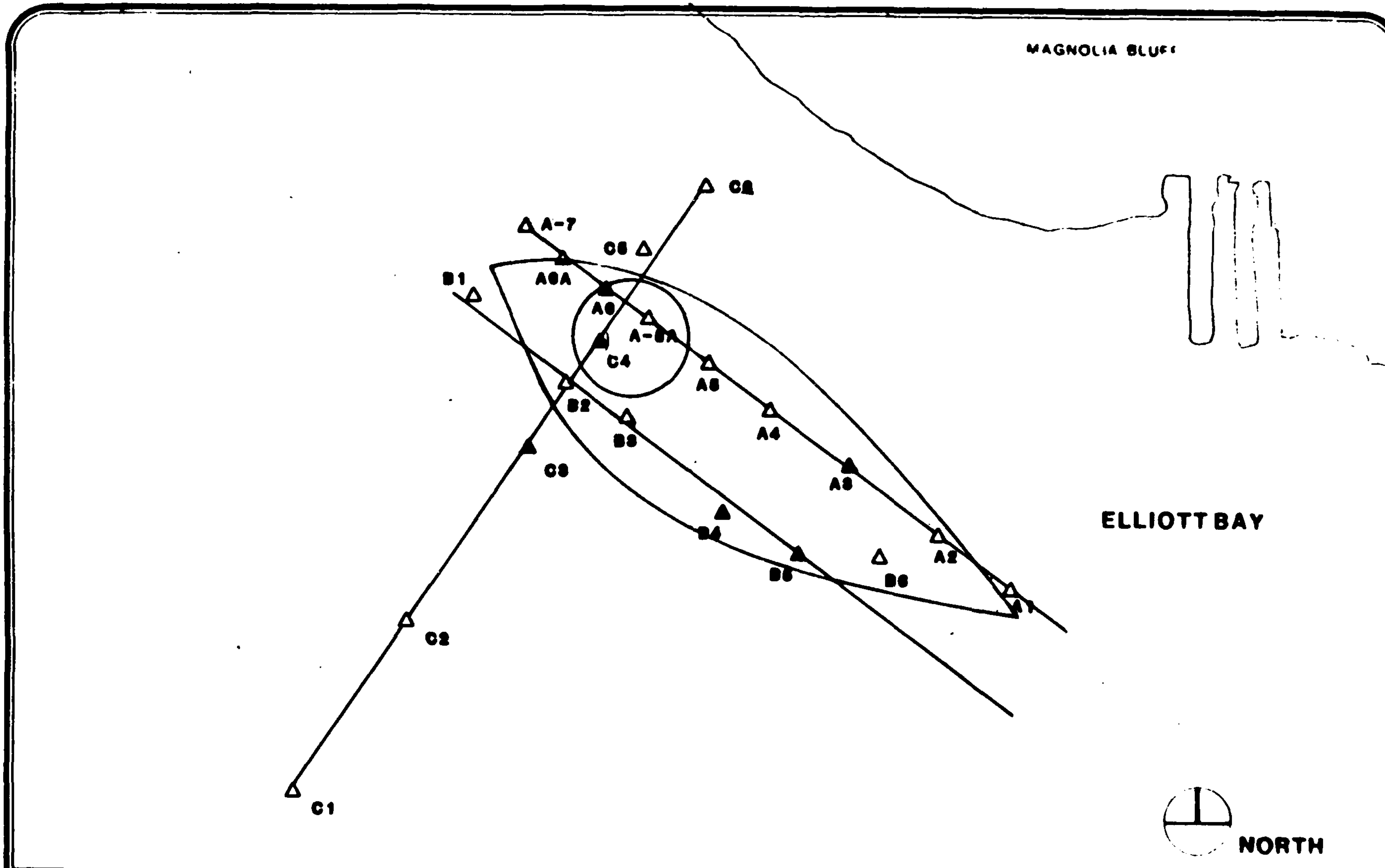
Field work was performed at the Fourmile Rock ZSF (Figure 3.5.1) in northern Elliott Bay on November 1 and 2, 1985. Two parallel transects (Transects A and B) served as the basis for MANTA operations. An additional onshore-offshore transect (Transect C), perpendicular to the other two transects and bisecting the Fourmile Rock Disposal Site, was selected in the field. Twenty-five REMOTS sampling stations were established on these three transects. From among the total of 85 photographic replicates taken, a total of 61 replicate REMOTS images were analyized. The 7 REMOTS stations noted in Figure 3.5.1 were used for ground-truthing with the Van Veen sampler.

3.5.1 Geophysical Characteristics

Sediment Grain Size

Sediment characteristics in the Fourmile Rock ZSF are shown in Figure 3.5.2. This portrayal is based on analysis of REMOTS major mode grain size data, an evaluation of PSD ground-truthing results and MANTA sonograms. Two major grain-size classes were present at this site. The deepest stations, E2C-1 through E2C-3, consisted of silt-clay sediments. Some shallower stations (E2C-3, E2B-2, E2B-5 and E2A-1) had a major mode in the silt-clay class and contained significant fractions of sands. Several stations located on Transects A, B, and C consisted of poorly-sorted, very fine to fine sands (E2A-2 through E2A-7, E2B-1, E2B-3, E2B-4, E2B-6 and E2C-5). The coarsest sediments were found at station (E2C-6), located in 45 meters of water. They consisted of medium sand.

Disposed dredge material was evident at a minimum of three stations (E2A-5A, E2A-6 and E2C-5). An example of the "chaotic" sedimentary fabric associated with disposed materials is shown in Plate 3.5.1 (Rep. E2A-5b). MANTA sonograms (Appendix C-3 and Exhibit A-2c) suggest the presence of dredge material at scattered locations along Transect A.



NAUTICAL MILE
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Figure 3.5.1.
Transects & REMOTS Stations in the Fourmile Rock ZSF

▲ REMOTS & VAN VEEN
△ REMOTS ONLY

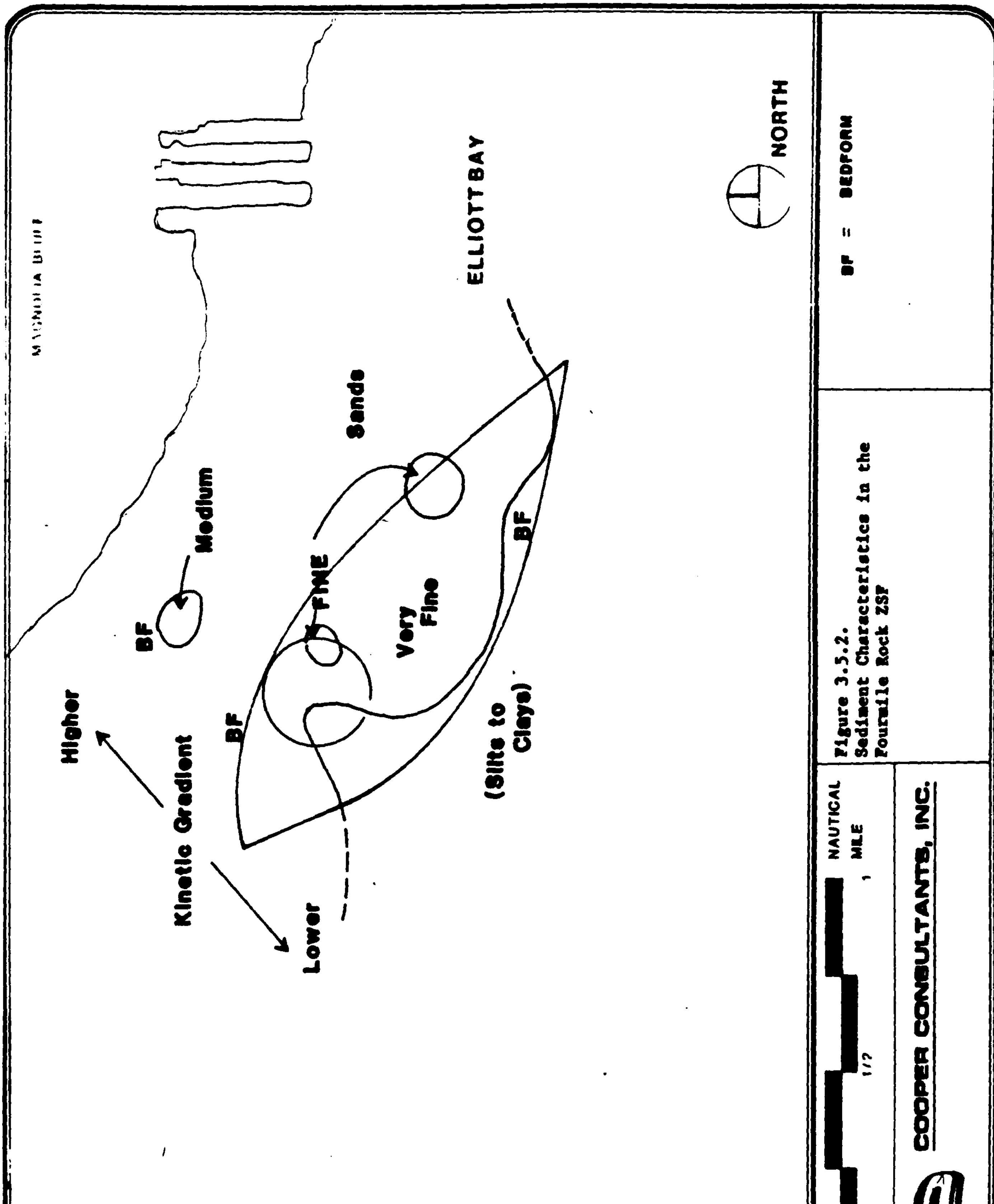

Figure 3.5.2.
Sediment Characteristics in the Fourmile Rock ZSF

Plate 3.5.1. "Chaotic" distribution of sediments at Station E2A-5. Low reflectance, high organic muds in place, on top of coarser materials is an indication of the presence of dredged materials. Station is within the DNR Disposal Site. (0.65X)

REMOTS Camera Prism Penetration Depth

The range of penetration values was between 0.04 and 18.34cm with a mean of 10.24 and a standard deviation of 5.26cm. Relatively shallow camera prism penetration depths were seen along Transect A, from E2A-4 northwest to E2A-7 at the far end of the transect, and inshore from Station E2C-4 to E2C-6 (See Appendix D-3). These stations had the coarsest sediments and probably have been most affected by disposal operations. Greater depths of penetration for the remaining stations appeared to be related to reduction of major sediment grain size class as well.

Small Scale Substrate Boundary Roughness and Other Physical Features.

Boundary Roughness. The apparent small-scale mean boundary roughness values for the Fourmile Rock ZSF (Figure 3.5.3) fell generally between 0.8 and 1.6cm, with a range of between 0.0 and 2.8cm. The mean of replicate values was 1.22cm, with a standard deviation of 0.7cm. One replicate at Station E2A-5A (Plate 3.5.1) exhibited a mean boundary roughness of 4.34cm and was more than 3cm greater than the others, due to presence of "chaotic" relict structure attributed to disposal activities. REMOTS photographs revealed that the majority of this micro-relief was due to activities of large macrofauna, as evidenced by the presence of fecal mounds and depressions (cf. Plate 3.5.2, Rep. E2A-2a). Persistence of well-developed boundary roughness suggests that lateral bedload transport was not occurring to a significant degree. Those portions of the ZSF with such micro-relief were indicative of a low velocity area (See Figure 3.5.2).

Bedforms. Bedforms were noted in REMOTS images at Stations E2A-1, E2B-6, E2A-6A, and E2C-6. MANTA sonograms indicated that bottom current generated wave forms occured in the area between Stations E2A-2 and E2A-1 (Appendix C-3). The apparent current direction was along the axis of the transect.

Coupled with data regarding sediment particle distribution and sorting characteristics, these attributes suggested a current gradient for the

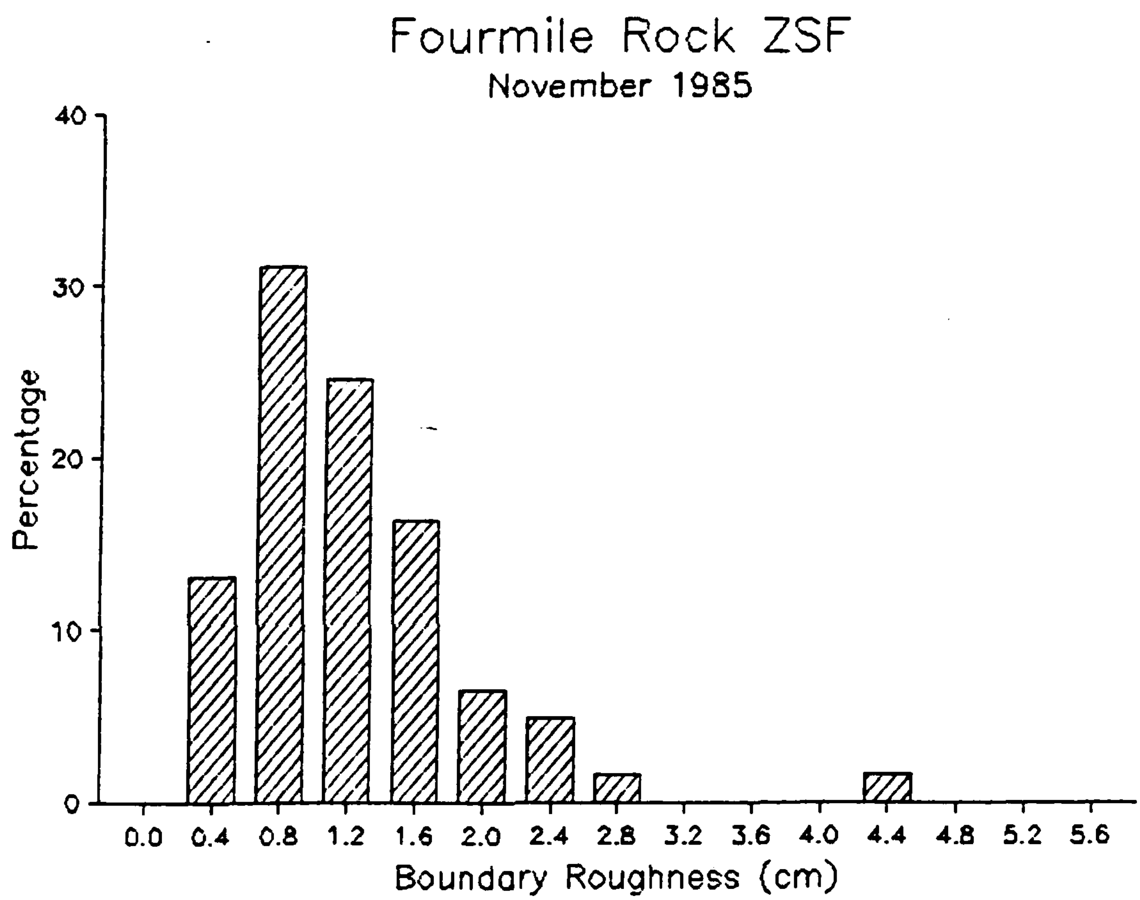

Figure 3.5.3.
Histogram of Small Scale Boundary Roughness in the Fourmile Rock ZSF

Plate 3.5.2. Micro-relief created by fecal mounds and depressions. (0.65X)

northwest segment of the ZSF which decreases from onshore to offshore. Additional stations offshore of Station E2B-6 will be required for documentation of along-bottom current regimes in this segment of the ZSF.

Redox Potential Discontinuity (RPD)

Placement of dredged materials and potential disruptive impacts on the fauna appeared to be the major cause of shallow mean apparent RPD values at the Fourmile Rock ZSF (in comparison to other areas surveyed). Shallow RPD values were noted for most of Transect A and B and the inshore segment of Transect C (Figure 3.5.4). The range of values was between 0.0 and 4.34cm, with a mean of 1.22cm and a standard deviation of 0.7cm (See Figure 3.5.5). Although additional stations would be required for more complete documentation (particularly associated with Transect C), the trend seemed to be one of increasing depth in RPD at greater distance from the Disposal Site: offshore along Transect C in deeper water, the extreme northeast end of Transect A (outside of disturbance) and potentially upcurrent of the Disposal Site at the northwest end of Transect B.

3.5.2 Biota

Infaunal Community Successional Stage

Figure 3.5.6 shows the distribution of apparent end-members of the infaunal successional community at the Fourmile Rock ZSF. Distribution of apparent Stage I and Stage III organisms appeared to be related to the presence of disposed dredge materials. This relationship was undoubtedly operating for all three replicates from Stations E2C-5 and E2A-6, where the apparent representative end-members were exclusively Stage I organisms and where sediment analyses indicated presence of disposed materials. All other stations showed a mixture of apparent Stage I and Stage III organisms. In most cases, the mean apparent RPD mirrored the apparent successional stage (See Appendix D-3).

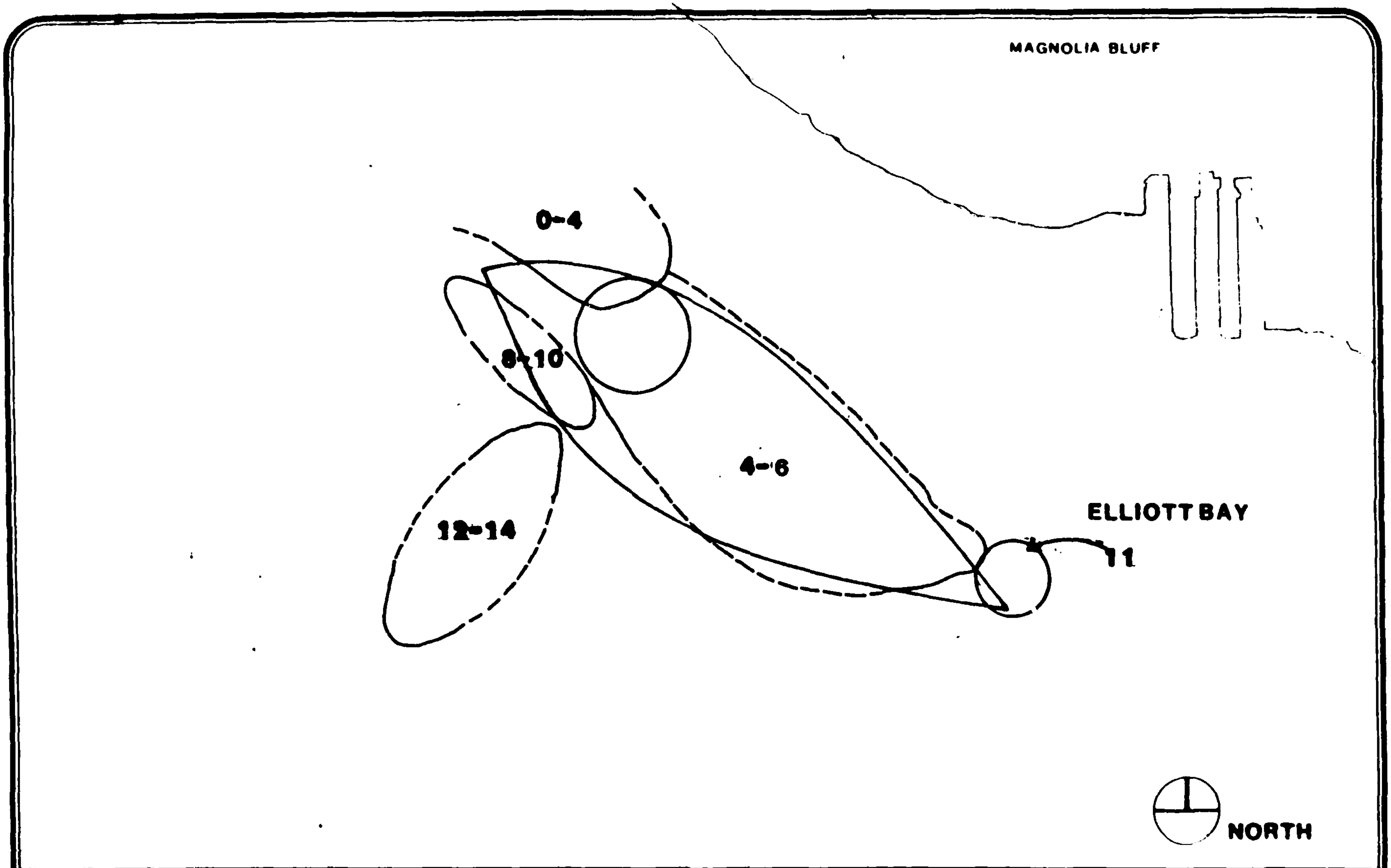

Figure 3.5.4.
Distribution of RPD depths in the Fourmile Rock ZSF

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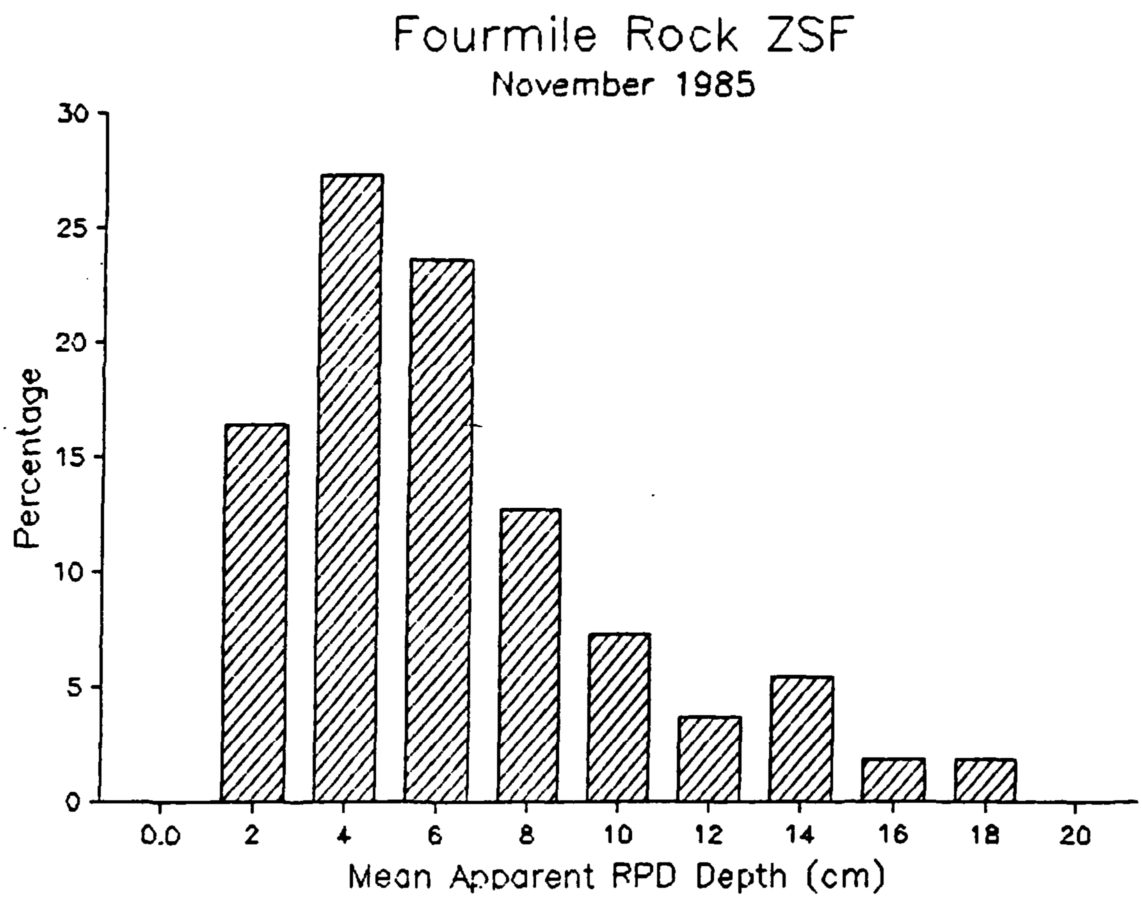

