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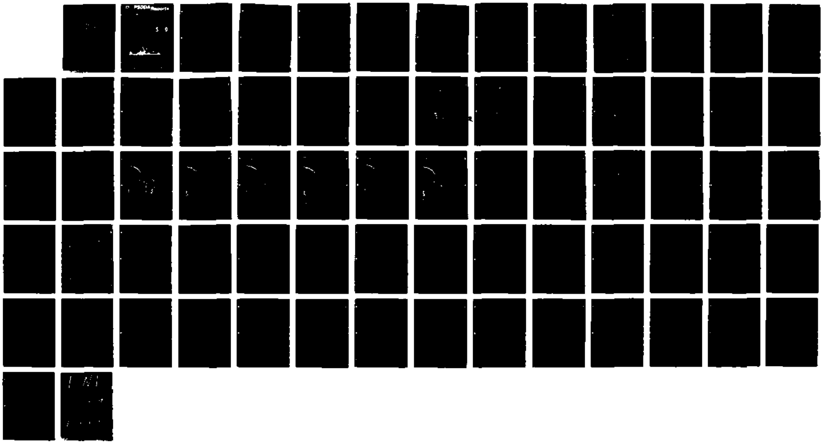

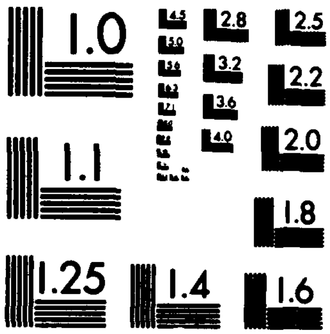

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PSDDA Reports

Puget Sound Dredged Disposal Analysis

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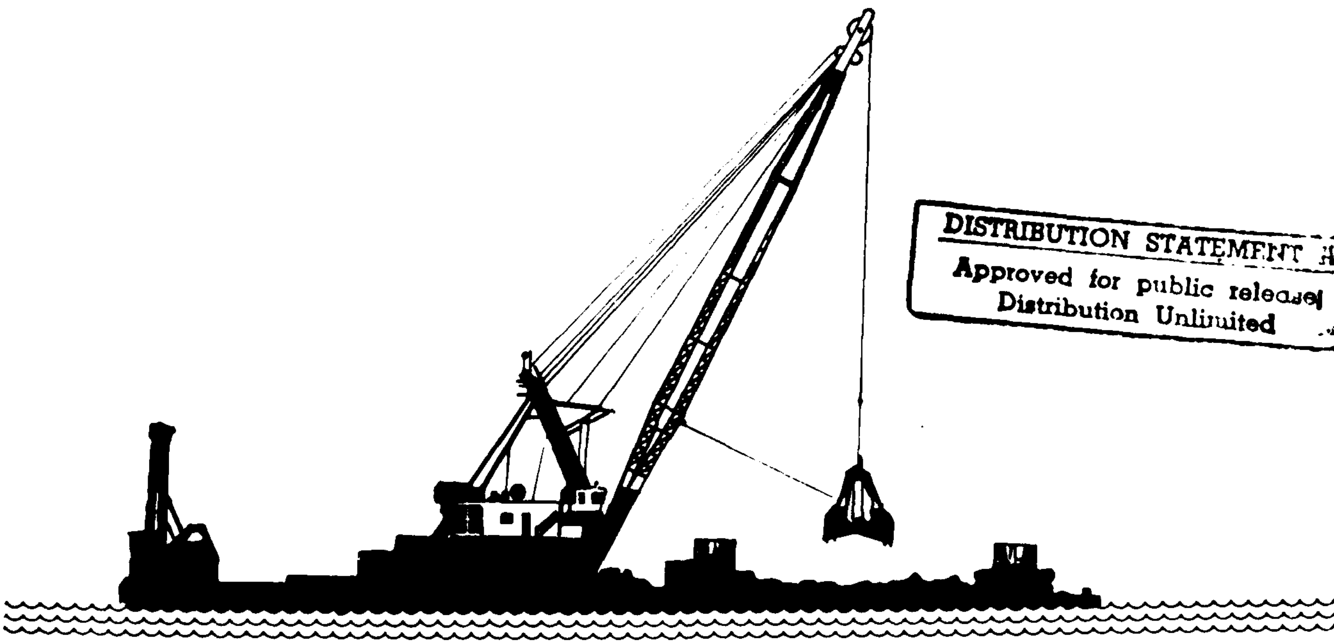
Washington State Dept. of Natural Resources