Figure 3.5.5.
Histogram of Apparent RPD Depths
in the Fourmile Rock ZSF

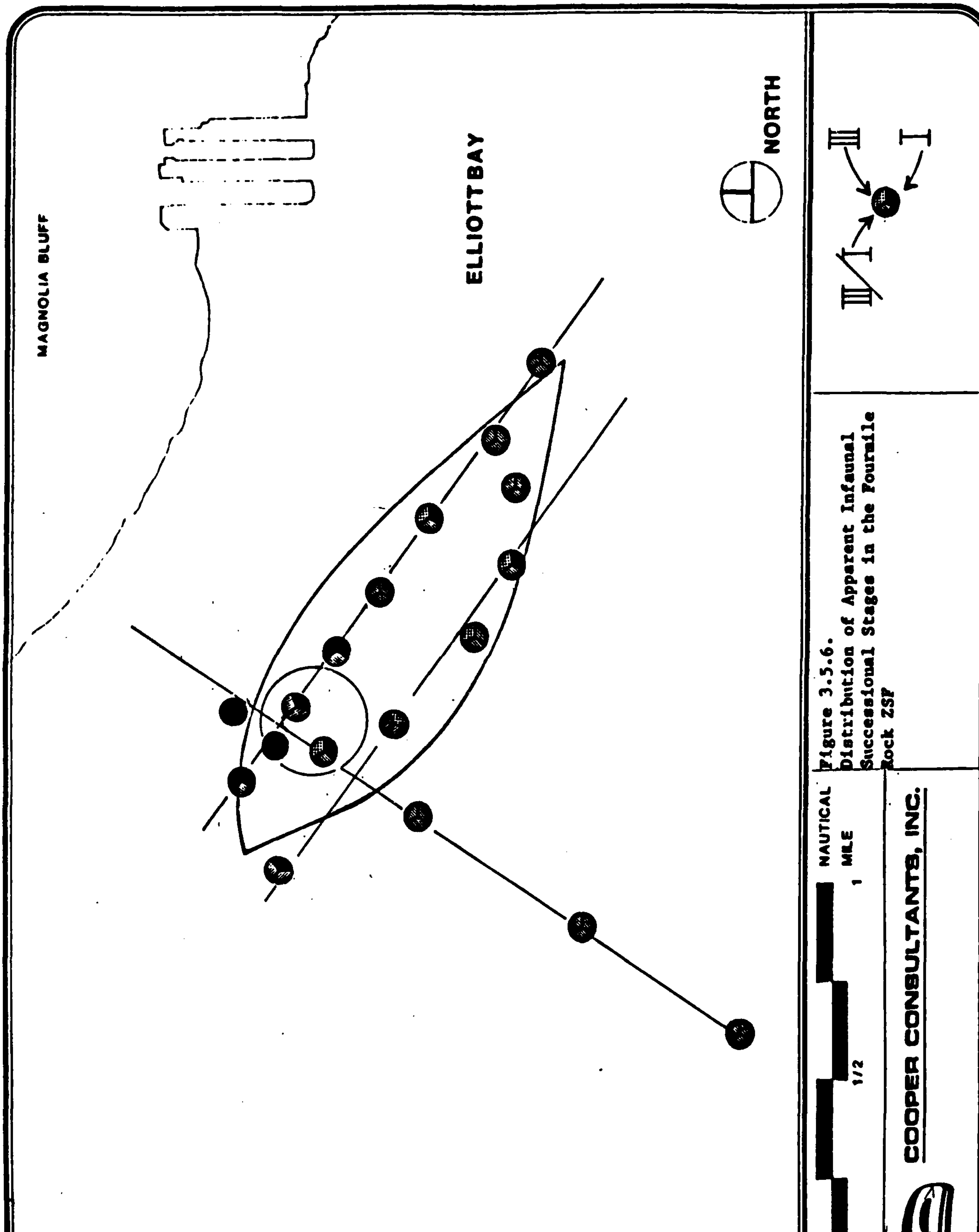

Figure 3.5.6.
Distribution of Apparent Infaunal Successional Stages in the Fourmile Rock ZSP

Other Biotic Community Elements

Many stations showed the presence of amphipods belonging to the family Podoceridae on their stick-like flagellae (e.g., Stations E2A-4, E2A-6; and Plate 3.5.1). No mobile megafauna were observed during the evaluation.

3.5.3 Conclusions

Kinetic (current velocity) gradients (Figure 3.5.2) are suggested by grain size and sorting information and the distribution of bedforms. It appears that the majority of permitted disposal operations have occurred in the area of greatest current velocity, although some less controlled disposal activities may have occurred in the southeastern segment of the ZSF as well.

3.6 Inner Elliott Bay ZSF

Field work was performed at the Inner Elliott Bay ZSF (Figure 3.6.1) between November 1 and 2, 1985. Three parallel transects (Transects A, B and C) served as the basis for MANTA operations and for locating 11 REMOTS stations. A total of 42 REMOTS replicate images were analyzed. The four REMOTS stations noted in Figure 3.6.1 were sampled during ground-truthing activities.

3.6.1 Geophysical Characteristics

Sediment Grain Size

Characterization of sediments in the Inner Elliott Bay ZSF (Figure 3.6.2) was based on REMOTS major mode grain size analysis, ground-truthing PSD evaluation and MANTA sonograms. In the absence of corroborating data on currents, sediment distribution appeared to be related to a kinetic or bottom current gradient. The kinetic gradient extended from the northeast (low) to the southwest (high) and seemed to correspond with a gradient in bathymetry.

Silt-clay sediments were identified at Stations E1A-1 and E1A-2 in 80 to 89 meters of water. The coarsest materials, consisting of rippled, poorly sorted fine sands were located at Station E1C-3, Plate 3.6.1) located at a depth of 59 meters. The remainder of the stations were intermediate in grain size and were generally represented by poorly sorted, very fine sands admixed with silts and clays.

REMOTS Camera Prism Penetration Depth

The range of penetration values was between 7.9 and 20.66cm, with a mean of 16.08cm and a standard deviation of 3.87cm. From Appendix D-4, shallower camera prism penetration depths were associated with the coarse sediments seen at Station E1C-3. The deepest penetration depths for the Inner Elliott Bay ZSF were in the soft sediments in the north and northeast segment of the ZSF (E1A-1, E1A-2 and E1B-4).

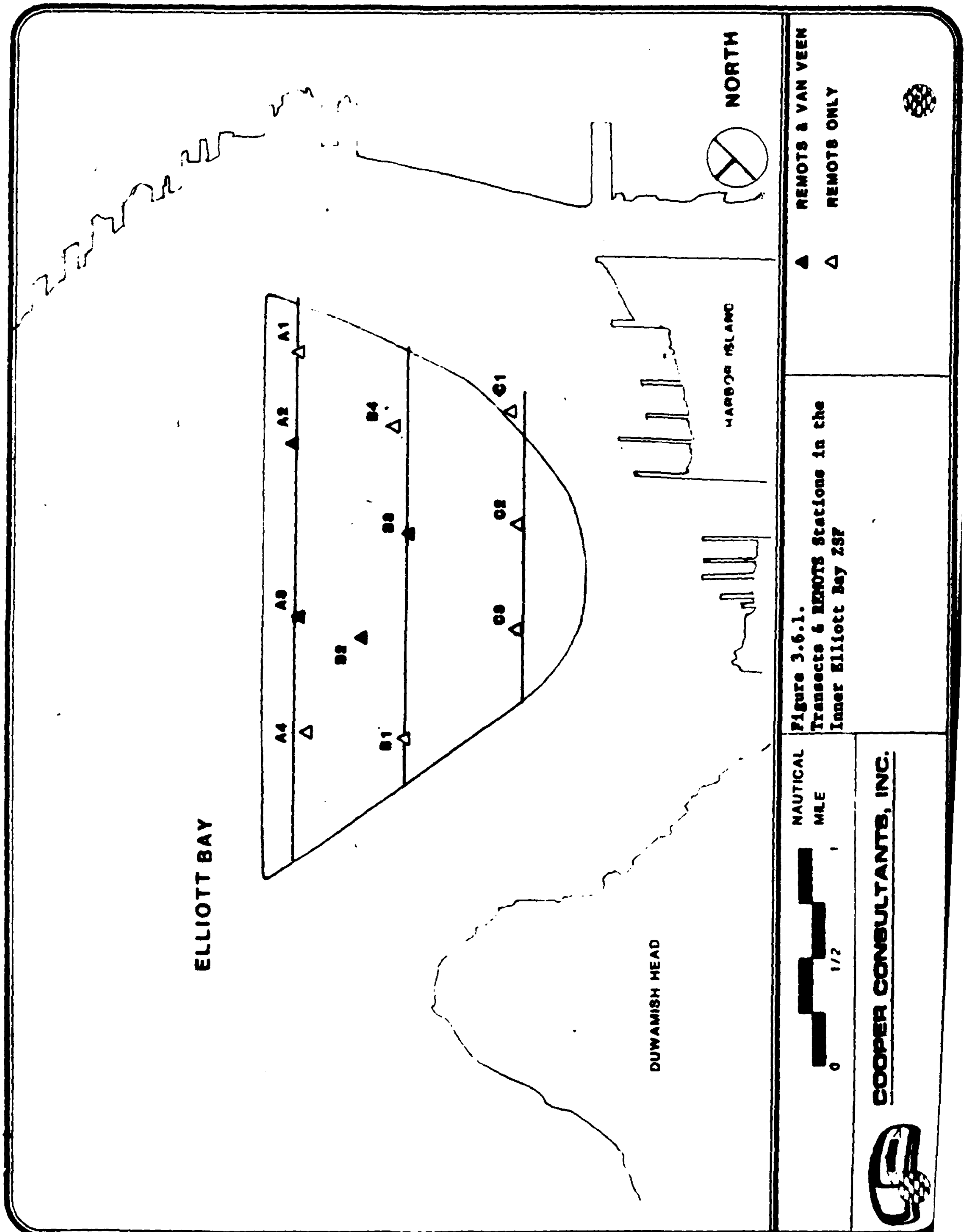

Figure 3.6.1.
Transects & REMOTS Stations in the Inner Elliott Bay ZSF

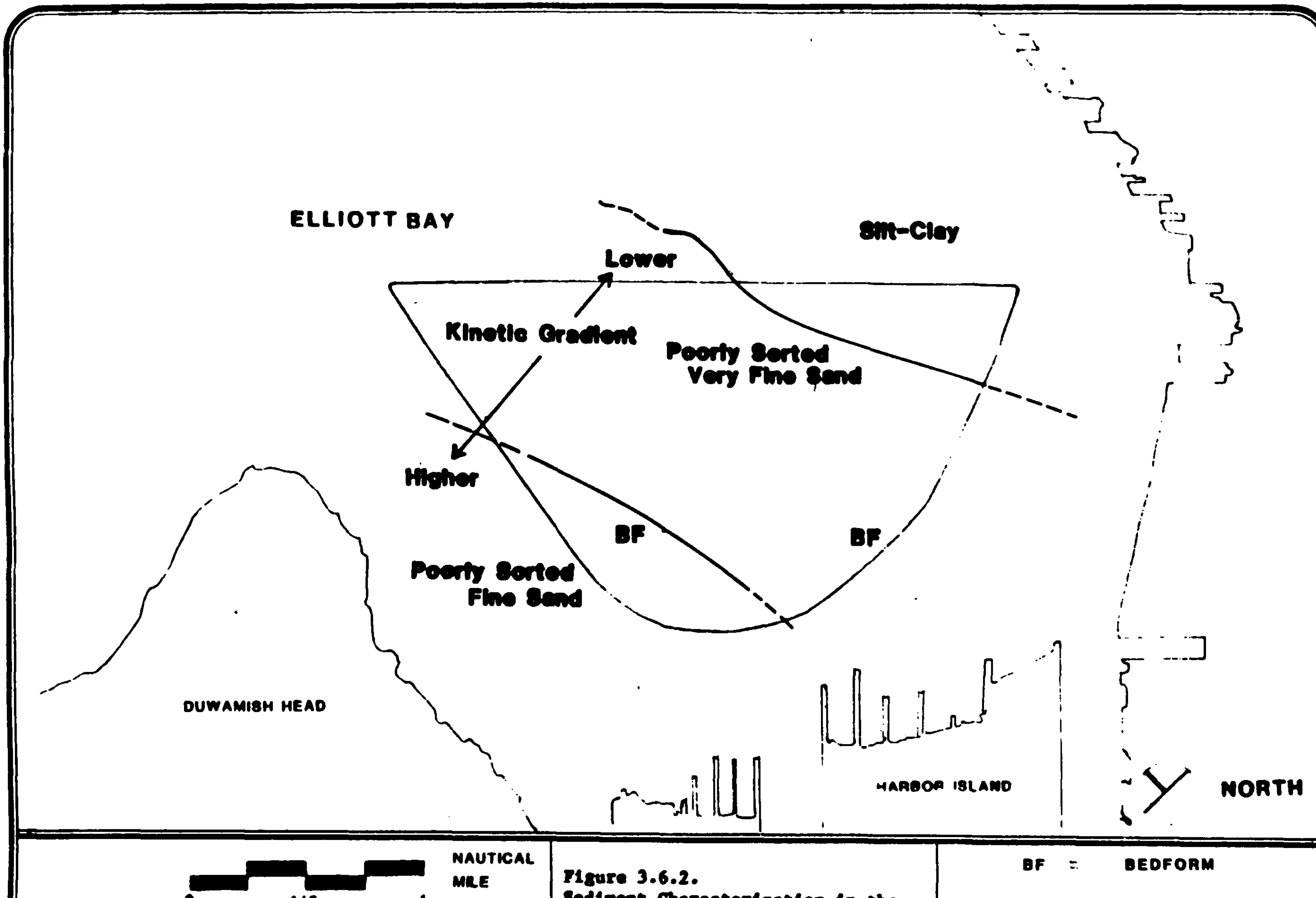

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Figure 3.6.2.
Sediment Characterization in the
Inner Elliott Bay ZSF

BF = BEDFORM

Plate 3.6.1. Rippled, poorly sorted fine sands at Station E1C-3. (0.65x)

Small-Scale Substrate Boundary Roughness and Other Physical Features

Boundary Roughness. Based on the percentage histogram presented in Figure 3.6.3 and data in Appendix D-4, apparent mean REMOTS small scale boundary roughness values for the Inner Elliott Bay ZSF generally fell between the 0.8 and 1.6cm class intervals, with a range of 0.0 to 4cm. The mean of values was 13.8cm, with a standard deviation of 0.73cm. The station with the highest mean boundary roughness (3.75cm) was E1A-1, where the lowest kinetic regime is anticipated. REMOTS data indicated that the majority of the micro-relief in the ZSF was of biogenic origin and was potentially modified by the effects of current regimes.

Bedforms. Bedforms were noted at Stations E1C-1 and E1C-3 (Figure 3.6.2).

MANTA sonograms (Appendix C-4 and Exhibit A-2d) suggest that deep anchor scars in fine sediments of the bottom are persistent over the short term. This supports other indications of low current velocities in the northeast quadrant.

Redox Potential Discontinuity (RPD)

The range of mean apparent RPD values for the Inner Elliott Bay ZSF was between 2.73 and 18.21cm, with a mean of 11.46cm and a standard deviation of 4.36cm. The percentage distribution of values appears in Figure 3.6.4. With the exception of the stations along Transect C, all RPD values were in excess of 9cm (Figure 3.6.5). The station with the highest mean apparent RPD was the deepest station, E1A-1, located in the area of finest sediments. The station with the lowest mean apparent RPD was E1C-3. This latter station was the shallowest and was located in the area of potentially highest kinetic energy and coarsest materials. It may be subject to repeated surficial disturbance. The intermediate stations were located in transitional depths of between 62 and 67 meters, and potentially demonstrate a region of intermediate current regimes and surficial disturbance.

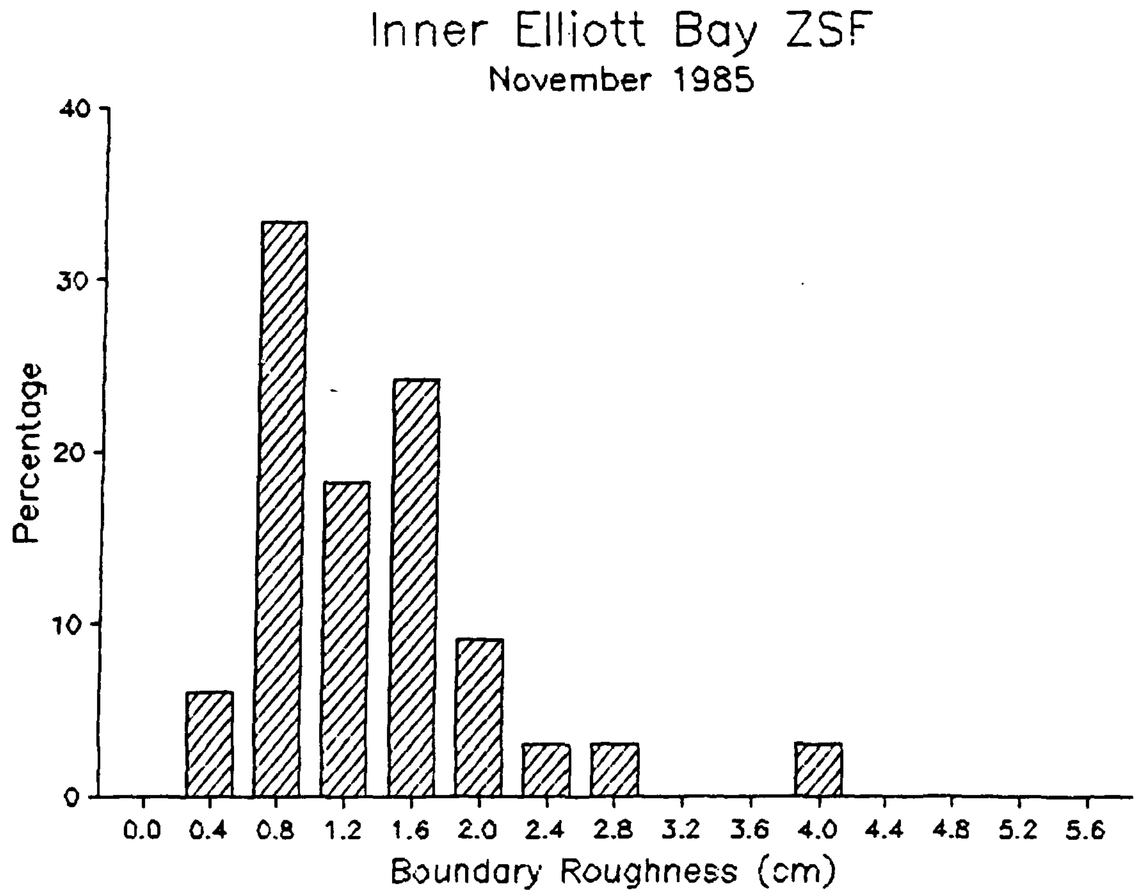

Figure 3.6.3.
Histogram of Small-scale Boundary Roughness in the Inner Elliott Bay ZSF

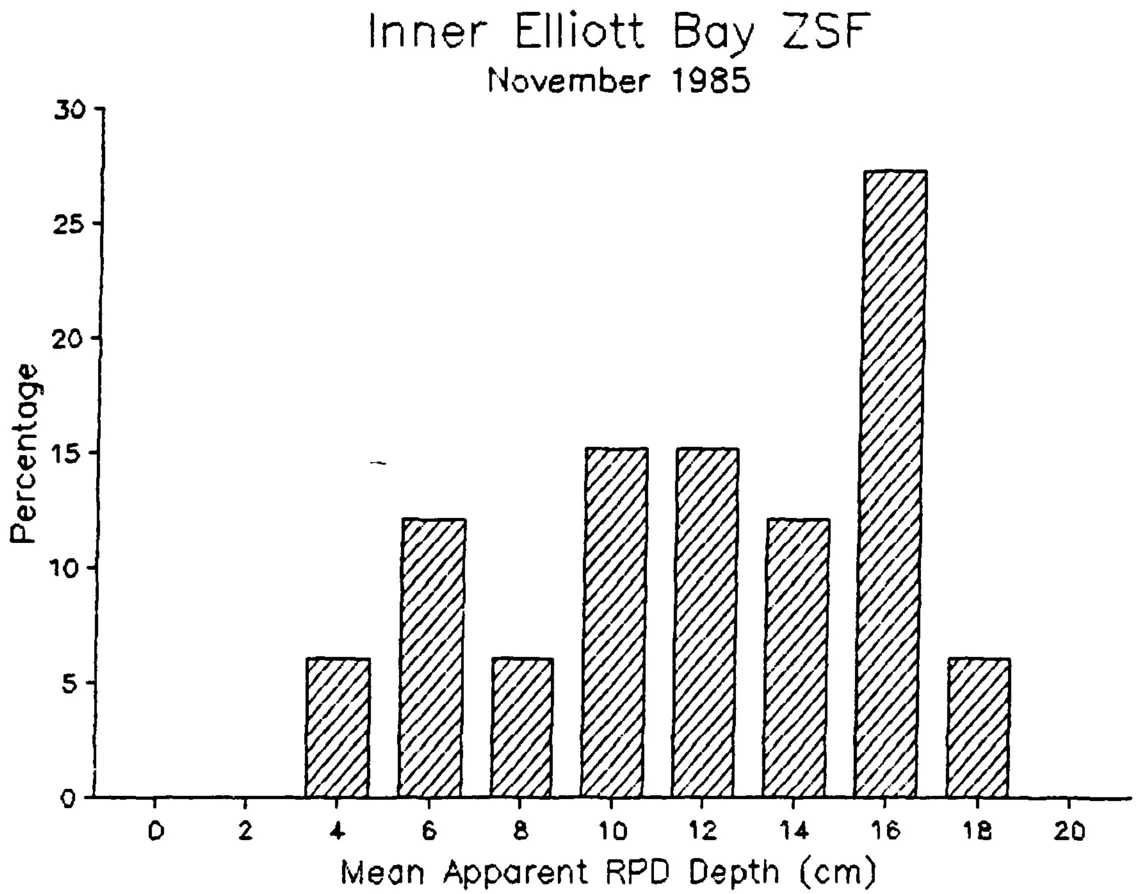

Figure 3.6.4.
Histogram of Mean Apparent RPD
Depths in the Inner Elliott Bay ZSF

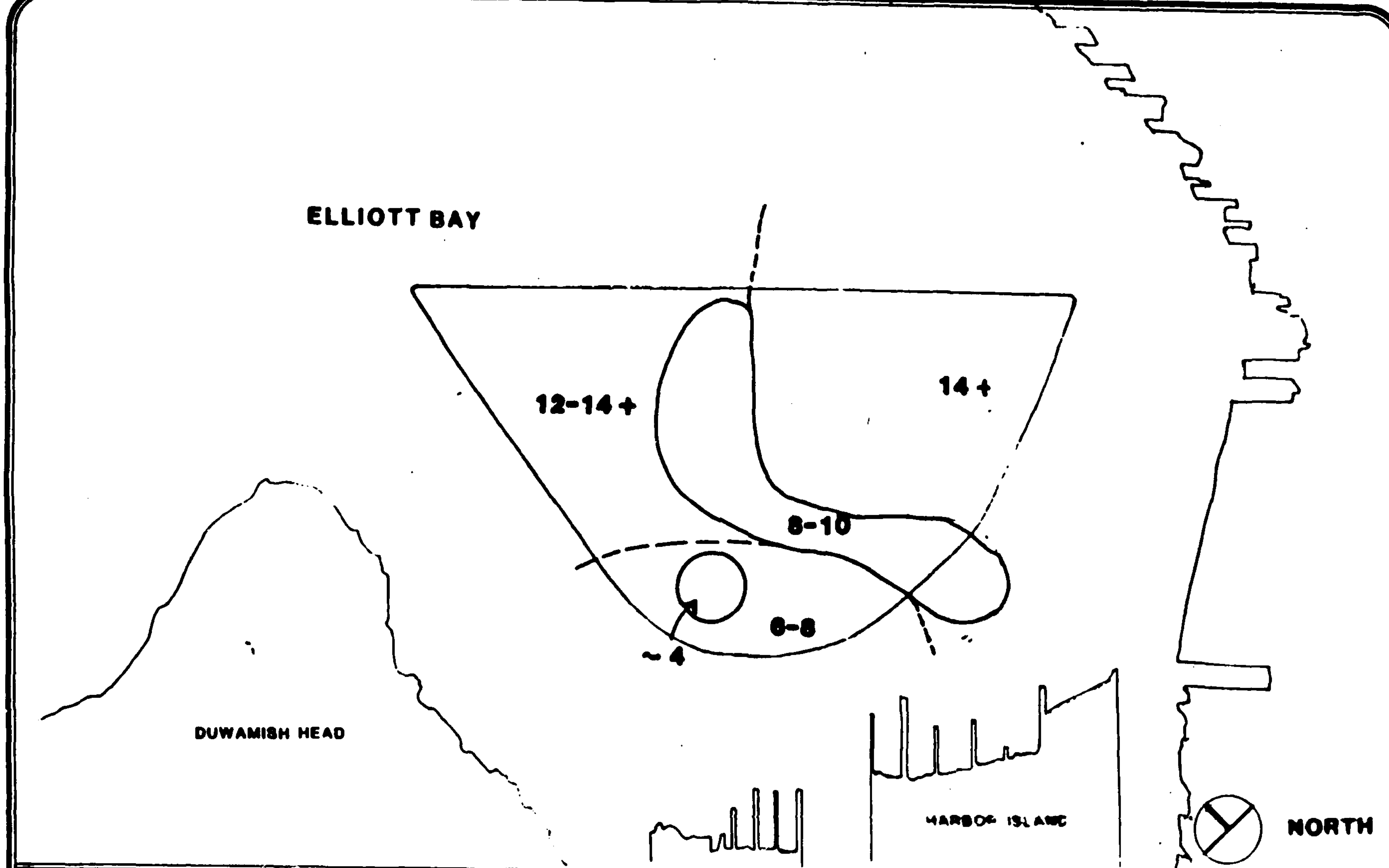

Figure 3.6.5.
Distribution of RPD depths in the Inner Elliott Bay ZSF

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3.6.2 Biota

Infaunal Community Successional Stage

Figure 3.6.6 shows the distribution of apparent end-members of the infaunal successional community at the Inner Elliott Bay ZSF. This distribution appears to be related to sediment distribution and along-bottom current regimes. REMOTS photographs (cf. Plate 3.6.2, Rep. ElA-1a) and MANTA 35mm still photographs show evidence of fecal mounds, depressions and feeding structures. These features suggest that head-down deposit feeders and burrowing shrimp were the apparent Stage III organisms dominating the fauna. REMOTS data for the ZSF indicate a nearly uniform configuration of the apparent successional community of Stage III organisms with a secondary overlay of opportunistic Stage I small polychaetes. At the two stations showing bedforms (an indication of kinetic disturbance), only Stage I groups were represented.

Other Biotic Community Elements

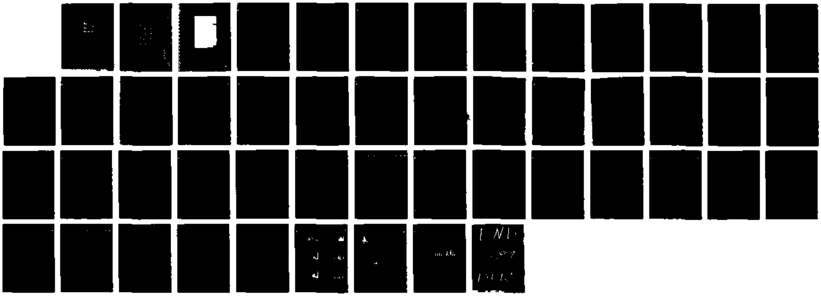
MANTA 35mm photographs and video data did not indicate the presence of megafauna such as fish or crabs, probably because of marginal visibility conditions in which this information was collected. Additional studies are needed to document the extent of these species.

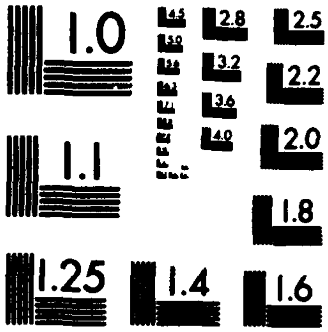
3.6.3 Conclusions

Kinetic (current velocity) gradients in the Inner Elliott Bay ZSF (Figure 3.6.2) were suggested by grain size and the distribution of bedforms. Based on the presence of silt-clay facies, deep RPD depths and apparently well-developed successional assemblages, the deep water to the northeast represents the lowest kinetic area. Transect C represents the area of potentially highest velocity along-bottom current.

AD-A184 932 CHECKING STUDIES ON ZONES OF SITING FEASIBILITY FOR DREDGED MATERIAL IN PUGET SOUND(U) COOPER CONSULTANTS INC BELLEVUE WA JAN 86 2/2

UNCLASSIFIED F/G 8/1 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

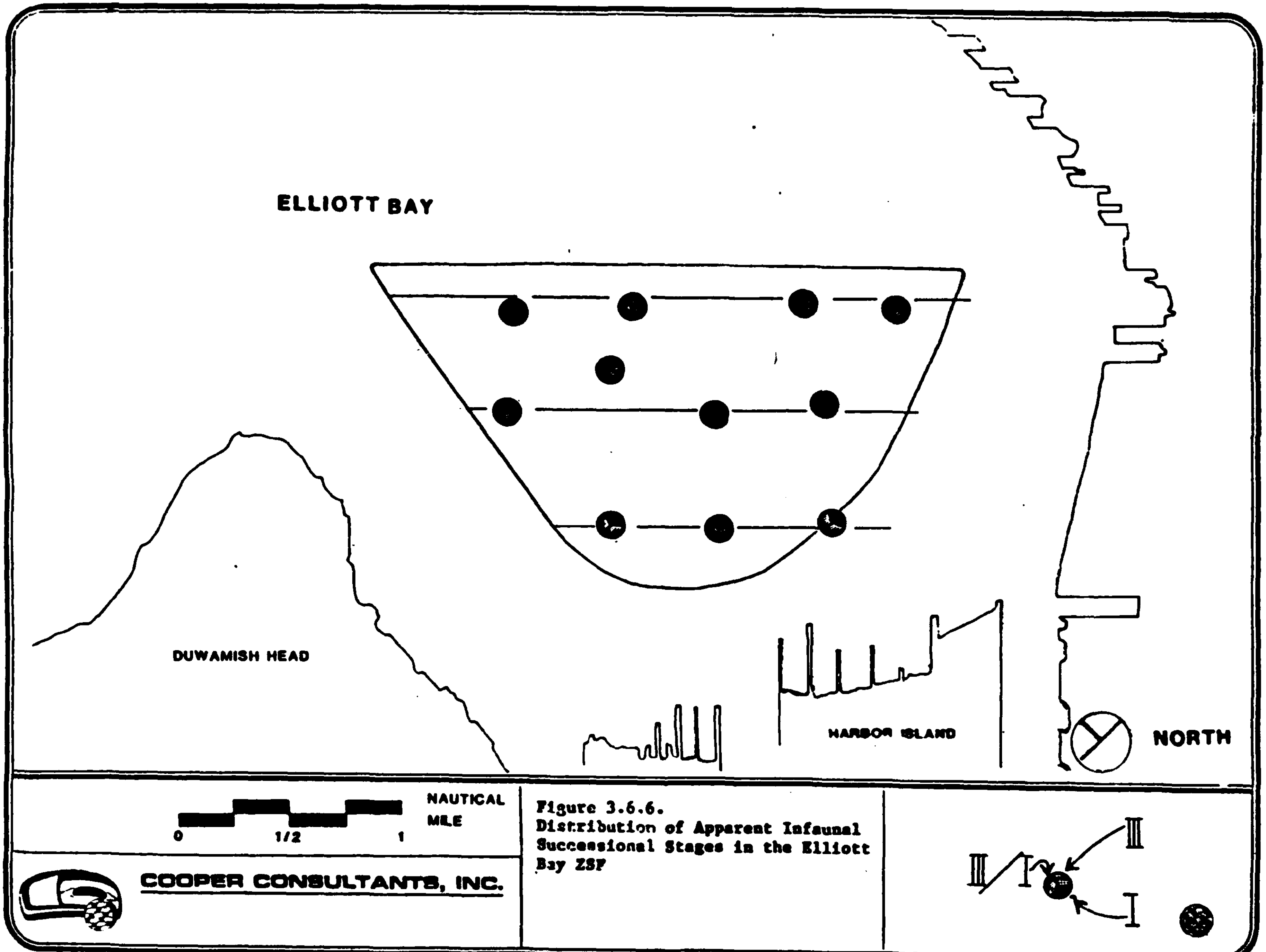


Figure 3.6.6.
Distribution of Apparent Infaunal Successional Stages in the Elliott Bay ZSF

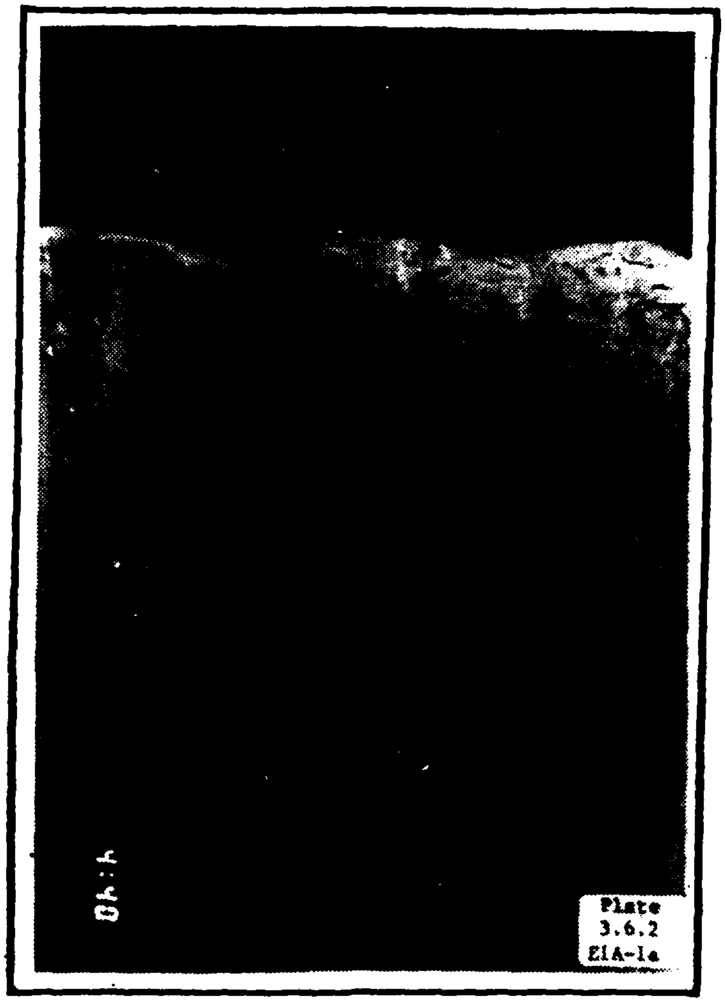


Plate 3.6.2. Micro-relief reflecting apparent Stage III organism. Note feeding burrow filled in with pelletal material. (0.65X)

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4.1 Literature Cited

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Chapman, P.M., R.N. Dexter, J. Morgan, R. Fink, D. Mitchell, R.M. Kocan, M.L. Landolt. 1984. Survey of biological effects of toxicants upon Puget Sound Biota - III. Tests in Everett Harbor, Samish and Bellingham Bays. NOAA Technical memorandum NOS OMA 2.

Comiskey, C.E., T.A. Farmer, C.C. Brandt, and G.P. Romberg. 1984. Toxicant Pretreatment Planning Study Technical Report C2: Puget Sound Benthic Studies and Ecological Implications. METRO Toxicant Program Report No. 6B, Water Quality Division, Municipality of Metropolitan Seattle.

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Dinnel, P.A., F.S. Ott, and Q.J. Stober. 1984. Marine Toxicology, Vol. X, Section 12. In Stober, Q.J., and K.K. Chew (principal investigators). Renton Sewage Treatment Plant Project: Seahurst Baseline Study. Fisheries Research Institute, FRI-UW-8413. University of Washington.

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EVS Consultants. Work in progress under contract to NOAA. Past and Ongoing Monitoring Programs in Puget Sound, Chapter 5, Tables 6 and 7. Tables from a manuscript describing Puget Sound monitoring programs and availability of specific data.

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Malins, D.C., B.B. McCain, M.S. Myers, D.W. Brown and S-L.Chan. 1983. Liver Diseases of Bottom Fish from Everett Harbor, Washington. COPAS Vol. 2, No. 4: 41-42. Marine Sciences Research Center, State University of New York, Stony Brook.

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Stober, Q.J., and K.K. Chew. 1984. Renton Sewage Treatment Plant Project: Duwamish Head. Fisheries Research Institute, FRI-UW-8417. University of Washington.

Tatem, H.E., and J.H. Johnson. 1978. Aquatic Disposal Field Investigations, Duwamish Waterway Disposal Site, Puget Sound, WA. Technical Report D-77-24. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

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Tetra Tech, Inc. 1985. Everett Harbor Action Plan: Initial Data Summaries and Problem Identification. Draft Report TC-3991-03. Environmental Protection Agency Region 10, Seattle, WA.

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U.S. Department of the Navy. 1985. Final Environmental Impact Statement: Carrier Battle Group, Puget Sound Region Homeporting Project, Technical Appendix Volume 1. Western Division, Naval Facilities Engineering Command, San Bruno, CA 94066.

U.S. Department of the Navy. 1985. Final Environmental Impact Statement: Carrier Battle Group, Puget Sound Region Homeporting Project, Technical Appendix Volume 2. Western Division, Naval Facilities Engineering Command, San Bruno, CA 94066.

Word, J.Q., P.O. Striplin, K. Keeley, J. Ward, P. Sparks-McConkey, L. Bentler, S. Hulsman, K. Li, J. Schroeder, and K. Chew. 1984. Subtidal Benthic Ecology, Vol. V, Section 6. In Stober, Q.J. and K.K. Chew (principal investigators). Renton Sewage Treatment Plant Project: Seahurst Baseline Study. Fisheries Research Institute, FRI-UW-8413. University of Washington.

4.2 Personal Communications

Ed Baker, NOAA Pacific Marine Environmental Laboratory, January 1986.

Herbert Curl, NOAA Pacific Marine Environmental Laboratory, December 1985.

Kurt Ebbesmeyer, Evans-Hamilton, Inc., January 1986.

Joseph Germano, Scienc Applications International Corporation, December 1985.

Peter Jumars, University of Washington School of Oceanography, January 1986.

John Malik, COE, January 1986.

APPENDIX A1

ANNOTATED BIBLIOGRAPHY OF ENVIRONMENTAL STUDIES REVIEW SOURCE DATA

A. General Puget Sound.

1. Battelle, Pacific Northwest Laboratory. 1985. Detailed chemical and biological analyses of selected sediments from Puget Sound, Figures 2 through 10, Draft Final Report.

   This document contains a list of individuals who could be contacted to ascertain if data pertinent to a particular ZSF are available or being collected. Most of the monitoring programs are concerned with water column parameters however, which may be of less value to characterization of ZSFs.

2. EVS Consultants. Work in progress under contract to NOAA.

   Past and ongoing monitoring programs in Puget Sound, Chapter 5, Tables 6 and 7. Tables from a manuscript describing Puget Sound monitoring programs and availability of specific data.

3. Harman, R. 1985. Subtidal communities in Central Puget Sound. Unpublished data sheets, diagrams and maps summarizing results of benthic samples taken throughout Puget Sound over the past 17 years. Shoreline Community College, Seattle, Washington.

   Harman has collected an extensive amount of data on benthic biota in Puget Sound. Sampling has taken place during the past 17 years and covers most of the Sound with usually one sample per site. Data are difficult to access because many are in the form of raw data sheets or sketch maps and summary diagrams. Several large summary maps are available. For many of the sites, preserved samples of the microflora and microfauna are available for further study. A classification system for benthic habitats has been developed based on the microbiota.

B. Elliott Bay

1. Dexter, R.N., D.K. Anderson, E.A. Quinlan, L.S. Goldstein, R.M. Strickland, S.P. Pavlou, J.R. Clayton, Jr., R.M. Kocan, and M. Landolt. 1981. A summary of knowledge of Puget Sound related to chemical contaminants. NOAA Technical Memorandum OMPA-13.

   Summarizes data available in 1980 on organic and inorganic contaminants and benthic biota. Contains site specific information for Elliott Bay.

2. Environmental Protection Agency. Work in progress under Contract DE-AC06-76RLO 1830.

The so called "eight bays" study. Only sample site maps were available for review. These maps indicate that useful data on Elliott Bay ZSFs may be available when this report is distributed.

3. Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks and H.O. Hodgins. 1980. Chemical contaminants and biological abnormalities in central and southern Puget Sound. NOAA Technical Memorandum OMPA-2.

Data are presented for benthic fauna (infaunal trophic index), fish species and the occurrence of lesions, trace metals and organic toxicants. Samples were taken in a ZSF only in Elliott Bay, all other samples were nearshore.

4. Romberg, G.P., S.P. Pavlou, R.F. Shokes, W. Horn, E.A. Crecelius, P. Hamilton, J.T. Gunn, R.D. Muench, and J. Vinelli. 1984. Toxicant pretreatment planning study technical report C1: Presence, distribution and fate of toxicants in Puget Sound and Lake Washington. METRO Toxicant Program Report No. 6A. Seattle, Washington.

Contains data on numerous samples in Elliott Bay and central Puget Sound in areas designated as ZSFs. Sediment samples were analyzed for EPA priority pollutants and trace organics, pesticides and trace metals. Spatial plots of concentration are provided.

5. Stober, Q.J., and K.K. Chew. 1984. Renton sewage treatment plant project: Duwamish Head. Fisheries Research Institute, FRI-UW-8417. University of Washington.

In Chapter 5, inner and outer Elliott Bay, including portions of the ZSFs, were sampled for sediment characteristics and benthic fauna. A preponderance of the 330 samples and 83 sites were located in the southern portion of the Bay. Samples were analyzed for volatile solids, organic nitrogen, BOD, TOC and benthic organisms, which were identified to species whenever possible. Cluster analysis provided grouping of benthic fauna into assemblages which were related to sediment characteristics. Chapter six presents limited data on demersal fish in Elliott Bay ZSFs. Chapter eight details the results of four sediment cores taken in Elliott Bay, at least one of which lies within an identified ZSF. Cores were analyzed for sedimentation rate (via lead-210), trace metals, sulfides, TOC, grain size, BOD, volatile solids, oil and grease and organic nitrogen.

6. Tatem, H.E., and J.H. Johnson. 1978. Aquatic disposal field investigations, Duwamish Waterway disposal site, Puget Sound, Washington. Technical Report D-77-24. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

   Physical, chemical and benthic faunal studies were carried out in Elliott Bay near the mouth of Duwamish Waterway. Sampling sites were subtidal out to about the 300 foot depth contour. The studies were part of a test program for the effects of dredged material disposal. Much of the work took place within the Elliott Bay ZSF. Appendix F contains data of Harman on benthic communities and community changes in response to dredged material disposal.

7. Tetra Tech, Inc. 1985. Elliott Bay toxics action plan: Initial data summaries and problem identification. Draft Report TC-3991-01. Environmental Protection Agency, Region 10, Seattle, Washington.

   This document is a summary and evaluation of documents and data for Elliott Bay. Information was classified into pollutant source studies, sediment contamination and bioaccumulation studies, sediment toxicology and bioassay studies, subtidal benthic infauna studies and fish pathology studies. Provides data summaries of reports and an evaluation of the usefulness of the data. Generalized data summary maps are provided as well as complete bibliographic references.

C. Port Gardner

1. Environmental Protection Agency, Work in progress under Contract DE-AC06-76RLO 1830.

   The so called "eight bays" study, only sample site maps were available for review. These maps indicate that useful data on Everett Harbor may be available when this report is distributed.

2. Tetra Tech, Inc. 1985. Everett Harbor action plan: Initial data summaries and problem identification. Draft Report TC-3991-03. Environmental Protection Agency, Region 10, Seattle, Washington.

   This document is a summary and evaluation of documents and data for Everett Harbor. Information is classified into pollutant source studies, sediment contamination and bioaccumulation studies, sediment toxicology and bioassay studies and fish pathology studies. In addition, there is information on microbial contamination. The report also maps all the sampling stations used in the reports evaluated. The maps are keyed to the bibliographic reference of the original study.

3. U.S. Department of the Navy. 1985. Final Environmental Impact Statement: Carrier Battle Group Puget Sound Region Homeporting Project, Technical Appendix, Volume 1. Western Division, Naval Facilities Engineering Command, San Bruno, CA 94066.

Appendix B contains species lists of aquatic flora and fauna present in the vicinity of Everett Harbor and Port Gardner. No specific locations are provided and only qualitative estimates of abundance are made.

4. U.S. Department of the Navy. 1985. Final Environmental Impact Statement: Carrier Battle Group, Puget Sound Region Homeporting Project, Technical Appendix, Volume 2. Western Division, Naval Facilities Engineering Command, San Bruno, CA 94066.

Appendix X provides the results of a mathematical model of water circulation in southern Whidbey Basin. This includes some information on currents at varying tidal stages in the area around Everett Bay and Port Gardner. It includes velocity vector maps of currents in Port Susan, Saratoga Passage and Everett Bay at four depth layers. Limited input data may compromise the validity of the model.