PUGET SOUND SEDIMENT DEPOSITION ANALYSIS: PHASE II



Prepared by: Evans Hamilton Inc.
Seattle, Washington

MAY 1987

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ECOLOGY

FINAL REPORT

PUGET SOUND SEDIMENT DEPOSITION ANALYSIS: PHASE II

by

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May 1, 1987

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ACKNOWLEDGEMENTS

The authors wish to thank those who assisted in this investigation. Special thanks to Chris Bannick and Gary Rosenthal who were most helpful in providing time in the execution of field and laboratory work. For the assistance in preparing this report Susan Ebbesmeyer, Toni Proctor, and Clay Wilson. Additional thanks goes to Mrs. Judy Heinze for the special support which was needed at the crucial time.

INTRODUCTION

Phase II of the Puget Sound Dredge Disposal Analysis (PSDDA), examined five Zones of Siting Feasibility (ZSFs). These zones were located in northern and southern Puget Sound, and as in the Phase I study, were evaluated for their suitability for the future disposal of dredged materials (Striplin et al., 1986). The Phase II area covers southern Puget Sound from the Narrows Bridge to Olympia, Northern Puget Sound from Foulweather Bluff and Saratoga Passage to the Canadian border, and the Strait of Juan de Fuca westward to Port Angeles. The Zones are located between Lummi and Sinclair Islands, in Bellingham Bay, east of McNeil Island, and between Anderson and Ketron Islands, and south of Devil's Head at the entrance to Drayton Passage (Figure 1).

Within each zone, preliminary disposal sites were located in areas where the tidal current energy was believed to be very low, because, under a "non-dispersive" philosophy, the goal was to choose sites where newly deposited dredged material generally would remain undisturbed. A number of checking studies were conducted in each ZSF to refine the disposal sites by identifying their gross physical and biological characteristics. A quantitative approach was required to confirm that the sites were situated within low energy or "depositional" environments where fine sediments naturally accumulate. A procedure was selected in which a statistical evaluation of physical characteristics of the sediments was carried out.

This procedure, termed "depositional analysis", is based on the fact that fine sediments and organic material settle out of the water column to the sea floor in areas of low energy. The method involves examining the sediment at each station located on a specific depth contour, and identifying areas of low energy through statistical evaluations of measures of organic content, grain size, and water content.

The methods used in the analysis were developed from observations made in southern California where the organic enrichment in the vicinity of municipal sewage outfalls was noted to be in direct proportion to distance from the discharge (Bascom, 1978). The concentration of organic material in the sediment decreased from the outfall in the direction of the alongshore current (Hendricks, 1976). Average values of 5 day biochemical oxygen demand measurements (BOD_5) along depth intervals were calculated and compared to the BOD_5 values at each station and the depositonal patterns due to the discharge plume were elucidated. The grid of stations established around the outfall region showed that the greatest amount of organic material deposited at the depth of the outfall and dispersed forming an eliptical pattern with the outfall at one apex. It was postulated that the natural deposition of particulate material may occur in a somewhat similar manner. However, the use of BOD_5 as the only indicator of deposition may not be adequate without a measure of grain size.