Appendix BB contains data from 55 grab samples of sediment from eleven stations representing eight potential dredge disposal sites. At least three of the sites appear to be within a ZSF. Data are presented on: grain size, percent volatiles, percent dry weight, sulfides, oil and grease, Hg, Cd, Cu, Zn, Pb, As, organic contaminants, PCBs, infaunal species, percent polychaetes, bioassay and bioaccumulation.

D. Commencement Bay.

1. Crecelius, E.A., R.G. Reily, N.S. Bloom and B.L. Thomas. 1985. History of contamination of sediments in Commencement Bay, Tacoma, Washington. NOAA Technical Memorandum NOS OMA 14.

Four sediment cores were taken in Commencement Bay, two of them were in the central area of interest relative to the ZSF. The sediments were analyzed for grain size, age, metals, aromatic hydrocarbons, chlorinated butadienes and PCBs. No PCBs were detected in the cores. A history of contamination for Commencement Bay is developed from the core analysis.

2. Dexter, R.N., D.K. Anderson, E.A. Quinlan, L.S. Goldstein, R.M. Strickland, S.P. Pavlou, J.R. Clayton, Jr., R.M. Kocan, and M. Landolt. 1981. A summary of knowledge of Puget Sound related to chemical contaminants. NOAA Technical Memorandum OMPA-13.

Summarizes data available in 1980 on organic and inorganic contaminants and benthic biota. Contains site specific information for Commencement Bay.

3. Donnelley, R., B. Miller, R. Lauth, and J. Shriner. 1984. Fish Ecology, Vol. VI, Section 7. In Stober, Q.J. and K.K. Chew (principal Investigators), Renton sewage treatment plant project: Seahurst baseline study. Fisheries Research Institute, FRI-UW-8413. University of Washington.

Presents data on fish species occurrence, abundance, location, general health and community structure (richness and diversity) for East Passage near Seahurst Bay.

4. Hileman, J., and M. Matta. 1983. Commencement Bay deep water sediment investigation: Tacoma, Washington, September 15-17, 1982. Environmental Protection Agency Region 10, Seattle, Washington. July 1983.

Numerous sample sites in Commencement Bay, many located in a ZSF. Sediment grab samples were analyzed for percent solids, PCBs, polychlorinated butadienes, volatile and semivolatile organic compounds, phenolics, cyanide and trace metals.

5. Word, J.Q., P.L. Striplin, K. Keeley, J. Ward, P. Sparks-McConkey, L. Bentler, S. Hulsman, K. Li, J. Schroeder, K. Chew. 1984. Subtidal Benthic Ecology, Vol. V, Section 6. In Stober, Q.J. and K.K. Chew (Principal investigators), Renton sewage treatment plant project: Seahurst baseline study. Fisheries Research Institute, FRI-UW-8413. University of Washington.

This report presents the results of sampling on several transects across central Puget Sound in East Passage and Colvos Passage between Alki Point and the mouth of Commencement Bay. Subtidal sediment samples were taken at depths greater than 185 meters. In the later stages some samples were taken at less than 185 meters. Bathymetric profiles are provided for each transect as are maps of sediment characteristics, shell debris and wood or wood fiber. Samples were analyzed for sediment texture, color, presence and type of odor, penetration depth, volatile solids, BOD, TOC, % dry weight. Organisms in the top 2cm of sediment were sampled, preserved and identified to the lowest practical taxonomic unit, usually species. Samples were collected at 106 stations.

APPENDIX A2

DOCUMENTS AND DATA SCREENED FOR ENVIRONMENTAL STUDIES REVIEW

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Chapman, P.M., R.N. Dexter, J. Morgan, R. Fink, D. Mitchell, R.M. Kocan, M.L. Landolt. 1984. Survey of biological effects of toxicants upon Puget Sound biota - III. Tests in Everett Harbor, Samish and Bellingham Bays. NOAA Technical memorandum NOS OMA 2.

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Malins, D.C., B.B. McCain, D.W. Brown, S-L. Chan, M.S. Myers, J.T. Landahl, P.G. Prohaska, A.J. Friedman, L.D. Rhodes, D.G. Burrows, W.D. Gronlund, and H.O. Hodgins. 1984. Chemical Pollutants in Sediments and Diseases of Bottom-dwelling Fish in Puget Sound, WA. Environ. Sci. Technol. Vol. 18, No. 9: 705-713.

Malins, D.C., M.M. Krahn, D.W. Brown, L.D. Rhodes, M.S. Myers, B.B. McCain and S-L. Chan. 1985. Toxic Chemicals in Marine Sediment and Biota from Mukilteo, Washington: Relationships with Hepatic Neoplsams and Other Hepatic Lesions in English Sole (Parophrys vetulus). JNIC Vol. 74, No. 2: 487-494.

Malins, D.C., M.M. Krahn, M.S. Myers, L.D. Rhodes, D.W. Brown, C.A. Krone, B.B. McCain, and S-L. Chan. 1985. Toxic Chemicals in Sediments and Biota from a Creosote-polluted Harbor: Relationships with Hepatic Neoplasms and other Hepatic Lesions in English Sole (Parophrys vetulus). Carcinogenesis Vol. 6, No. 10.

Malins, D.C., M.S. Meyers, and W.T. Roubal. 1983. Organic Free Radicals Associated with Idiopathic Liver Lesions of English Sole (Parophrys vetulus) from Polluted Marine Environments. Environ. Sci. Technol., Vol. 17, No. 11: 679-685.

Romberg, G.P., S.P. Pavlou, R.F. Skokes, W. Horn, E.A. Crecelius, P. Hamilton, J.T. Gunn, R.D. Muench, and J. Vinelli. 1984. Toxicant Pretreatment Planning Study Technical Report C1: Presence, Distribution and Fate of Toxicants in Puget Sound and Lake Washington. METRO Toxicant Program Report No. 6A. Seattle, Washington.

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TABLE I

PERSONAL CONTACTS PROVIDING ASSISTANCE
IN SELECTION OF LITERATURE AND DATA SOURCES

Name	Organization
John Armstrong	EPA Region 10
Herbert Curl	Pacific Marine Env. Lab
Elizabeth Day	Evans Hamilton, Inc.
Libby Goldstein	EVS Consultants, Inc.
Lynn Goodwin	WA Department of Fisheries
Bert Hamner	COE, Seattle District
Robert Harman	Shoreline Community College
John Hughes	National Marine Fish. Service
James Hileman	EPA Region 10
Edward Long	NOAA
John Malek	COE, Seattle District
Donald Malins	NOAA
Robert Matsuda	Seattle METRO
Gary Mauseth	Nortec, Inc.
Bruce McCain	NOAA
Bruce Miller	UW Department of Fisheries
Frederick Nichols	USGS, Menlo Park
Robert Pastorek	Tetra Tech, Inc.
Patrick Romberg	Seattle METRO
David Schuldt	COE, Seattle District
Jerry Stober	UW Fisheries Research Inst.
Ronald Thom	University of Washington
Barry Townes	EPA Region 10

APPENDIX B

DETAILED DISCUSSION OF FIELD ELEMENTS

B.1 MANTA

The MANTA ROV system includes submersible-contained high-resolution sidescan sonar (90 kHz), high-resolution/low incident light television camera, stereo 35mm still camera, positioning sonary systems (forward obstacle avoidance, bottom following and support vessel relative positioning), attitude controls and sensors, propulsion, current meter and depth sensor. During operations the ROV was controlled in response to umbilical telemetry and established navigational inputs via computer driven surface support systems aboard the RV Marysville. Real time data logging enabled on-board generation of track position information as well as depth, height off-bottom and locations of selected points (stations) along transects.

Sidescan Sonar Operations.

It had initially been determined that the MANTA would be flown at a 3 meter height off-bottom along transects for collection of sidescan sonar data to maximize the opportunity to take 35mm color stereo slides of surfical characteristics. Every other transect would then be flown at a height of 1 meter for collection of video information. Sub-marginal visibility encountered at most locations resulted in difficulties collecting useful visual images with either video or still cameras. Accordingly, the MANTA was typically flown at a height off-bottom of 10 meters to widen trace width along the bottom (compared to that anticipated for 3 meter flights, trace width increased from approximately 400 feet to 600 feet).

Every 50 meters along each transect, a "station" mark was generated on the sidescan record to facilitate later "fixing" of blocks of data collected at these "stations." Limited visual information was collected at selected stations by flying the MANTA at minimal heights above the bottom (e.g., 0.4 to 0.8m). Although MANTA terrain following capabilities enable flights at such close distance, obstacle avoidance systems must be deactivated for appropriate flight control. The practice is hazardous and is therefore not routinely performed, particularly in areas with potential large debris or large scale changes in bottom relief.

To highlight the video information collected, a summary videotape was edited by ZSF from the total of all footage. MANTA 35mm individual and stereo images were prepared from among those taken (Exhibit A-3). At the completion of the MANTA cruise, in addition to the production of video tape and 35mm stereo slide information, sidescan sonar records were produced which were annotated for prominant features, positional information, depth, time and date and other pertinent information (Exhibit A-2). This body of data is also available as discrete "data blocks" organized by MANTA station (Exhibit A-4).

B.2 REMOTS

Sediment-profile images were taken using a Benthos Model 3731 Sediment-Profile Camera (Figure 3.1.2). The camera consists of a wedge-shaped prism with a plexiglass face plate. Light is provided by an internal strobe. The back of the prism has a mirror mounted at a 45° angle to reflect the profile of the sediment-water interface up to the camera which is mounted horizontally on the top of the prism. The prism is filled with distilled water and the sediment profile to be photographed is directly against the face plate. Resultant photographic images are unaffected by ambient water visibility.

The camera prism is mounted on an assembly that can be moved up and down by producing tension or slack on the winch wire. As the camera is lowered, tension on the winch wire keeps the prism in the up position. The support frame contacts the bottom first, and the area to be photographed directly under the prism is not disturbed. Once the camera's frame touches the bottom, slack on the winchwire allows the prism to descend to the substrate. The bottom of the optical prism (shaped like an inverted periscope) consists of a knife-edge blade which cuts a vertical profile of the bottom. The prism is driven several centimeters into the mud by the weight of the assembly. The rate of fall of the optical prism is controlled by an adjustable "passive" hydraulic piston, allowing the optical prism to enter the bottom at approximately 6cm/sec. This slow fall rate insures that the descending prism will not wash or otherwise disturb the sediment-water interface.

The camera trigger is tripped on impact with the bottom, activating a time delay for the shutter release sufficient to allow maximum sediment penetration by the prism. For the next photographic replicate, as the camera is raised to a height of about three meters from the bottom, a wiper blade cleans off any mud adhering to the prism faceplate, the film is advanced by a motor drive and the strobes are recharged. The camera can then be lowered for another replicate image. Dependent upon navigational requirements and once the winchwire is paid out to within three meters of the substrate at a station, six replicate images can be taken within five to six minutes.

B.3 Van Veen Grab

At 33 stations selected from those occupied by REMOTS, a non-replicated ground-truthing effort was conducted.

A modified $0.1m^2$ Van Veen grab sampler, used as a standard for Puget Sound studies, was employed in a dual array configuration for this study. The grab was lowered to the bottom, and was triggered upon contact with the substrate. The mini-ranger coordinates, depth sounder and winch meter wheel values were read and recorded, along with time of bottom contact.

The modified Van Veen grab takes relatively undisturbed $0.1m^2$ samples of soft bottoms. The hinged top of the grab consists of a 0.5mm mesh screen and a rubber flap, which may be raised for inspection of surface condition of the substrate, including animal tracks, fecal mounds and other details. Careful sample taking also ensures that the light surface sediments on mud bottoms remain as well.

Due to consistency of the substrates sampled, acceptability for depth of penetration for each grab was determined upon recovery and inspection. Generally, a grab was assumed to be acceptable in soft substrates if penetration exceeded 8cm. If on inspection, it was obvious that excessive penetration had occurred and a portion of the substrate had been forced out through the cover screen, the grab was subject to rejection.

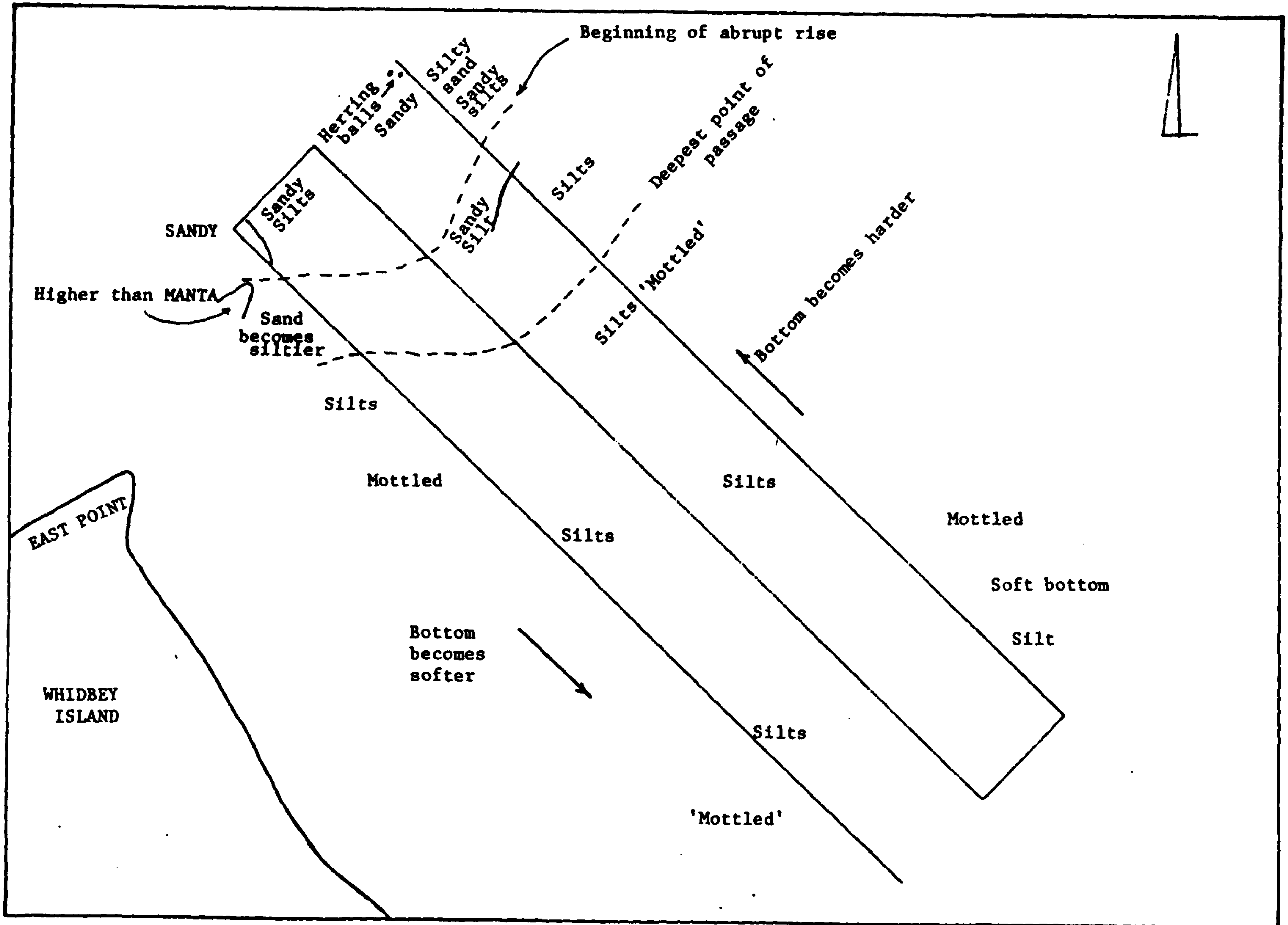
When the grab sampler was retrieved on-board, it was placed in a rectangular tray specifically designed for these operations. If a visual check of the contents of the grab indicates that an unacceptable sample has been taken, the sample is discarded and the grab is re-set and lowered to a point 2 meters off the bottom. Once the vessel is again verified to be on station, the grab is lowered to the bottom, triggered and recovered. If subsequent sampling efforts are unsuccessful, another nearby station satisfying the sampling requirements will be selected or station occupation will be rescheduled for a consecutive day.

Ground-Truthing Sampling

The dual Van Veen sampler array allowed synoptic (side-by-side) sampling for physical/chemical and biota samples. One sampler was designated as the "PSD/chemistry" grab and the other was utilized for biota only.

For subsequent laboratory determination of particle size distribution (PSD), a 1 to 2 cm deep core of sediment was taken from the undisturbed substrate surface of one Van Veen grab and held in iced storage on-board. To provide a sample for potential future analysis of sediment metals and organics, the remaining undisturbed surface of the same grab was sampled to a depth of 1 to 2cm deep with appropriate implements, placed in appropriately cleaned, prepared labelled containers and stored on ice for transfer to archiving.

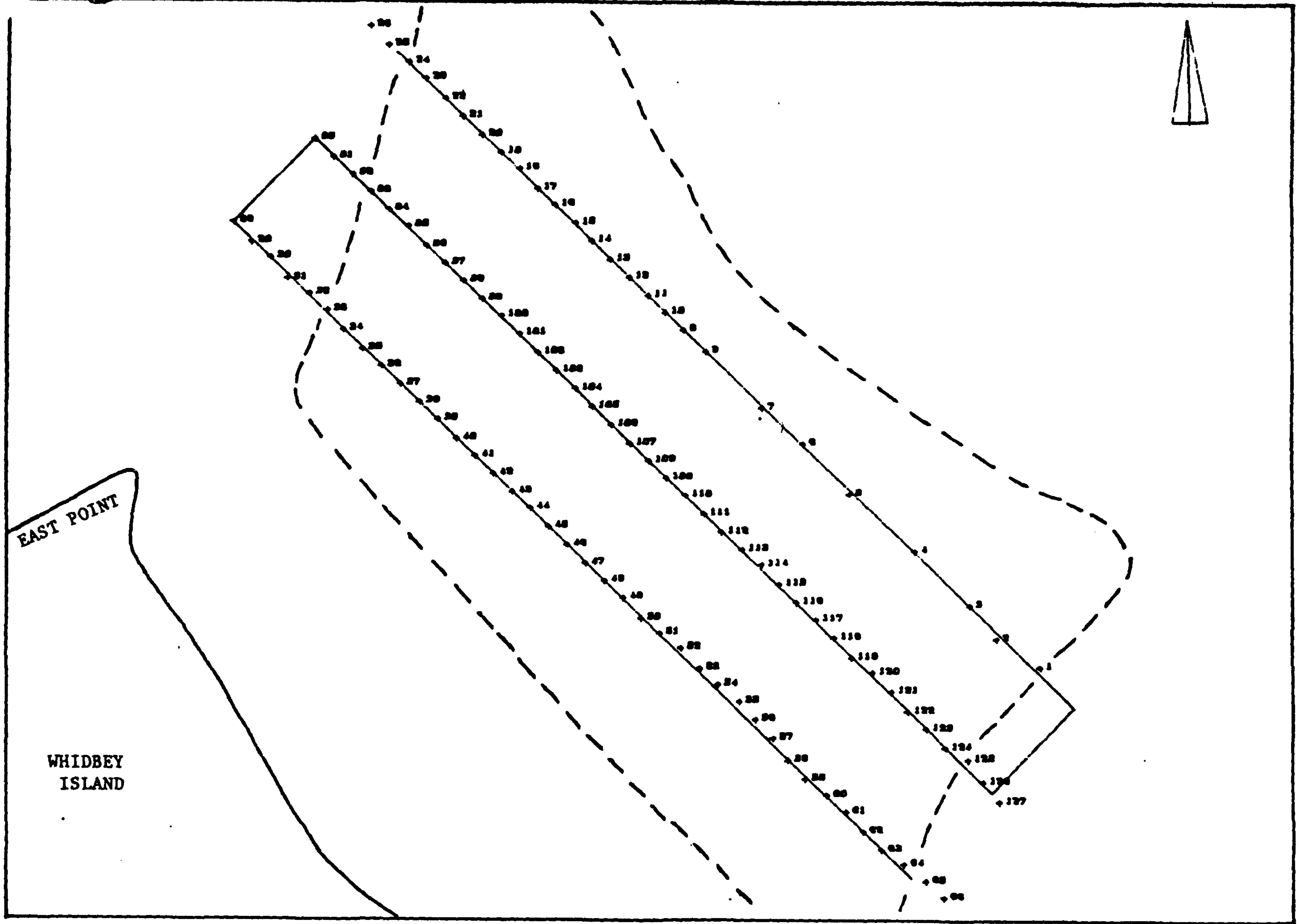
Following recording of substrate penetration depth, as well as surfical characteristics such as apparent sediment texture, color and odor, the sediment from the remaining grab sample was sieved through 1mm mesh with a gentle water spray. The retained biota and other material was preserved with a buffered seawater formalin solution in an internally and externally labeled plastic bag and held for archiving.



SCALE: 200.00 M. PER CM.

SARATOGA SONOGRAPH DATA

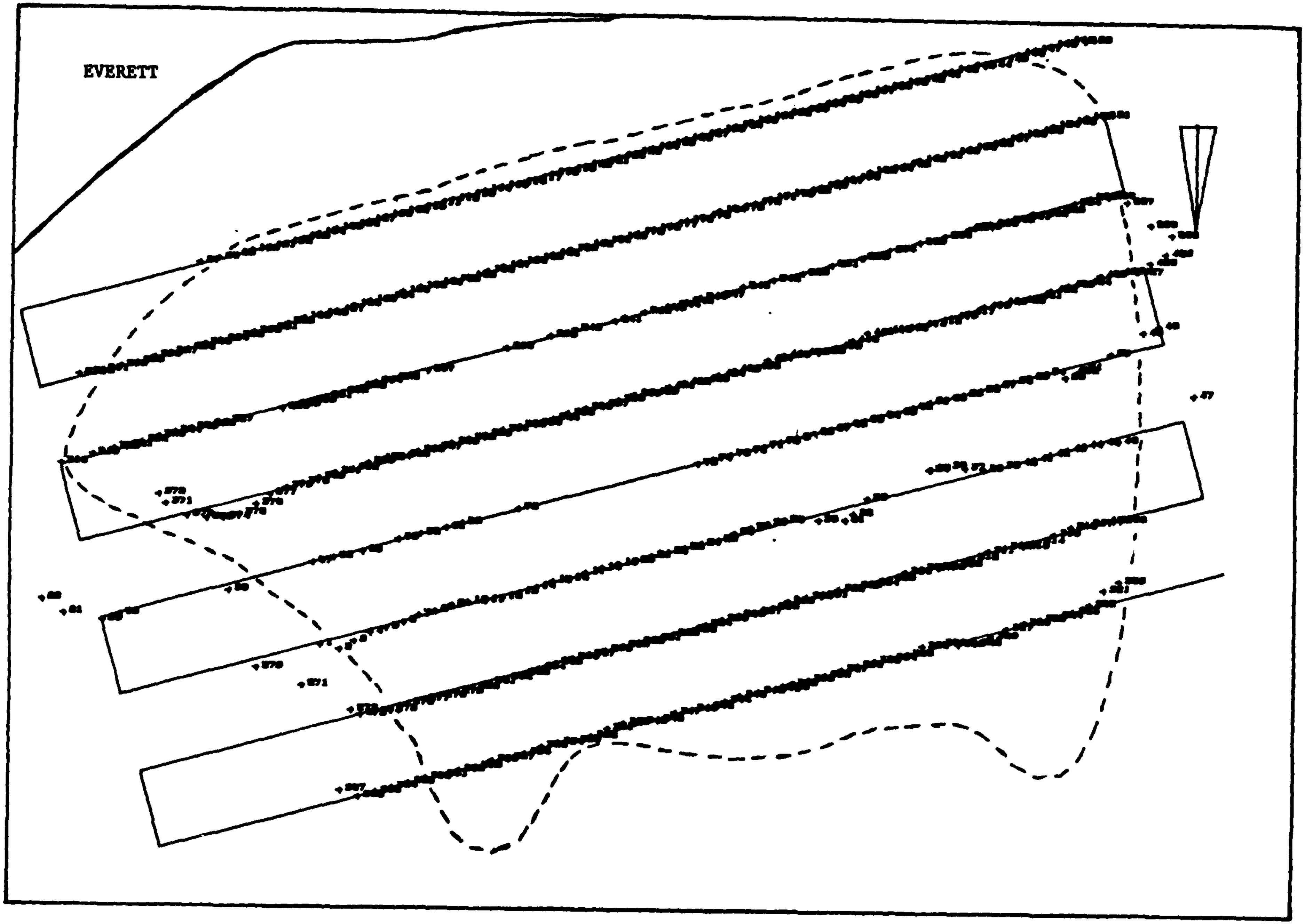
APPENDIX C-1



SCALE: 200.00 M. PER CM.

SARATOGA PASSAGE TRACK PLOT

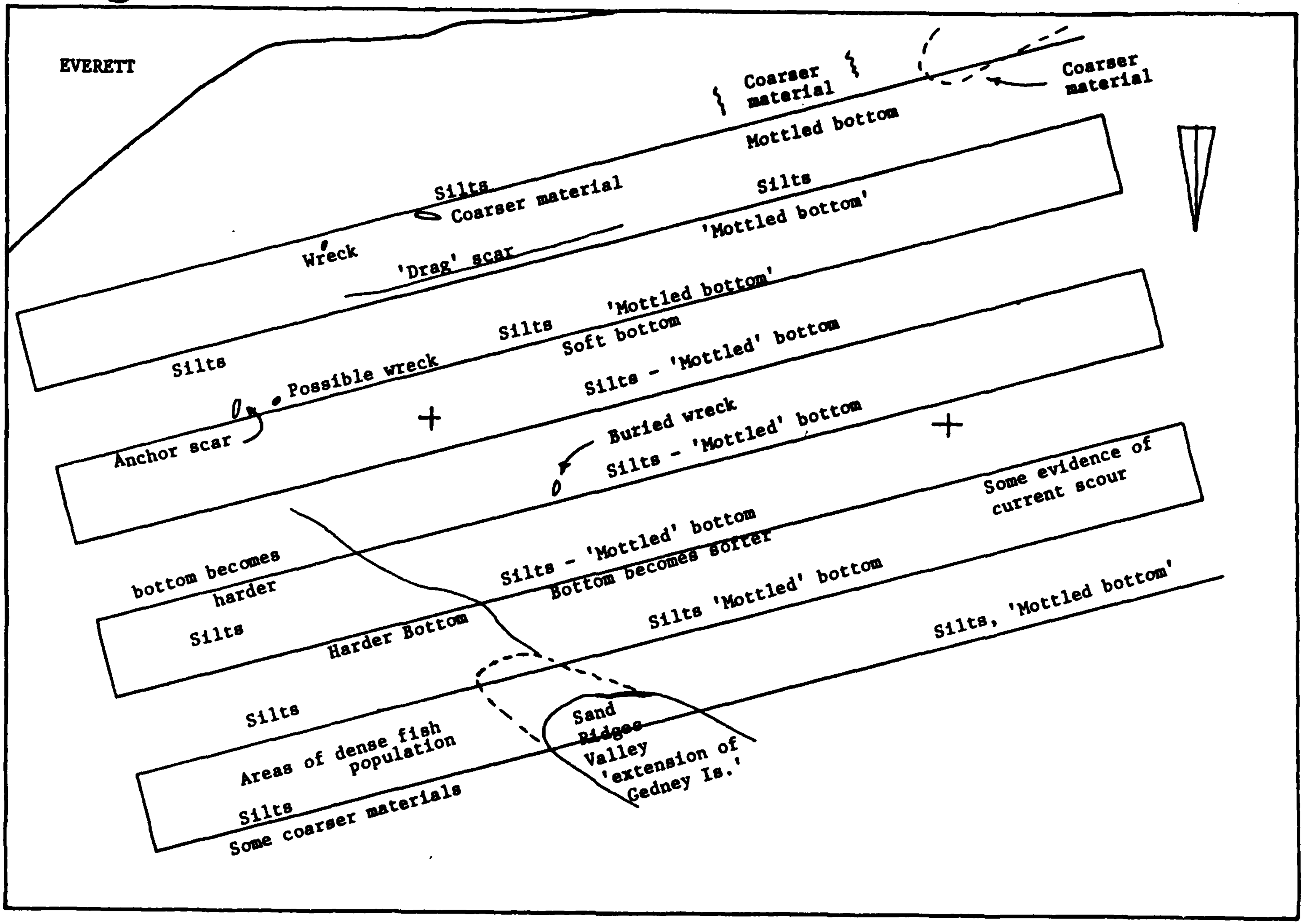
APPENDIX C-1



SCALE: 300.00 M. PER CM.

PORT GARDNER/EVERTT TRACK PLOT

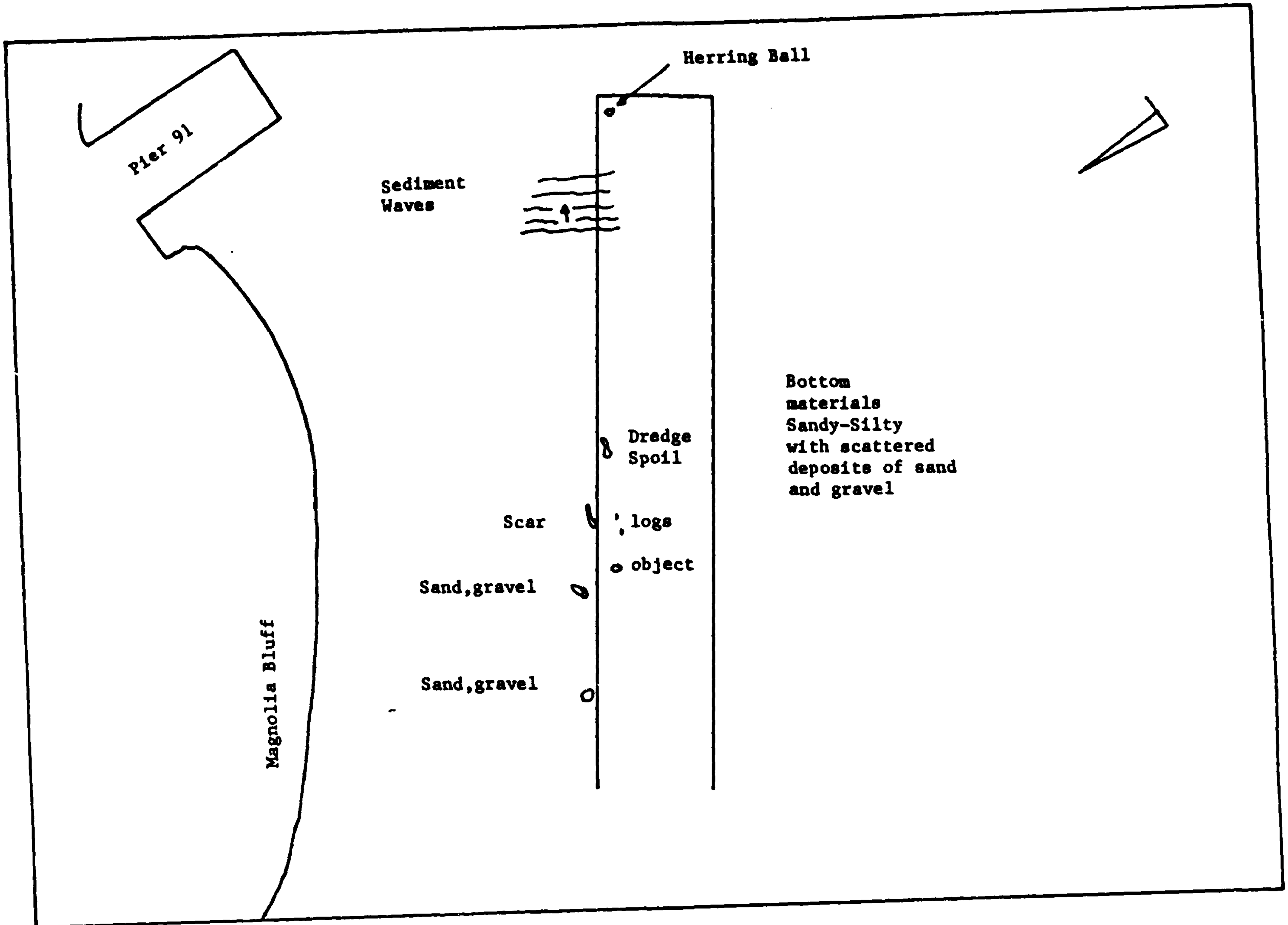
APPENDIX C -2



SCALE: 300.00 M. PER CM.

PORT GARDNER SONOGRAPH DATA

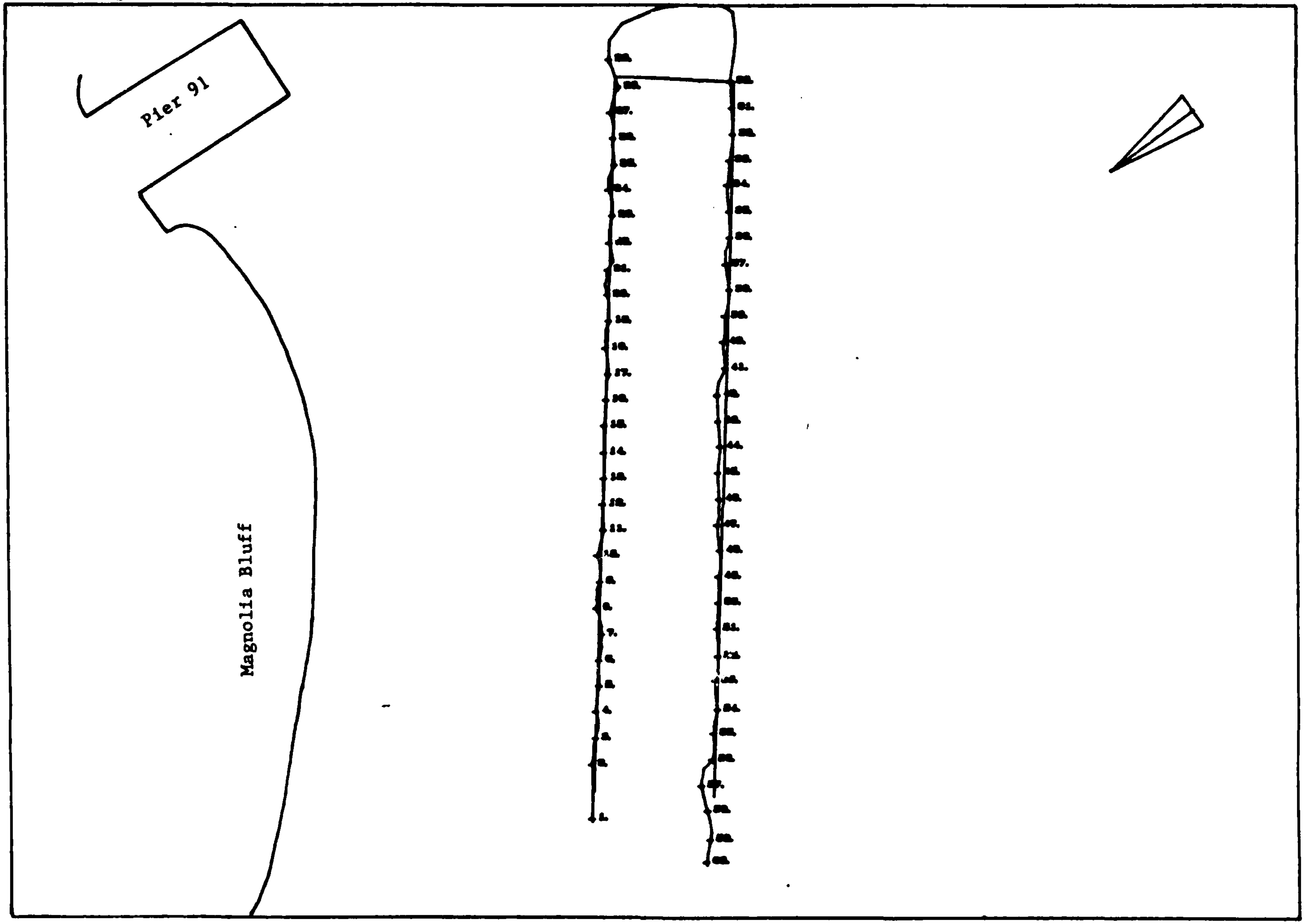
APPENDIX C-2



SCALE: 200.00 M. PER CM.

FOUR MILE ROCK SONOGRAPH DATA

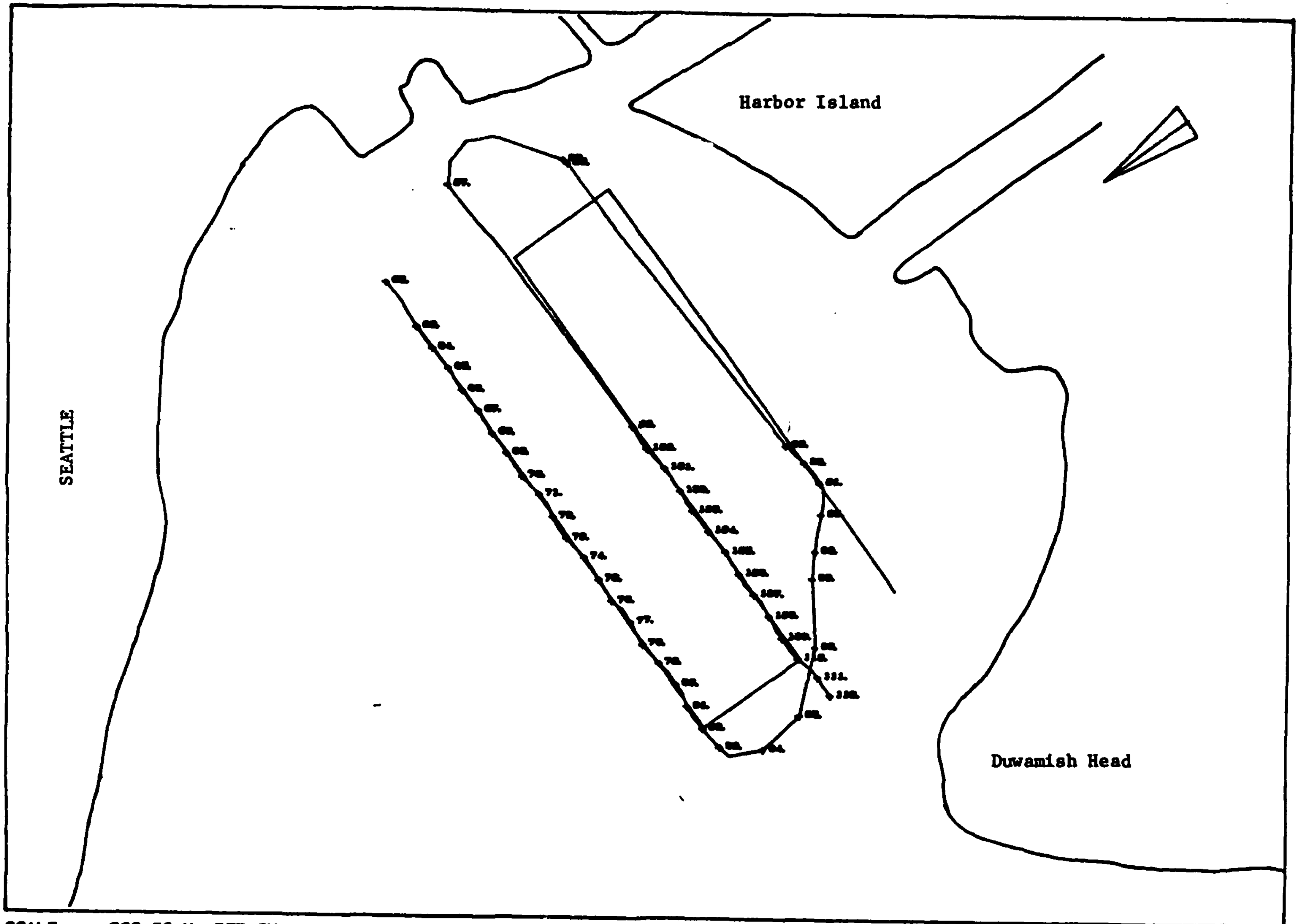
APPENDIX C-3



SCALE: 200.00 M. PER CM.

FOUR MILE ROCK TRACK PLOT

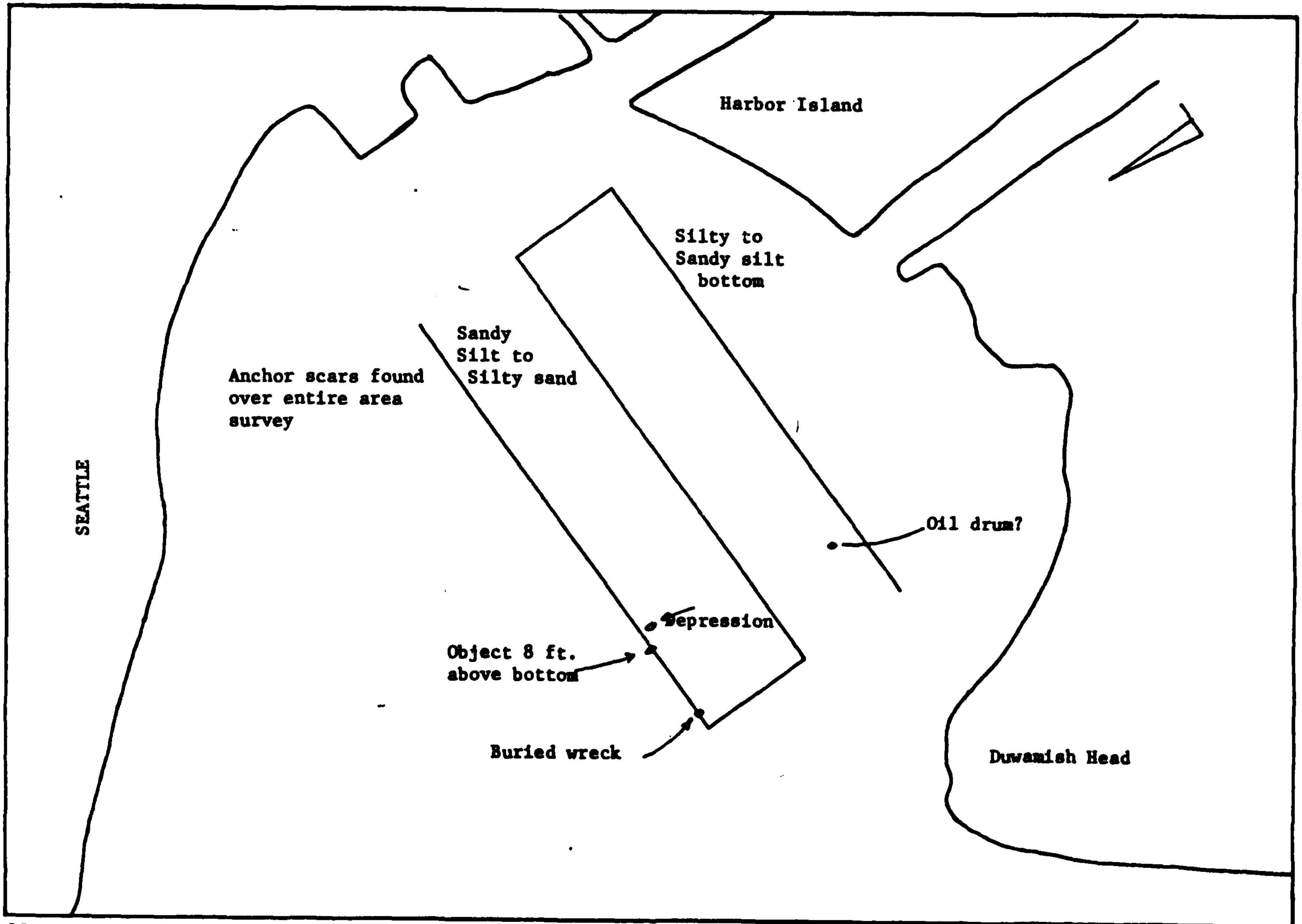
APPENDIX C-3



SCALE: 200.00 M. PER CM.

ELLIOTT BAY TRACK PLOT

APPENDIX C-4



SCALE: 200.00 M. PER CM.