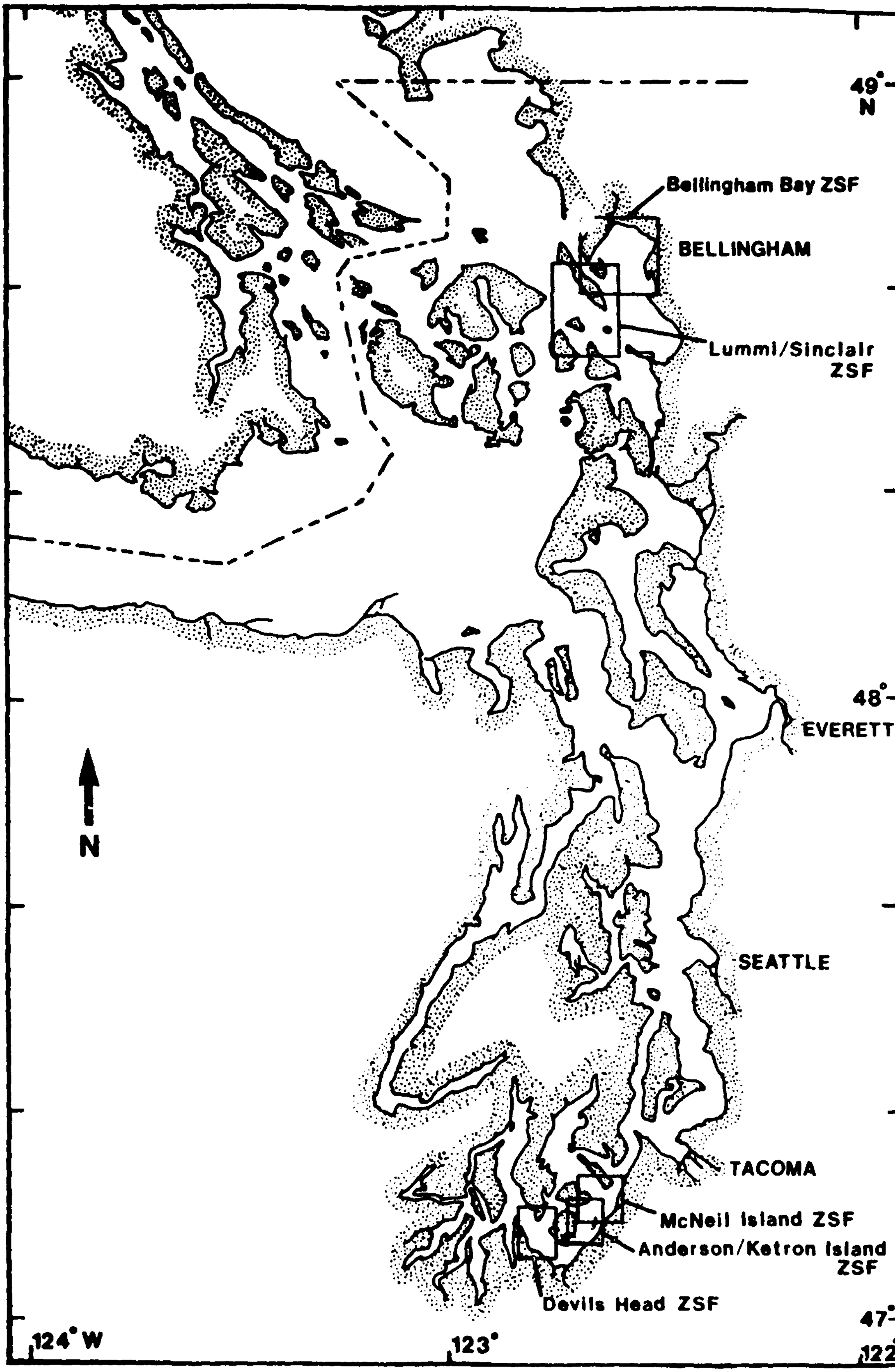

Figure 1. Map of Puget Sound showing the general study areas.