ELLOITT BAY SONOGRAPH DATA

APPENDIX C-4

LISTING FOR: Puget Sound REMOTS Survey — SARATOGA PASSAGE APPENDIX D-1

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
SPB-1	10/31/85	18	09:44	≥4 φ	≥4-3 φ	8.96	STAGE 1	15.82	3.17
SPB-1	10/31/85	20	09:46	≥4 φ	≥4-3 φ	13.41	1 ON 3	17.78	2.07
SPB-1	10/31/85	21	09:47	≥4 φ	≥4-3 φ	13.41	1 ON 3	17.52	1.03
SPB-2	10/31/85	23	09:58	≥4 φ	≥4-3 φ	13	1 ON 3	18.04	.81
SPB-2	10/31/85	24	10:00	≥4 φ	≥4-3 φ	14.26	1 ON 3	17.93	1.77
SBP-2	10/31/85	25	10:00	≥4 φ	≥4-3 φ	11.81	1 ON 3	17.56	2.14
SPC-1	10/31/85	1	10:49	≥4 φ	≥4-3 φ	12.88	1 ON 3	18.33	1.11
SPC-1	10/31/85	2	10:50	≥4 φ	≥4-3 φ	9.54	1 ON 3	10.99	9.22
SPC-1	10/31/85	3	10:51	≥4 φ	≥4-3 φ	10.45	1 ON 3	18.11	1.18
SPC-2	10/31/85	7	11:03	≥4 φ	≥4-3 φ	5.61	STAGE 1	18.22	1.33
SPC-2	10/31/85	8	11:04	≥4 φ	≥4-3 φ	15.78	1 ON 3	18.52	.59
SPC-2	10/31/85	9	11:05	≥4 φ	≥4-3 φ	11.93	1 ON 3	17.08	2.21
SPC-3	10/31/85	12	11:16	≥4-3 φ	≥4-2 φ	10.04	1 ON 3	18	.81
SPC-3	10/31/85	13	11:18	≥4-3 φ	≥4-2 φ	10.4	1 ON 3	16.52	.59
SPC-3	10/31/85	14	11:19	≥4 φ	≥4-2 φ	10.55	1 ON 3	14.74	.53
SPA-1	10/31/85	3	19:50	≥4 φ	≥4-3 φ	10.38	1 -> 2	16.36	1.91
SPA-1	10/31/85	6	19:52	≥4 φ	≥4-3 φ	6.17	STAGE 1	14.08	.04
SPA-2	10/31/85	12	09:04	≥4 φ	≥4-3 φ	14.53	1 ON 3	19.11	.61
SPA-2	10/31/85	13	09:06	≥4 φ	≥4-3 φ	13.08	1 ON 3	16.55	2.59
SPA-3	10/31/85	15	09:21	≥4 φ	≥4-3 φ	12.19	1 ON 3	16.24	3.43
SPA-3	10/31/85	16	09:22	≥4 φ	≥4-3 φ	10.39	STAGE 1	19.11	.31
SPA-3	10/31/85	17	09:23	≥4 φ	≥4-3 φ	7.34	1 ON 3	10.76	3.09
SPB-3	10/31/85	30	10:16	≥4 φ	≥4-3 φ	6.19	STAGE 1	17.89	2.21
SPB-3	10/31/85	28	10:14	≥4 φ	≥4-3 φ	6.58	STAGE 3	20.63	0
SPB-3	10/31/85	29	10:15	≥4 φ	≥4-3 φ	9.04	STAGE 3	20.63	0
N						25		25	23
Mean						10.71		17.09	1.93
Std. Dev.						2.82		2.37	1.88
Min.						5.61		10.76	0.00
Max.						15.78		20.63	9.22

LISTING FOR: Puget Sound REMOTS Survey -- PORT GARDNER

APPENDIX D-2

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
G 1-1	10/29/85	1	9.:20	≥4-3 φ	≥4-2 φ	6.92	1 ON 3	13.02	1.79
G 1-1	10/29/85	2	9.:21	4-3 φ	≥4-1 φ	8.46	1 ON 3	8.72	1.22
G 1-1	10/29/85	3	9.:21	≥4-3 φ	≥4-1 φ	8.07	1 ON 3	13.9	.57
G 1-2	10/29/85	7	9.:32	4-3 φ	≥4-1 φ	6.14	1 ON 3	6.07	1.63
G 1-2	10/29/85	8	9.:33	4-3 φ	≥4-1 φ	5.02	1 ON 3	7.38	2.04
G 1-2	10/29/85	9	9.:34	4-3 φ	≥4-1 φ	6.17	1 ON 3	7.21	.98
G 1-3	10/29/85	13	09:44	≥4 φ	≥4-2 φ	9.74	1 ON 3	15.03	2.36
G 1-3	10/29/85	14	9.:44	≥4-3 φ	≥4-2 φ	10.59	1 ON 3	13.36	.98
G 1-3	10/29/85	15	9.:45	≥4-3 φ	≥4-2 φ	9.85	1 ON 3	11.65	.9
G 1-4	10/29/85	19	9.:55	≥4-3 φ	≥4-2 φ	9.41	1 ON 3	9.21	.81
G 1-4	10/29/85	21	9.:56	4-3 φ	≥4-2 φ	5.54	1 ON 3	7.62	.81
G 1-4	10/29/85	23	9.:57	4-3 φ	≥4-2 φ	8.4	1 ON 3	8.48	.9
G 1-5	10/29/85	25	10:07	≥4 φ	≥4-3 φ	10.92	1 ON 3	11.41	.9
G 1-5	10/29/85	26	10:08	≥4 φ	≥4-2 φ	9.13	1 ON 3	9.09	1.39
G 1-5	10/29/85	27	10:08	≥4-3 φ	≥4-2 φ	9.21	1 ON 3	9.29	.9
G 1-6	10/29/85	32	10:19	≥4 φ	≥4-3 φ	8.96	1 ON 3	15	1.47
G 1-6	10/29/85	33	10:19	≥4 φ	≥4-3 φ	9.34	1 ON 3	19.56	1.39
G 1-6	10/29/85	34	10:20	≥4 φ	≥4-3 φ	10.75	1 ON 3	16.03	4.73
G 2-4	10/28/85	27	14:53	≥4 φ	≥4-3 φ	9.75	1 ON 3	17.8	1.66
G 2-4	10/28/85	28	14:54	≥4 φ	≥4-3 φ	7.45	1 ON 3	11.01	3.95
G 2-4	10/28/85	30	14:56	≥4 φ	≥4-3 φ	9.59	1 ON 3	15.24	1.42
G 2-5	10/28/85	33	15:15	≥4 φ	≥4-2 φ	8.06	1 ON 3	10.28	1.42
G 2-5	10/28/85	34	15:15	≥4 φ	≥4-2 φ	7.43	1 ON 3	17.25	.39
G 2-5	10/28/85	36	15:17	≥4 φ	≥4-2 φ	7.64	1 ON 3	15.07	3.71
G 2-6	10/28/85	2	15:54	≥4 φ	≥4-2 φ	6.51	1 ON 3	10.26	1.18
G 2-6	10/28/85	5	15:56	≥4-3 φ	≥4-2 φ	11.11	1 ON 3	12.75	.95
G 2-6	10/28/85	7	15:58	≥4-3 φ	≥4-2 φ	8.32	Indet	9.71	1.34

APPENDIX D-2

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
G 2-7	10/28/85	9	16:10	≥4-3 φ	≥4-2 φ	9.11	1 ON 3	10.07	2.45
G 2-7	10/28/85	12	16:12	≥4-3 φ	≥4-2 φ	7.9	1 ON 3	16.70	1.10
G 2-7	10/28/85	14	16:13	≥4-3 φ	≥4-2 φ	10.39	1 ON 3	14.29	4.11
G 2-8	10/28/85	15	16:24	4-3 φ	≥4-2 φ	9.05	1 ON 3	15.52	.71
G 2-8	10/28/85	18	16:27	≥4-3 φ	≥4-2 φ	16.14	1 ON 3	16.15	.95
G 2-8	10/28/85	19	16:27	4-3 φ	≥4-2 φ	0.62	1 ON 3	15.40	2.05
G 2-9	10/28/85	22	16:38	≥4-3 φ	≥4-2 φ	6.19	1 ON 3	12.4	2.05
G 2-9	10/28/85	23	16:39	4-3 φ	≥4-2 φ	6.37	STAGE 1	14.17	.63
G 2-9	10/28/85	25	16:40	4-3 φ	≥4-2 φ	4.96	STAGE 1	13.5	1.11
G 1-7	10/28/85	1	13:39	≥4 φ	≥4-2 φ	12.01	1 ON 3	19.16	1.56
G 1-7	10/28/85	2	13:40	≥4 φ	≥4-3 φ	10.02	1 ON 3	12.55	1.49
G 1-7	10/28/85	3	13:40	≥4 φ	≥4-2 φ	13.19	1 ON 3	16.73	.63
G 2-1	10/28/85	7	13:59	≥4 φ	≥4-2 φ	10.09	1 ON 3	10.10	.94
G 2-1	10/28/85	8	14:00	≥4 φ	≥4-2 φ	13.42	1 ON 3	16.14	1.72
G 2-1	10/28/85	9	14:01	≥4 φ	≥4-3 φ	7.27	1 ON 3	10.63	5.71
G 2-2	10/28/85	13	14:17	≥4 φ	≥4-3 φ	9.01	1 ON 3	14.09	1.95
G 2-2	10/28/85	14	14:18	≥4 φ	≥4-3 φ	15.53	1 ON 3	17.51	.47
G 2-2	10/28/85	15	14:19	≥4 φ	≥4-3 φ	7.12	1 ON 3	13.25	2.03
G 2-3	10/28/85	19	14:36	≥4 φ	≥4-3 φ	9.12	1 ON 3	16.15	1.49
G 2-3	10/28/85	20	14:37	≥4 φ	≥4-3 φ	9.71	1 ON 3	17.67	1.02
G 2-3	10/28/85	21	14:38	≥4 φ	≥4-3 φ	14.77	1 ON 3	16.42	.86
G 3-1	10/28/85	27	16:59	4-3 φ	≥4-2 φ	3.63	1 ON 3	5.36	1.49
G 3-1	10/28/85	28	17:00	4-3 φ	≥4-2 φ	4.96	1 ON 3	7.16	.63
G 3-1	10/28/85	30	17:01	≥4-3 φ	≥4-2 φ	5.53	STAGE 1	8.95	.94
G 3-2	10/28/85	1	17:54	≥4-3 φ	≥4-2 φ	7.43	1 ON 3	15.08	1.26
G 3-2	10/28/85	2	17:55	≥4-3 φ	≥4-2 φ	0.85	STAGE 3	13.34	2.05
G 3-2	10/28/85	4	18:15	≥4-3 φ	≥4-2 φ	11.11	1 ON 3	15.98	1.5
G 3-3	10/28/85	7	18:29	≥4-3 φ	≥4-2 φ	10.1	1 ON 3	12.95	3.95

APPENDIX D-2

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
G 3-3	10/28/85	9	10:30	>4 φ	>4-2 φ	4.30	STAGE 1	10.16	1.09
G 3-3	10/28/85	10	10:32	>4 φ	>4-2 φ	9.1	STAGE 1	16.46	1.11
G 3-4	10/28/85	13	10:50	>4-3 φ	>4-2 φ	7.75	1 ON 3	12.71	2.05
G 3-4	10/28/85	14	10:50	>4-3 φ	>4-2 φ	8.53	1 ON 3	17.29	1.66
G 3-4	10/28/85	17	10:52	>4 φ	>4-2 φ	12.98	STAGE 3	17.56	1.5
G 3-5	10/28/85	19	19:04	>4 φ	>4-3 φ	13.49	1 ON 3	10.39	1.10
G 3-5	10/28/85	20	19:04	>4 φ	>4-3 φ	9.82	1 ON 3	13.30	2.13
G 3-5	10/28/85	22	19:06	>4 φ	>4-3 φ	14.50	1 ON 3	16.62	3.07
G 3-6	10/28/85	25	19:22	>4 φ	>4-3 φ	12.26	1 ON 3	15.04	3
G 3-6	10/28/85	26	19:23	>4 φ	>4-3 φ	12.2	1 ON 3	12.95	2.29
G 3-6	10/28/85	29	19:24	>4 φ	>4-3 φ	12.42	1 ON 3	13.5	4.50
G 3-7	10/28/85	31	19:37	>4 φ	>4-3 φ	9.53	1 ON 3	16.3	3.47
G 3-7	10/28/85	32	19:37	>4 φ	>4-3 φ	13.78	1 ON 3	14.41	2.29
G 3-7	10/28/85	35	19:39	>4 φ	>4-3 φ	12.08	1 ON 3	15.24	.47
G 3-8	10/29/85	1	10:51	>4 φ	>4-3 φ	11.08	1 ON 3	10.59	.95
G 3-8	10/29/85	2	10:50	>4 φ	>4-3 φ	11.02	1 ON 3	13.26	1.10
G 3-8	10/28/85	5	10:53	>4 φ	>4-3 φ	13.46	1 ON 3	17.49	.71
G 3-9	10/29/85	8	11:04	>4 φ	>4-3 φ	13.14	1 ON 3	19.15	1.97
G 3-9	10/29/85	9	11:05	>4 φ	>4-3 φ	15.40	1 ON 3	19.50	.55
G 3-9	10/29/85	11	11:06	>4 φ	>4-3 φ	16.1	1 ON 3	10.43	2.37
G 4-1	10/29/85	14	11:20	>4 φ	>4-3 φ	14.54	1 ON 3	10.74	1.11
G 4-1	10/29/85	15	11:21	>4 φ	>4-3 φ	10.34	1 ON 3	17.8	1.10
G 4-1	10/29/85	18	11:22	>4 φ	>4-3 φ	9.91	1 ON 3	15.75	1.34
G 4-2	10/29/85	20	11:34	>4 φ	>4-3 φ	9.86	1 ON 3	15.83	1.26
G 4-2	10/29	22	05:05	>4 φ	>4-3 φ	10.6	1 ON 3	15.99	1.11
G 4-2	10/29/85	25	11:37	>4 φ	>4-3 φ	11.65	1 ON 3	16.62	1.09
G 4-3	10/29/85	26	11:48	>4 φ	>4-3 φ	12.68	1 ON 3	12.81	3.27
G 4-3	10/29/85	27	11:49	>4 φ	>4-3 φ	9.65	STAGE 3	15.18	4.50

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
G 4-3	10/29/85	29	11:50	≥4 φ	≥4-3 φ	9.0	1 ON 3	19.15	2.13
G 4-4	10/29/85	33	12:01	≥4 φ	≥4-3 φ	0.64	1 ON 3	10.57	1.00
G 4-4	10/29/85	35	12:02	≥4 φ	≥4-3 φ	16.23	1 ON 3	17.1	1.0
G 4-4	10/29/85	36	12:03	≥4 φ	≥4-3 φ	13.20	1 ON 3	16.98	1.55
G 4-5	10/29/85	1	12:17	≥4 φ	≥4-3 φ	13.97	1 ON 3	14.32	2.06
G 4-5	10/29/85	2	12:17	≥4 φ	≥4-3 φ	0.63	1 ON 3	10.12	.9
G 4-5	10/29/85	4	12:18	≥4 φ	≥4-3 φ	0.71	1 ON 3	10.66	2.7
G 4-6	10/29/85	8	12:29	≥4 φ	≥4-3 φ	14.24	1 ON 3	17.55	1.15
G 4-6	10/29/85	9	12:30	≥4 φ	≥4-3 φ	10.25	1 ON 3	16.41	1.39
G 4-6	10/29/85	12	12:31	≥4 φ	≥4-3 φ	10.09	1 ON 3	15.34	2.62
G 4-7	10/29/85	14	12:43	≥4 φ	≥4-2 φ	15.09	1 ON 3	15.03	.9
G 4-7	10/29/85	15	12:43	≥4 φ	≥4-3 φ	10.03	1 ON 3	16.33	1.31
G 4-7	10/29/85	18	12:45	≥4-3 φ	≥4-2 φ	13.95	1 ON 3	10.41	2.45
G 4-8	10/29/85	20	12:57	4-3 φ	≥4-2 φ	6.15	1 ON 3	17.35	2.05
G 4-8	10/29/85	21	12:58	≥4-3 φ	≥4-2 φ	7.3	1 ON 3	16.9	.9
G 4-8	10/29/85	24	13:00	4-3 φ	4-2 φ	4.06	1 ON 3	13.07	1.06
G 5-1	10/29/85	26	13:10	4-3 φ	≥4-2 φ	0.52	1 ON 3	15.22	.90
G 5-1	10/29/85	27	13:11	≥4-3 φ	≥4-2 φ	7.00	1 ON 3	13.46	2.29
G 5-1	10/29/85	28	13:12	4-3 φ	≥4-2 φ	6.56	1 ON 3	10.97	1.64
G 5-2	10/29/85	1	13:24	≥4 φ	≥4-3 φ	10.43	1 ON 3	16.61	1.15
G 5-2	10/29/85	3	13:25	≥4 φ	≥4-3 φ	9.92	1 ON 3	16.37	1.23
G 5-2	10/29/85	5	13:26	≥4 φ	≥4-2 φ	13.02	1 ON 3	16.00	3.6
G 5-3	10/29/85	7	13:37	≥4 φ	≥4-3 φ	11	1 ON 3	16.61	1.55
G 5-3	10/29/85	9	13:38	≥4 φ	≥4-3 φ	9.65	STAGE 3	15.59	1.31
G 5-3	10/29/85	11	13:39	≥4 φ	≥4-3 φ	9.16	1 ON 3	16.65	1.96
[illegible] 5-4	10/29/85	13	13:50	≥4 φ	≥4-3 φ	2.39	STAGE 1/	20.25	1.15
G 5-4	10/29/85	16	13:51	≥4 φ	≥4-3 φ	5.99	1 ON 3	16.4	.49
G 5-4	10/29/85	18	13:52	≥4 φ	≥4-3 φ	11.79	1 ON 3	15.71	1.55

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
6 5-5	10/29/85	22	14:06	>4 φ	>4-3 φ	11.2	1 ON 3	14.01	1.0
6 5-5	10/29/85	23	14:07	>4 φ	>4-3 φ	12.52	STAGE 3	16.49	.57
6 5-5	10/29/85	24	14:07	>4 φ	>4-3 φ	10.06	1 ON 3	16.02	1.39
6 5-6	10/29/85	25	14:17	>4 φ	>4-3 φ	12.5	1 ON 3	16.73	1.55
6 5-6	10/29/85	28	14:19	>4 φ	>4-3 φ	14.95	1 ON 3	15.01	2.21
6 5-6	10/29/85	29	14:19	>4 φ	>4-3 φ	12.28	STAGE 3	15.42	1.47
6 5-7	10/29/85	32	14:31	>4 φ	>4-3 φ	11.94	1 ON 3	18.53	1.96
6 5-7	10/29/85	34	14:32	>4 φ	>4-3 φ	11.96	1 ON 3	19.02	1.39
6 5-7	10/29/85	36	14:33	>4 φ	>4-3 φ	10.41	1 ON 3	17.1	.98
6 6-1	10/29/85	1	14:50	>4 φ	>4-3 φ	8.2	STAGE 3	15.3	1.55
6 6-1	10/29/85	3	14:51	>4 φ	>4-3 φ	12.63	1 ON 3	19.18	1.08
6 6-1	10/29/85	6	14:53	>4 φ	>4-3 φ	9.08	1 ON 3	15.38	1.31
6 6-2	10/29/85	7	15:03	>4 φ	>4-3 φ	10.5	1 ON 3	15.42	2.94
6 6-2	10/29/85	9	15:04	>4 φ	>4-3 φ	10.25	1 ON 3	17.76	2.21
6 6-2	10/29/85	11	15:05	>4 φ	>4-3 φ	12.64	1 ON 3	17.51	.65
6 6-3	10/29/85	12	15:14	>4 φ	>4-3 φ	8.71	1 ON 3	15.08	.6
6 6-3	10/29/85	13	15:15	>4 φ	>4-3 φ	7.26	1 ON 3	14.21	2.1
6 6-3	10/29/85	14	15:15	>4 φ	>4-3 φ	7.65	1 ON 3	13.5	.82
6 6-4	10/29/85	18	15:26	>4 φ	>4-3 φ	9.63	1 ON 3	12.94	.82
6 6-4	10/29/85	19	15:27	>4 φ	>4-3 φ	12.06	1 ON 3	15.45	.97
6 6-4	10/29/85	20	15:27	>4 φ	>4-3 φ	9.04	1 ON 3	13.17	.97
6 6-5	10/29/85	24	15:39	>4 φ	>4-3 φ	9.54	1 ON 3	13.8	.6
6 6-5	10/29/85	25	15:39	>4 φ	>4-3 φ	8.98	STAGE 3	12.02	1.58
6 6-5	10/29/85	26	15:40	>4 φ	>4-3 φ	8.55	1 ON 3	13.5	.67
6 6-6	10/29/85	30	15:51	4-3 φ	>4-1 φ	1.03	1 ON 3	6.38	1.12
6 6-6	10/29/85	31	15:52	4-3 φ	>4-1 φ	1.32	1 ON 3	8.21	1.05
6 6-6	10/29/85	32	15:52	4-3 φ	>4-1 φ	1.12	1 ON 3	6.53	1.05
6 7-1	10/29/85	1	16:07	>4-3 φ	>4-2 φ	7.12	1 ON 3	11.03	.9

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
6 7-1	10/29/85	2	16:07	>4-3 φ	>4-2 φ	9.3	STAGE 3	9.11	1.05
6 7-1	10/29/85	3	16:08	>4-3 φ	>4-2 φ	6.52	1 ON 3	11.66	1.05
6 7-2	10/29/85	7	16:19	>4 φ	>4-2 φ	11.01	1 ON 3	10.84	1.72
6 7-2	10/29/85	8	16:19	>4-3 φ	>4-2 φ	9.19	1 ON 3	8.55	1.95
6 7-2	10/29/85	9	16:20	>4-3 φ	>4-2 φ	10.27	1 ON 3	11.96	.6
6 7-3	10/29/85	13	16:35	>4 φ	>4-3 φ	12.06	1 ON 3	15.45	1.2
6 7-3	10/29/85	14	16:35	>4 φ	>4-3 φ	3.52	STAGE 1	12.49	2.4
6 7-3	10/29/85	15	16:36	>4 φ	>4-3 φ	6.65	STAGE 1	12.94	1.58
6 7-4	10/29/85	18	16:48	>4 φ	>4-3 φ	11.78	1 ON 3	16.58	1.95
6 7-4	10/29/85	19	16:48	>4 φ	>4-3 φ	5.09	1 ON 3	10.58	4.35
6 7-4	10/29/85	20	16:49	>4 φ	>4-3 φ	12.47	STAGE 3	10.3	1.27
6 7-5	10/29/85	8	10:09	>4 φ	>4-3 φ	11.75	1 ON 3	16.69	1.2
6 7-5	10/29/85	9	10:09	>4 φ	>4-3 φ	10.31	1 ON 3	14.66	1.72
6 7-5	10/29/85	10	10:10	>4 φ	>4-3 φ	6.03	1 ON 3	14.18	1.35
6 7-6	10/29/85	14	10:22	>4 φ	>4-3 φ	6.56	1 ON 3	13.2	.67
6 7-6	10/29/85	15	10:23	>4 φ	>4-3 φ	10.02	1 ON 3	16.39	1.58
6 7-6	10/29/85	16	10:23	>4 φ	>4-3 φ	11.59	1 ON 3	15.19	.97
6 8-1	10/29/85	24	17:08	>4 φ	>4-3 φ	10.95	1 ON 3	15.07	1.12
6 8-1	10/29/85	25	17:08	>4 φ	>4-3 φ	11.78	1 ON 3	16.54	1.35
6 8-1	10/29/85	26	17:09	>4 φ	>4-3 φ	11.01	1 ON 3	15.11	1.5
6 8-2	10/29/85	30	17:22	>4 φ	>4-3 φ	11.27	1 ON 3	16.21	1.42
6 8-2	10/29/85	31	17:22	>4 φ	>4-3 φ	13.35	1 ON 3	10.19	1.05
6 8-2	10/29/85	32	17:23	>4 φ	>4-3 φ	8.44	1 ON 3	15.71	1.35
6 8-3	10/29/85	0	17:38	>4 φ	>4-3 φ	5.69	1 ON 3	15.3	.52
6 8-3	10/29/85	1	17:38	>4 φ	>4-3 φ	5.35	STAGE 1	10.5	1.58
6 8-3	10/29/85	2	17:39	>4 φ	>4-3 φ	7.95	1 ON 3	15.04	2.02
6 8-5	10/29/85	25	19:04	3-2 φ	>4-1 φ	0	STAGE 1	4.46	1.22
6 8-5	10/29/85	26	19:04	3-2 φ	>4-1 φ	0	STAGE 1	5.25	.53

APPENDIX D-2

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
G 8-5	10/29/85	27	07:05	3-2 φ	≥4-1 φ	0	STAGE 3	4.92	.75
G 8-6	10/29/85	30	19:16	4-3 φ	≥4-2 φ	.94	1 ON 3	7.9	1.07
G 8-6	10/29/85	32	19:17	3-2 φ	≥4-1 φ	.09	STAGE 1	6.07	.92
G 8-6	10/29/85	33	7.:10	4-3 φ	≥4-3 φ	.0	1 ON 3	8.26	1.06
G9-7	10/30/85	2	11:23	4-3 φ	≥4-1 φ	5.4	STAGE 3	13.05	1.59
G9-7	10/30/85	3	11:24	4-3 φ	≥4-2 φ	4.50	1 ON 3	16.79	.95
G9-5	10/30/85	8	11:36	4-3 φ	≥4-2 φ	2.46	STAGE 1	13.96	.72
G9-5	10/30/85	9	11:37	4-3 φ	≥4-2 φ	2.15	STAGE 1	4.9	1.27
G9-4	10/30/85	10	11:45	≥4-3 φ	≥4-2 φ	7.06	1 ON 3	13.04	1.19
G9-4	10/30/85	11	11:45	≥4-3 φ	≥4-2 φ	4.34	STAGE 1	12.61	1.67
G9-4	10/30/85	12	11:46	≥4-3 φ	≥4-2 φ	4.53	1 ON 3	13.41	.0
G9-3	10/30/85	13	11:49	≥4-3 φ	≥4-2 φ	4.10	STAGE 1	11.97	.64
G9-3	10/30/85	14	11:50	4-3 φ	≥4-2 φ	3	1 ON 3	15.99	1.91
G9-3	10/30/85	15	11:50	≥4-3 φ	≥4-2 φ	4.2	1 ON 3	11.06	1.91
G9-2	10/30/85	16	11:56	≥4-3 φ	≥4-2 φ	4.43	STAGE 3	16.11	.95
G9-2	10/30/85	17	11:56	≥4-3 φ	≥4-3 φ	4.02	1 ON 3	14.72	1.03
G9-2	10/30/85	18	11:57	≥4-3 φ	≥4-2 φ	6.02	1 ON 3	14.04	1.43
G9-1	10/30/85	19	12:02	4-3 φ	4-2 φ	4.47	1 ON 3	11.10	1.51
G9-1	10/30/85	20	12:03	≥4-3 φ	≥4-2 φ	6.77	1 ON 3	16.07	3.42
G9-1	10/30/85	21	12:03	≥4-3 φ	≥4-3 φ	5.54	1 ON 3	16.47	1.35
G9-0	10/30/85	23	12:15	4-3 φ	≥4-3 φ	4.55	1 ON 3	6.09	1.11
G9-0	10/30/85	24	12:16	4-3 φ	4-2 φ	3.5	1 ON 3	5.45	1.19
G10-3	10/30/85	25	12:26	4-3 φ	4-2 φ	5.44	1 ON 3	12.73	.64
G10-3	10/30/85	26	12:26	≥4-3 φ	≥4-2 φ	5.60	STAGE 1	12.97	.72
G10-3	10/30/85	27	12:57	4-3 φ	4-2 φ	5.33	STAGE 1	9.03	.0
G10-4	10/30/85	28	12:33	≥4-3 φ	≥4-2 φ	5.20	1 ON 3	13.45	.72
G10-4	10/30/85	29	12:34	≥4-3 φ	≥4-2 φ	6.5	1 ON 3	14.16	.0
G10-4	10/30/85	30	12:34	≥4-3 φ	≥4-2 φ	6.69	1 ON 3	13.33	1.51

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
610-2	10/30/85	32	12:42	$\geq$4-3 ϕ	$\geq$4-2 ϕ	4.95	1 ON 3	14.56	.08
610-2	10/30/85	33	12:42	$\geq$4-3 ϕ	$\geq$4-2 ϕ	5.19	1 ON 3	12.73	1.51
610-1	10/30/85	35	12:49	$\geq$4-3 ϕ	$\geq$4-2 ϕ	5.29	1 ON 3	13.72	.72
N						198		198	198
Mean						8.77		14.19	1.54
Std. Dev.						3.54		3.51	0.90
Min.						0.00		4.46	0.39
Max.						16.23		20.25	5.71

LISTING FOR: Puget Sound REMOTS Survey - ELLIOTT BAY - SITE E-2 APPENDIX D 3

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
E2 A-1	11/2/85	1	12:06	≥4 ɸ	≥4-2 ɸ	7.72	1 ON 3	14.29	.97
E2 A-1	11/2/85	2	12:07	≥4 ɸ	≥4-2 ɸ	13.53	1 ON 3	18.34	1.05
E2 A-1	11/2/85	4	12:08	≥4 ɸ	≥4-2 ɸ	11.71	1 ON 3	18.22	1.72
E2 A-2	11/2/85	5	12:17	4-3 ɸ	≥4-1 ɸ	3.75	1 ON 3	9.64	1.58
E2 A-2	11/2/85	6	12:18	4-3 ɸ	≥4-1 ɸ	2.31	1 ON 3	8.47	.83
E2 A-2	11/2/85	7	12:18	4-3 ɸ	4-2 ɸ	5.09	1 ON 3	11.21	.52
E2 A-3	11/2/85	9	12:26	3-2 ɸ	≥4-1 ɸ	6.6	STAGE 3	12.53	1.27
E2 A-3	11/2/85	10	12:27	3-2 ɸ	≥4-1 ɸ	3.89	STAGE 1	9.68	.6
E2 A-3	11/2/85	11	12:27	3-2 ɸ	≥4-1 ɸ	5.21	1 ON 3	9	.75
E2 A-4	11/2/85	13	12:35	4-3 ɸ	≥4-2 ɸ	3.75	1 ON 3	6.07	1.12
E2 A-4	11/2/85	14	12:36	4-3 ɸ	≥4-1 ɸ	6.45	1 ON 3	6.94	.9
E2 A-4	11/2/85	15	12:37	4-3 ɸ	≥4-1 ɸ	5.14	1 ON 3	7.13	1.05
E2 A-5	11/2/85	17	12:46	3-2 ɸ	≥4-1 ɸ	NA	STAGE 1	3.68	1.07
E2 A-5	11/2/85	18	12:47	4-3 ɸ	≥4-0 ɸ	NA	1 ON 3	4.99	2.47
E2 A-5	11/2/85	19	12:47	4-3 ɸ	≥4-1 ɸ	NA	STAGE 1	4.8	1.42
E2 A-6	11/2/85	22	12:57	4-3 ɸ	≥4-2 ɸ	0	STAGE 1	2.51	1.12
E2 A-6	11/2/85	23	12:58	≥4-3 ɸ	≥4-1 ɸ	0	STAGE 1	2.51	1.27
E2 A-6	11/2/85	24	12:58	≥4 ɸ	≥4-1 ɸ	0	STAGE 1	6.71	.75
E2 A-7	11/2/85	25	13:07	4-3 ɸ	≥4-1 ɸ	0	1 ON 3	3.94	1.2
E2 A-7	11/2/85	27	13:09	≥4-3 ɸ	≥4-1 ɸ	1.71	1 ON 3	3.75	.82
E2 B-1	11/2/85	28	13:21	≥4-3 ɸ	≥4-1 ɸ	7.19	1 ON 3	13.57	2.55
E2 B-1	11/2/85	29	13:21	≥4-3 ɸ	≥4-1 ɸ	0.54	STAGE 1	14.77	.67
E2 B-1	11/2/85	30	13:22	≥4-3 ɸ	≥4-2 ɸ	0.39	1 ON 3	13.61	1.58
E2 B-2	11/2/85	32	13:33	≥4 ɸ	≥4-3 ɸ	0.71	1 ON 3	9.08	.82
E2 B-2	11/2/85	34	13:35	≥4-3 ɸ	≥4-2 ɸ	0.19	1 ON 3	11.44	1.35
E2 B-2	11/2/85	34	13:35	≥4 ɸ	≥4-2 ɸ	0.7	1 ON 3	13.31	.82
E2 C-2	11/2/85	0	15:29	≥4 ɸ	≥4-2 ɸ	10.84	1 ON 3	16.65	1.95

APPENDIX D-3

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
E2C-2	11/2/85	1	15:29	≥4 φ	≥4-2 φ	12.85	1 ON 3	17.51	1.58
E2C-2	11/2/85	2	15:30	≥4 φ	≥4-2 φ	17.63	1 ON 3	17.74	1.87
E2C-3	11/2/85	4	15:42	≥4 φ	≥4-2 φ	10.45	1 ON 3	17.5	2.09
E2C-3	11/2/85	5	15:42	≥4 φ	≥4-2 φ	13.23	1 ON 3	16.06	1.47
E2C-3	11/2/85	6	15:43	≥4 φ	≥4-2 φ	14.9	1 ON 3	18.2	2.41
E2C-4	11/2/85	8	15:53	4-3 φ	≥4-1 φ	4.94	STAGE 1	4.81	1.01
E2C-4	11/2/85	10	15:54	4-3 φ	≥4-1 φ	6.13	STAGE 2	6.87	.93
E2C-4	11/2/85	9	15:54	4-3 φ	≥4-1 φ	5.06	1 ON 3	5.55	1.55
E2C-5	11/2/85	12	16:05	≥4 φ	≥4-1 φ	2.1	STAGE 1	5.16	.05
E2C-5	11/2/85	13	16:05	4-3 φ	≥4-1 φ	4.46	STAGE 1	4.01	.62
E2C-5	11/2/85	14	16:06	≥4-3 φ	≥4-1 φ	3.62	STAGE 1	6.03	1.32
E2C-6	11/2/85	16	16:13	3-2 φ	4-1 φ	NA	Indet	1.36	.47
E2C-6	11/2/85	17	16:14	2-1 φ	4-1 φ	NA	Indet	1.17	.31
E2C-6	11/2/85	18	16:14	2-1 φ	4-1 φ	0	Indet	.04	0
E2A-5A	11/2/85	20	16:25	3-2 φ	≥4-1 φ	4.87	STAGE 1	4.01	1.17
E2A-5A	11/2/85	21	16:25	≥4-3 φ	≥4-1 φ	3.66	1 ON 3	8.73	4.34
E2A-5A	11/2/85	22	16:26	3-2 φ	≥4-0 φ	3.05	1 ON 3	7.04	.05
E2A-6A	11/2/85	24	16:36	≥4-3 φ	≥4-1 φ	3.11	1 ON 3	6.09	.78
E2A-6A	11/2/85	25	16:37	≥4-3 φ	≥4-1 φ	7.53	STAGE 1	9	.78
E2A-6A	11/2/85	26	16:37	4-3 φ	≥4-1 φ	1.04	STAGE 1	4.42	1.09
E2B-3	11/02/85	2	13:52	≥4-3 φ	≥4-2 φ	4.33	STAGE 3	12.02	.92
E2B-3	11/02/85	3	13:52	≥4-3 φ	≥4-2 φ	7.2	1 ON 3	14.04	.92
E2B-3	11/02/85	5	13:54	≥4 φ	≥4-2 φ	3.93	1 ON 3	13.77	1.6
E2B-4	11/02/85	6	14:05	≥4-3 φ	≥4-1 φ	1.34	STAGE 3	12.66	.38
E2B-4	11/02/85	7	14:05	≥4-3 φ	≥4-2 φ	5.27	1 ON 3	14.76	.69
E2B-4	11/02/85	8	14:06	≥4-3 φ	≥4-2 φ	5.58	STAGE 3	12.59	1.22
E2B-5	11/02/85	11	14:18	≥4 φ	≥4-3 φ	4.75	STAGE 3	14.42	1.53
E2B-5	11/02/85	12	14:18	≥4 φ	≥4-3 φ	3.57	STAGE 1	11.7	1.41

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
E2B-6	11/02/85	15	14:31	≥4-3 φ	≥4-2 φ	3.27	1 ON 3	15.49	.99
E2B-6	11/02/85	16	14:31	≥4 φ	≥4-3 φ	4.47	1 ON 3	15.68	.46
E2B-6	11/02/85	17	14:32	≥4-3 φ	≥4-2 φ	4.99	1 ON 3	16.59	1.22
E2C-1	11/02/85	19	14:58	≥4 φ	≥4-3 φ	4.06	STAGE 1	16.13	.53
E2C-1	11/02/85	21	14:59	≥4 φ	≥4-3 φ	5.28	1 ON 3	15.91	2.02
E2C-1	11/02/85	25	15:01	≥4 φ	≥4-3 φ	3.9	STAGE 3	17.62	1.22
N						55		61	61
Mean						5.81		10.24	1.22
Std. Dev.						3.86		5.26	0.70
Min.						0.00		0.04	0.00
Max.						17.63		18.34	4.34

LISTING FOR: Puget Sound REMOTS Survey -- ELLIOTT BAY - Site E-1

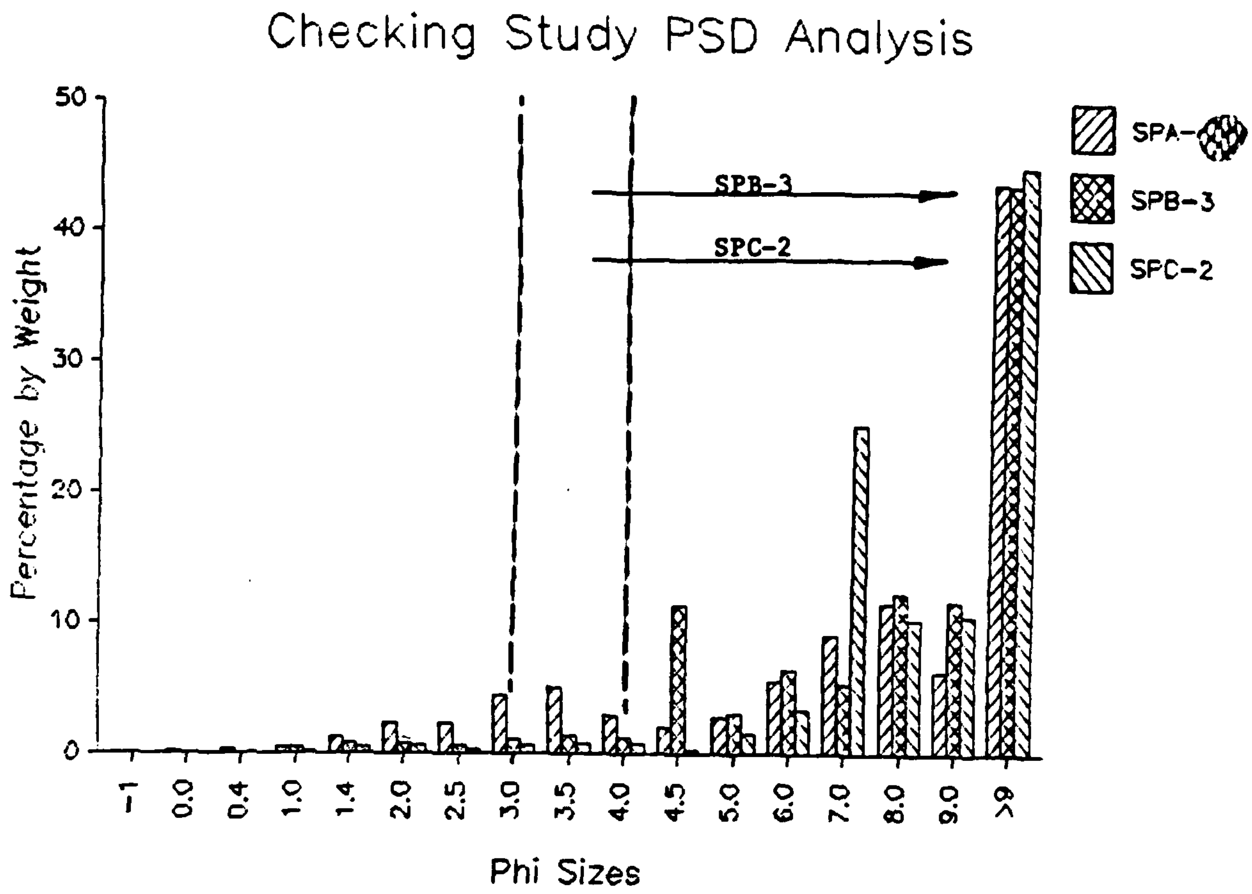
APPENDIX D 4

STATION	FIELD DATE	FRAME #	TIME	MAJOR MODE	G.S. TOTAL RANGE	RPD DEPTH	S. STAGE	PRISM PENETRATION	BOUNDARY ROUGHNESS
E1 A-1	16.37	2	16:37	≥4 φ	≥4-3 φ	12.95	1 ON 3	10.2	1.06
E1 A-1	11/1/85	4	16:39	≥4 φ	≥4-3 φ	16.1	1 ON 3	20.29	.90
E1 A-1	11/1/5	5	16:40	≥4 φ	≥4-3 φ	10.21	1 ON 3	10.17	.65
E1 A-2	11/1/85	6	16:49	≥4 φ	≥4-2 φ	15.36	1 ON 3	19.72	1.55
E1 A-2	11/1/85	7	16:50	≥4 φ	≥4-3 φ	17.55	1 ON 3	20.54	.65
E1 A-2	11/1/85	8	16:51	≥4 φ	≥4-2 φ	13.64	1 ON 3	20.66	.49
E1 A-3	11/1/85	11	17:03	≥4-3 φ	≥4-2 φ	9.36	1 ON 3	14.09	.90
E1 A-3	11/1/85	12	17:04	≥4-3 φ	≥4-2 φ	10.03	1 ON 3	10.13	1.64
E1 A-3	11/1/85	13	17:05	≥4-3 φ	≥4-2 φ	7.90	1 ON 3	10.6	1.39
E1 A-4	11/1/85	14	17:13	≥4-3 φ	≥4-1 φ	16.30	1 ON 3	19.0	1.55
E1 A-4	11/1/85	15	17:13	≥4 φ	≥4-2 φ	11.6	1 ON 3	15.30	2.13
E1 A-4	11/1/85	17	17:15	≥4-3 φ	≥4-1 φ	14.46	1 ON 3	10.16	.9
E1 B-1	11/1/85	12	15:19	≥4-3 φ	≥4-1 φ	12.56	1 ON 3	19.0	1.31
E1 B-1	11/1/85	13	15:20	≥4-3 φ	≥4-2 φ	9.03	1 ON 3	14.65	2.70
E1 B-1	11/1/85	14	5.:21	≥4-3 φ	≥4-2 φ	14.02	1 ON 3	17.67	1.0
E1 B-2	11/1/85	16	15:43	4-3 φ	≥4-2 φ	11.47	1 ON 3	14.20	1.96
E1 B-2	11/1/85	17	15:44	4-3 φ	≥4-1 φ	5.32	1 ON 3	11.05	1.0
E1 B-2	11/1/85	18	15:45	4-3 φ	≥4-1 φ	11.67	1 ON 3	16.2	1.55
E1 B-3	11/1/85	20	15:58	≥4-3 φ	≥4-2 φ	15.45	1 ON 3	17.92	.65
E1 B-3	11/1/85	21	15:59	≥4-3 φ	≥4-2 φ	16.21	1 ON 3	10.58	4.01
E1 B-3	11/1/85	22	16:00	≥4-3 φ	≥4-2 φ	11.01	1 ON 3	14.12	.65
E1 B-4	11/1/85	24	16:11	≥4-3 φ	≥4-2 φ	14.79	1 ON 3	10.62	1.06
E1 B-4	11/1/85	25	16:13	≥4-3 φ	≥4-2 φ	16.09	1 ON 3	20.33	.02
E1 B-4	11/1/85	26	16:14	≥4-3 φ	≥4-2 φ	15.66	1 ON 3	20.25	.90
E1 C-1	11/1/85	1	14:36	4-3 φ	≥4-2 φ	5.06	STAGE 1	0.22	1.0
E1 C-1	11/1/85	2	14:37	4-3 φ	≥4-2 φ	9.69	1 ON 3	17.60	2.21
E1 C-1	11/1/85	3	14:38	4-3 φ	≥4-2 φ	10.41	1 ON 3	17.1	.49

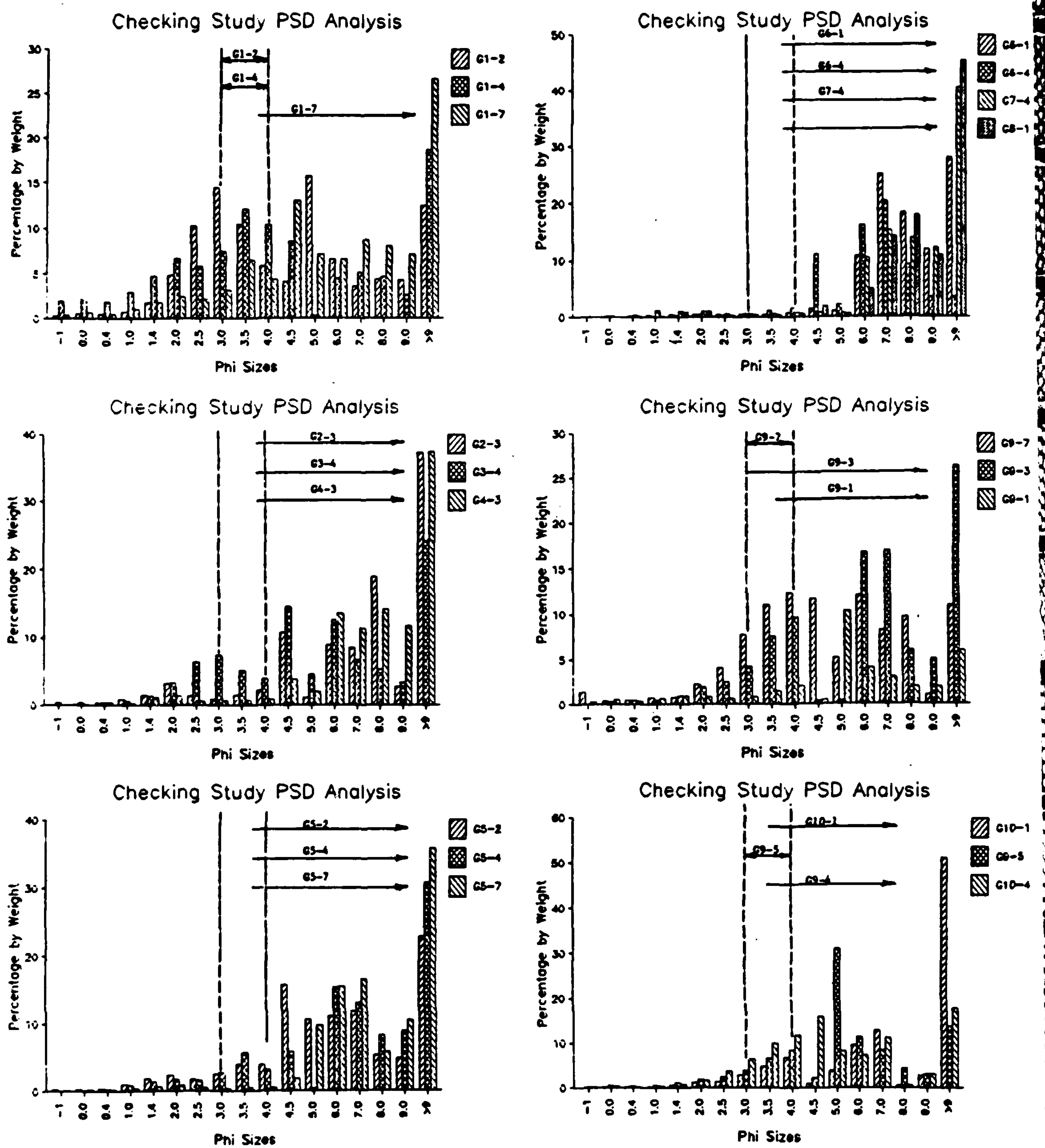
WA13 Checking Study PSD Analysis--1/08/86

STATION	PhiSize	-1	0.0	0.4	1.0	1.4	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	>9	<,=4	wt>4	Corr Fines Total	TOTAL
	mm	2.00	1		.5		.25		.126		.063		.032	.016	.008	.004	.002	<.002				
	Class	gravel	sand										silt					clay				
Saratoga Passage ZSF																						
SPA-4	weight	.00	.049	.075	.133	.314	.595	.591	1.16	1.34	.764	.5	.7	1.45	2.35	3	1.65	11.4	5.02	21.1	.421	26.066
	percentg	.00	.186	.288	.510	1.20	2.28	2.27	4.44	5.13	2.93	1.92	2.69	5.56	9.02	11.5	6.33	43.74	19.2	80.8		100
SPB-3	weight	.00	0	0	.098	.192	.191	.14	.246	.35	.31	2.75	.75	1.55	1.3	3	2.85	10.55	1.53	22.8	.455	24.277
	percentg	.00	0	0	.404	.791	.787	.577	1.01	1.44	1.28	11.3	3.09	6.38	5.35	12.4	11.7	43.46	6.29	93.7		100
SPC-2	weight	.00	0	0	.042	.099	.131	.079	.129	.155	.167	.05	.35	.75	5.5	2.25	2.3	9.8	.802	21	.42	21.802
	percentg	.00	0	0	.193	.454	.601	.362	.592	.711	.766	.229	1.61	3.44	25.2	10.3	10.5	44.95	3.68	96.3		100
Port Gardner ZSF																						
61-2	weight	.11	.226	.193	.359	.807	2.22	4.72	6.63	4.80	2.68	1.85	7.25	3	1.6	2	1.95	5.75	22.7	23.4	.468	46.142
	percentg	.23	.490	.418	.778	1.75	4.80	10.2	14.4	10.4	5.80	4.01	15.7	6.50	3.47	4.33	4.23	12.46	49.3	50.7		100
61-4	weight	.82	.923	.789	1.25	2.02	2.88	2.52	3.23	5.21	4.46	3.65	.1	1.9	2.2	2	1.1	8.05	24.1	19	.38	43.102
	percentg	1.91	2.14	1.83	2.91	4.68	6.67	5.85	7.48	12.1	10.3	8.47	.232	4.41	5.10	4.64	2.55	18.68	55.9	44.1		100
61-7	weight	.11	.21	.162	.336	.574	.77	.672	1.01	2.10	1.40	4.2	2.3	2.1	2.8	2.6	2.3	8.6	7.34	24.9	.498	32.244
	percentg	.35	.651	.502	1.04	1.78	2.39	2.08	3.14	6.50	4.34	13.0	7.13	6.51	8.68	8.06	7.13	26.67	22.8	77.2		100
62-3	weight	.00	.024	.108	.219	.392	.879	.355	.247	.418	.621	2.95	.3	2.45	2.35	5.2	.75	10.25	3.26	24.3	.485	27.513
	percentg	.00	.087	.393	.796	1.42	3.19	1.29	.898	1.52	2.26	10.7	1.09	8.90	8.54	18.9	2.73	37.26	11.9	88.1		100
63-4	weight	.12	.148	.127	.216	.508	1.27	2.49	2.88	2.01	1.54	5.65	1.75	4.9	2.6	2.05	1.3	9.4	11.3	27.7	.553	38.958
	percentg	.31	.380	.326	.554	1.30	3.26	6.39	7.40	5.15	3.96	14.5	4.49	12.6	6.67	5.26	3.34	24.13	29.0	71.0		100
64-3	weight	.00	.018	.101	.067	.288	.333	.168	.186	.172	.227	.95	.5	3.4	2.85	3.55	2.95	9.4	1.56	23.6	.472	25.16
	percentg	.00	.072	.401	.266	1.14	1.32	.668	.739	.684	.902	3.78	1.99	13.5	11.3	14.1	11.7	37.36	6.20	93.8		100
65-2	weight	.07	.079	.13	.325	.638	.797	.575	.82	1.34	1.34	5.35	3.6	3.75	4	1.8	1.65	7.8	6.11	28.0	.559	34.059
	percentg	.20	.232	.382	.954	1.87	2.34	1.69	2.41	3.92	3.94	15.7	10.6	11.0	11.7	5.28	4.84	22.90	17.9	82.1		100
65-4	weight	.00	.034	.092	.272	.445	.555	.512	.855	1.82	1.03	1.85	.1	4.95	4.2	2.65	2.85	9.85	5.62	26.5	.529	32.072
	percentg	.00	.106	.287	.848	1.39	1.73	1.60	2.67	5.69	3.22	5.77	.312	15.4	13.1	8.26	8.89	30.71	17.5	82.5		100
65-7	weight	.04	.076	.072	.083	.17	.215	.124	.092	.142	.145	.5	2.65	4.2	4.5	1.55	2.85	9.7	1.16	26.0	.519	27.112
	percentg	.16	.280	.266	.306	.627	.793	.457	.339	.524	.535	1.84	9.77	15.5	16.6	5.72	10.5	35.78	4.29	95.7		100
66-1	weight	.00	0	0	.061	.105	.117	.089	.093	.111	.162	.35	.25	2.55	5.95	4.35	2.85	6.65	.738	23.0	.459	23.688
	percentg	.00	0	0	.258	.443	.494	.376	.393	.469	.684	1.48	1.06	10.8	25.1	18.4	12.0	28.07	3.12	96.9		100
66-4	weight	.00	.041	.034	.035	.07	.123	.088	.156	.323	.464	3.2	.65	4.7	5.9	2.65	1	1	1.33	27.6	.551	28.884
	percentg	.00	.142	.118	.121	.242	.426	.305	.540	1.12	1.61	11.1	2.25	16.3	20.4	9.17	3.46	3.462	4.62	95.4		100
67-4	weight	.00	.023	.067	.265	.222	.236	.135	.12	.133	.168	.15	.15	2.35	3.45	3.1	2.75	9.1	1.37	21.1	.421	22.419
	percentg	.00	.103	.299	1.18	.990	1.05	.602	.535	.593	.749	.669	.669	10.5	15.4	13.8	12.3	40.59	6.11	93.9		100
68-1	weight	.00	0	.019	.034	.188	.224	.08	.097	.106	.133	.45	.15	1.15	3.35	4.2	2.55	10.6	.881	22.5	.449	23.331
	percentg	.00	0	.081	.146	.806	.960	.343	.416	.454	.570	1.93	.643	4.93	14.4	18.0	10.9	45.43	3.78	96.2		100
69-1	weight	.24	.527	.339	.651	.873	.834	.648	.8	1.43	2.01	.45	10.4	4.05	3	1.95	1.95	5.95	8.35	27.7	.554	[illegible]49
	percentg	.68	1.46	.940	1.81	2.42	2.31	1.80	2.22	3.96	5.57	1.25	28.7	11.2	8.32	5.41	5.41	16.51	23.2	76.8		100
69-3	weight	.00	.085	.125	.123	.275	.565	.702	1.22	2.16	2.76	.1	.1	4.8	4.85	1.7	1.45	7.55	8.02	20.6	.411	28.567
	percentg	.00	.298	.438	.431	.963	1.98	2.46	4.27	7.56	9.67	.350	.350	16.8	17.0	5.95	5.08	26.43	28.1	71.9		100

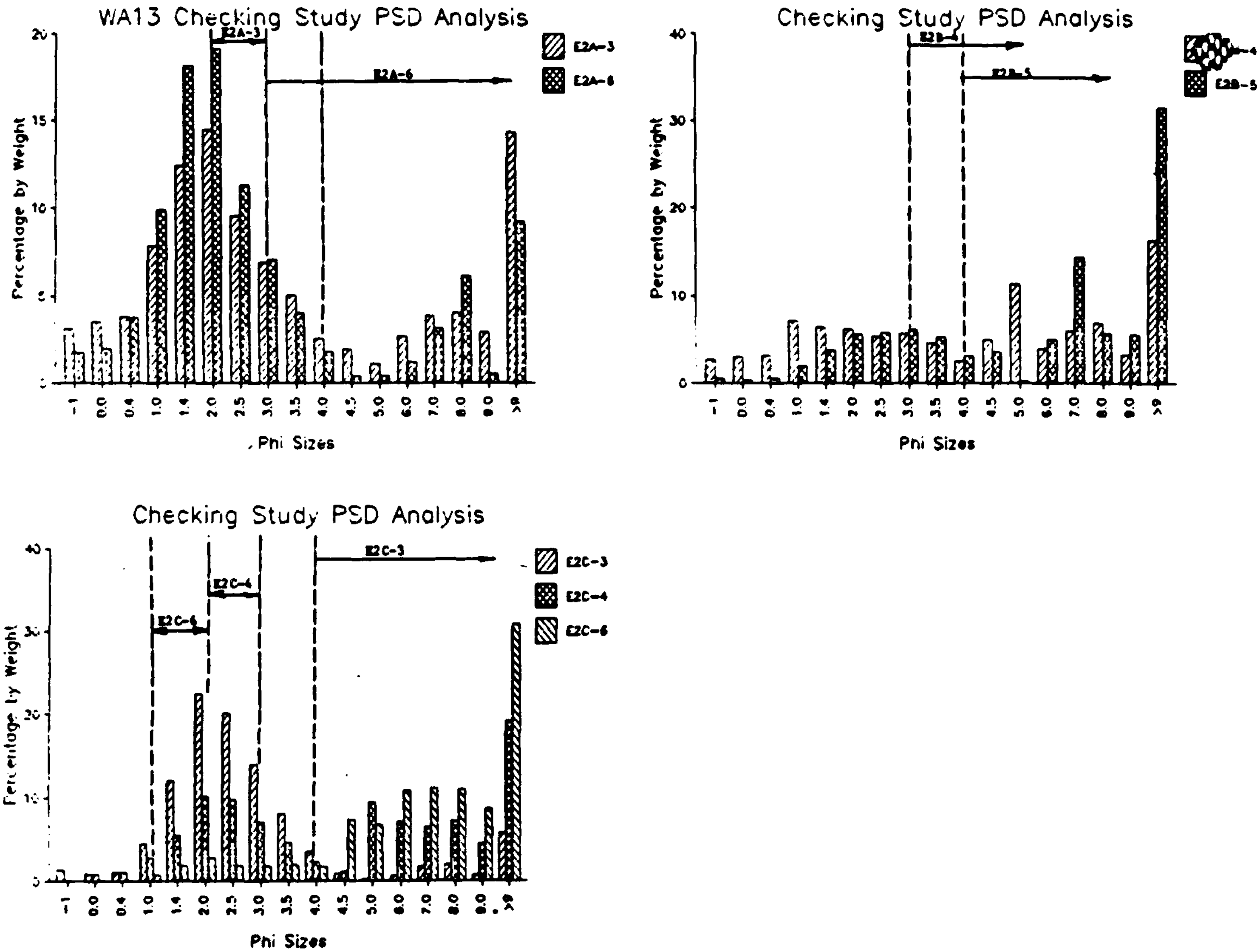
STATION	PhiSize	-1	0.0	0.4	1.0	1.4	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	>9	<,=4	wt>4	Corr. Fines Total	TOTAL
	mm	2.00	1		.5		.25		.126		.063		.032	.016	.008	.004	.002	<.002				
	Class	gravel					sand						silt					clay				
Port Gardner (continued)																						
69-5	weight	.08	.156	.115	.161	.356	.609	.807	1.32	2.27	2.94	.75	10.8	3.95	2.9	1.5	1.1	4.75	8.81	25.8	.515	34.557
	percentg	.23	.451	.333	.466	1.03	1.76	2.34	3.81	6.58	8.50	2.17	31.3	11.4	8.39	4.34	3.18	13.75	25.5	74.5		100
69-7	weight	.47	.142	.172	.261	.251	.767	1.40	2.68	3.84	4.30	4.05	1.8	4.2	2.85	3.35	.35	3.8	14.3	20.4	.408	34.664
	percentg	1.34	.410	.496	.753	.724	2.21	4.02	7.72	11.1	12.4	11.7	5.19	12.1	8.22	9.66	1.01	10.96	41.1	58.9		100
610-1	weight	.04	.101	.085	.115	.275	.573	.662	1.34	2.33	3.31	.4	1.85	4.7	6.3	.25	1.35	24.95	8.83	39.8	.796	48.626
	percentg	.07	.208	.175	.236	.566	1.18	1.36	2.75	4.79	6.82	.823	3.80	9.67	13.0	.514	2.78	51.31	18.2	81.8		100
610-4	weight	.03	.139	.047	.103	.289	.617	1.32	2.30	3.62	4.24	5.8	3	2.65	4.05	.2	1.15	6.45	12.7	23.3	.466	35.998
	percentg	.09	.386	.131	.286	.803	1.71	3.65	6.38	10.0	11.8	16.1	8.33	7.36	11.3	.556	3.19	17.92	35.3	64.7		100
Fourmile Rock ZSF																						
E2A-3	weight	1.37	1.54	1.68	3.47	5.51	6.42	4.23	3.06	2.22	1.13	.85	.5	1.2	1.7	1.8	1.3	6.35	30.6	13.7	.274	44.319
	percentg	3.09	3.48	3.79	7.83	12.4	14.5	9.55	6.90	5.00	2.55	1.92	1.13	2.71	3.84	4.06	2.93	14.33	69.1	30.9		100
E2A-6	weight	.85	.978	1.82	4.83	8.85	9.34	5.52	3.45	1.96	.879	.2	.2	.6	1.55	3	.25	4.5	38.5	10.3	.206	48.766
	percentg	1.74	2.01	3.73	9.90	18.2	19.1	11.3	7.07	4.01	1.80	.410	.410	1.23	3.18	6.15	.513	9.228	78.9	21.1		100
E2B-4	weight	1.07	1.19	1.26	2.85	2.55	2.45	2.15	2.28	1.84	1.04	2	4.5	1.6	2.35	2.75	1.3	6.5	18.7	21	.42	39.682
	percentg	2.69	2.99	3.18	7.19	6.43	6.18	5.41	5.74	4.65	2.63	5.04	11.3	4.03	5.92	6.93	3.28	16.38	47.1	52.9		100
E2B-5	weight	.26	.168	.234	.851	1.59	2.36	2.43	2.58	2.22	1.33	1.5	.1	2.1	6	2.4	2.35	13.25	14.0	27.7	.554	41.721
	percentg	.62	.403	.561	2.04	3.82	5.66	5.82	6.18	5.33	3.18	3.60	.240	5.03	14.4	5.75	5.63	31.76	33.6	66.4		100
E2C-3	weight	.72	.446	.614	2.49	6.66	12.4	11.1	7.68	4.44	1.95	.45	.1	.35	.95	1.1	.4	3.2	48.5	6.55	.131	55.015
	percentg	1.31	.811	1.12	4.52	12.1	22.5	20.1	14.0	8.07	3.55	.818	.182	.636	1.73	2.00	.727	5.817	88.1	11.9		100
E2C-4	weight	.05	.3	.352	.944	1.87	3.44	3.30	2.41	1.58	.778	.35	3.2	2.4	2.2	2.45	1.55	6.5	15.0	18.7	.373	33.676
	percentg	.16	.891	1.05	2.80	5.55	10.2	9.81	7.17	4.69	2.31	1.04	9.50	7.13	6.53	7.28	4.60	19.30	44.6	55.4		100
E2C-6	weight	.00	.053	.041	.219	.552	.843	.562	.552	.587	.512	2.25	2.05	3.3	3.4	3.35	2.65	9.4	3.92	26.4	.528	30.321
	percentg	.00	.175	.135	.722	1.82	2.78	1.85	1.82	1.94	1.69	7.42	6.76	10.9	11.2	11.0	8.74	31.00	12.9	87.1		100
Inner Elliott Bay ZSF																						
E1A-2	weight	.09	.012	.028	.083	.601	.914	.557	.408	.382	.265	.35	4.7	2.7	3.1	3.4	2.45	9.35	3.34	26.1	.521	29.386
	percentg	.29	.041	.095	.282	2.05	3.11	1.90	1.39	1.30	.902	1.19	16.0	9.19	10.5	11.6	8.34	31.82	11.4	88.6		100
E1A-3	weight	1.64	.909	.486	.92	1.63	3.04	3.41	3.37	2.57	1.10	1.4	.8	2	5.45	3.05	1.65	9.05	19.1	23.4	.468	42.475
	percentg	3.86	2.14	1.14	2.17	3.83	7.17	8.04	7.93	6.06	2.58	3.30	1.88	4.71	12.8	7.18	3.88	21.31	44.9	55.1		100
E1B-2	weight	3.66	1.90	1.84	4.53	6.31	6.17	3.65	2.25	1.57	1.02	.15	3.45	1	2.65	1.45	1.35	5.2	32.9	15.3	.305	48.14
	percentg	7.61	3.95	3.81	9.41	13.1	12.8	7.57	4.68	3.27	2.11	.312	7.17	2.08	5.50	3.01	2.80	10.80	68.3	31.7		100
E1B-3	weight	.27	.239	.194	.466	.934	1.36	1.50	1.81	2.05	1.65	3.45	4	.75	6.65	3.5	1.5	8.95	10.5	28.8	.576	39.264
	percentg	.68	.609	.494	1.19	2.38	3.47	3.81	4.61	5.22	4.19	8.79	10.2	1.91	16.9	8.91	3.82	22.79	26.7	73.3		100
Duplicates																						
69-1	weight	.23	.301	.238	.606	.95	.939	.785	.992	1.43	1.89	8.95	3.7	3.35	2.9	3.95	1.2	6.45	8.35	30.5	.61	38.854
	percentg	.59	.775	.613	1.56	2.45	2.42	2.02	2.55	3.67	4.86	23.0	9.52	8.62	7.46	10.2	3.09	16.60	21.5	78.5		100
69-5	weight	.05	.15	.114	.168	.326	.742	1.23	1.84	2.70	3.22	12	3.25	5.4	4.8	1.95	.5	7	10.5	34.9	.698	45.432
	percentg	.11	.330	.251	.370	.718	1.63	2.70	4.05	5.94	7.08	26.4	7.15	11.9	10.6	4.29	1.10	15.41	23.2	76.8		100
E2C-3	weight	1.06	.618	.769	2.97	8.88	16.8	15.2	10.6	5.89	2.67	2.25	.6	.85	1.15	1.25	.15	4.45	65.5	10.7	.214	76.155
	percentg	1.39	.812	1.01	3.89	11.7	22.1	19.9	13.9	7.74	3.51	2.95	.788	1.12	1.51	1.64	.197	5.843	85.9	14.1		100



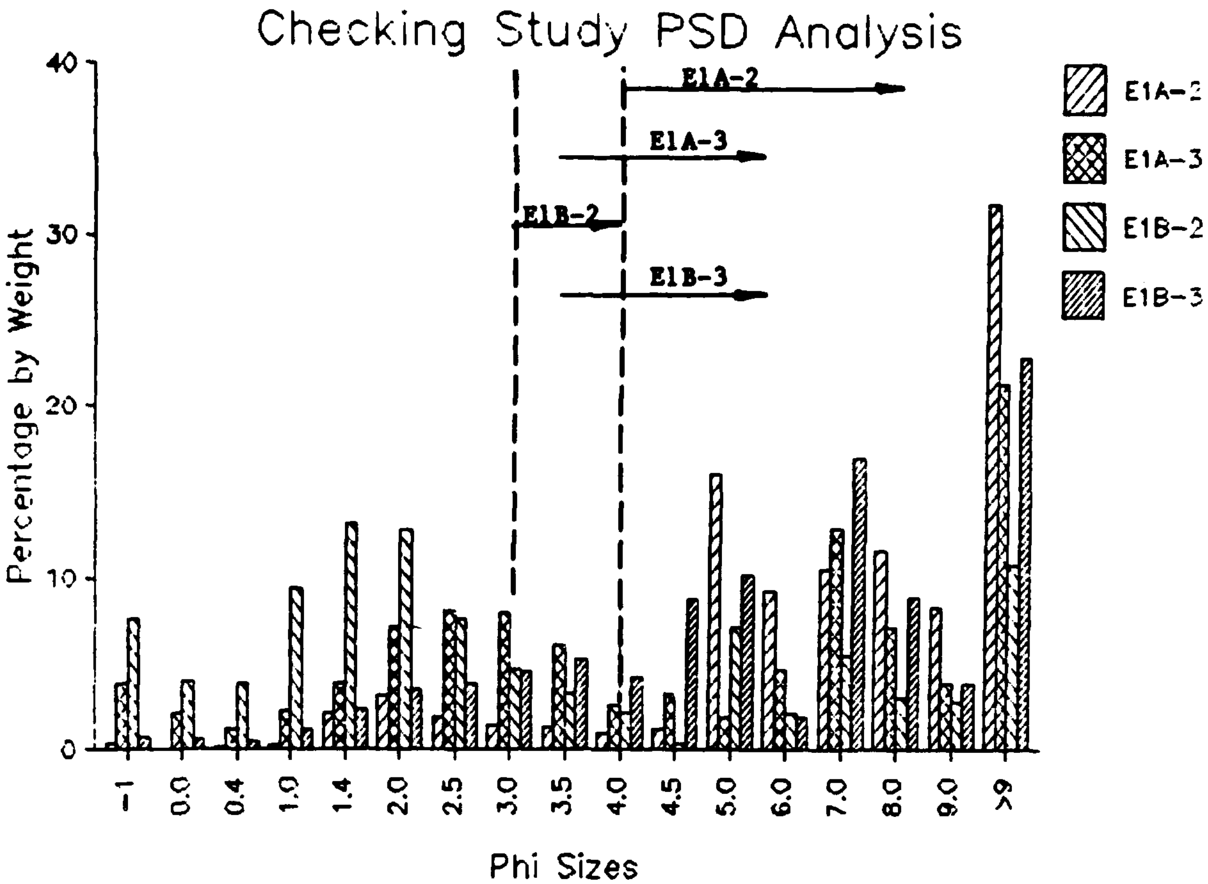
E-1. Comparison of REMOTS and PSD analyses for the Saratoga Passage ZSF. Three REMOTS stations were selected for re-sampling and analysis, to determine a more complete range of particle sizes (Photographic images from one REMOTS station wer not able to be analyzed). Arrows refer to the range of major modes of particle size classes determined by the REMOTS analysis.



E-2. Comparison of REMOTS and PSD analyses for the Port Gardner ZSF. Nineteen REMOTS stations were selected for re-sampling and analysis, to determine a more complete range of particle sizes. Arrows refer to the range of major modes of particle size classes determined by the REMOTS analysis.



E-3. Comparison of REMOTS and PSD analyses for the Fourmile Rock ZSF. Seven REMOTS stations were selected for re-sampling and analysis, to determine a more complete range of particle sizes. Arrows refer to the range of major modes of particle size classes determined by the REMOTS analysis.



E-4. Comparison of REMOTS and PSD analyses for the Inner Elliott Bay ZSF. Four REMOTS stations were selected for re-sampling and analysis, to determine a more complete range of particle sizes. Arrows refer to the range of major modes of particle size classes determined by the REMOTS analysis.

END

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