The depositional analysis was refined by adding the grain size, percent volatile solids, and percent water to the analysis for studies in Puget Sound. The technique was used during the Seahurst and Duwamish Head baseline studies to identify areas where the depositon of organic material from an outfall most likely would occur (Word et al., 1984a, b). A comparison was made of the percent volatile solids, five-day biochemical oxygen demand, percent water, and median grain size of sediment samples taken from a number of stations located in the East Passage of central Puget Sound. Because of the natural depth dependent variation of these parameters, only samples taken at similar depths were statistically compared. Stations where sediment samples had high levels of organic material, high water content, and high percent clay were always found to be located in areas with low current speeds or tidal eddies. This correlation suggested that these areas were sediment sinks, or were depositional in nature. The fact that fine sediments tend to settle in low current areas is not surprising, but the significance of elevated values of the other parameters requires further explanation. A high level of volatile solids (% VS) indicates that a large percentage of the sediment by weight is volatile at 550°C. This volatile material consists of organic and inorganic solids. High BOD_5 values indicate the presence of a large amount of biologically available organic material. A high BOD_5 value is anticipated in sediments with high % VS but may not correlate with % VS if the organic material is not readily available to microorganisms. Large BOD_5 values suggest that organic material is accumulating rapidly through settlement, or that there is a large amount of biological activity generating organic material for microbial use. Percent water is a by-product of the volatile solids analysis, and a high percent water usually coincides with small seidment grain sizes.

None of the depositional analysis parameters independently provides complete assurance that an area is depositional. For instance, past studies have found that sediment grains between 0.1 and 0.5 mm sometimes are more easily eroded than sediments that are either larger or smaller (Moherek, 1978; Kendall, 1983). Therefore, if the selection of a depositional site depended solely on locating sediments with fine grain size and high percent clay, there is a possibility that an area of even lower energy could be overlooked. However, when at least one of the other parameters (volatile solids, BOD_5, or percent water) also indicates a low energy environment, the site may be labeled depositional with a high degree of confidence.

By examining existing bottom sediments through the depositional analysis methods, the end product of the Puget Sound basin's natural erosion and accretion process is being observed directly. The exact pathway by which the sediments arrived at a site may not be completely understood, but the knowledge that very fine sediments are accumulating greatly simplifies the task of predicting the fate of dredged material that is disposed at the site. If the disposal methods are selected to minimize the amount of material that is lost during its descent through the water column, and if the material's erodability characteristics are similar to those of the existing bottom sediments, the conclusion that the dredged material will also remain in place may be made with a high degree of certainty.

MATERIALS AND METHODS

A total of 251 stations were sampled throughout all five ZSF's. Stations were selected along transect lines at specific depth intervals (50', 100', 200', 300', 400', 500', 600', 700') so that comparisons could be made among transects and to allow statistical computations of areas of elevated organics and smaller grain sizes for each depth sampled.

Fifty-nine stations were sampled at the Lummi/Sinclair Island ZSF on the 22nd, 25th, and 26th of September 1986. There were 40 stations established in Bellingham Bay on October 15-16 1986 (Fig. 2). In south Puget Sound, 149 stations were distributed among the three ZSF's. Sampling in south Sound occurred from October 20 to October 25 1986. The McNeil Island ZSF consisted of 42 stations, the Anderson/Ketron Island ZSF consisted of 66 stations and there were 41 stations in Devils Head ZSF (Fig. 2).

NAVIGATION

To achieve accurate station positioning a combination of navigational aids were employed. At the ZSF off Lummi and Sinclair Islands there was strong interference in the area making navigation by LORAN C unreliable. A Mini-Ranger III System (MRS) was used in conjunction with a variable range radar providing a positioning accuracy of approximately six meters.

In Bellingham Bay variable radar range was used in conjunction with LORAN C coordinates providing a positioning accuracy of approximately 18.5 meters. Navigation using LORAN C in Nisqually Reach (south Puget Sound) was not possible due to some strong interference in the area. Navigation was therefore accomplished using a Mini-Ranger III System (MRS) which provided accurate positioning to within three meters.

The water depth criteria used during this project for acceptable depth variation during replicate sampling were either 10% of the established depth or 20 feet, whichever was less. Depths were measured using recording paper and digital output fathometers.

FIELD SAMPLING PROCEDURES

Subtidal sediment samples were collected in a consistent repeatable manner with a 0.1 m^2 modified van Veen grab sampling device. Upon collection, the physical characteristics of the sediment were described and recorded for each sample. This information included sediment texture and color; strength and type of odors; sampler penetration depth, degree of leakage, and sediment surface disturbance; and any obvious abnormalities such

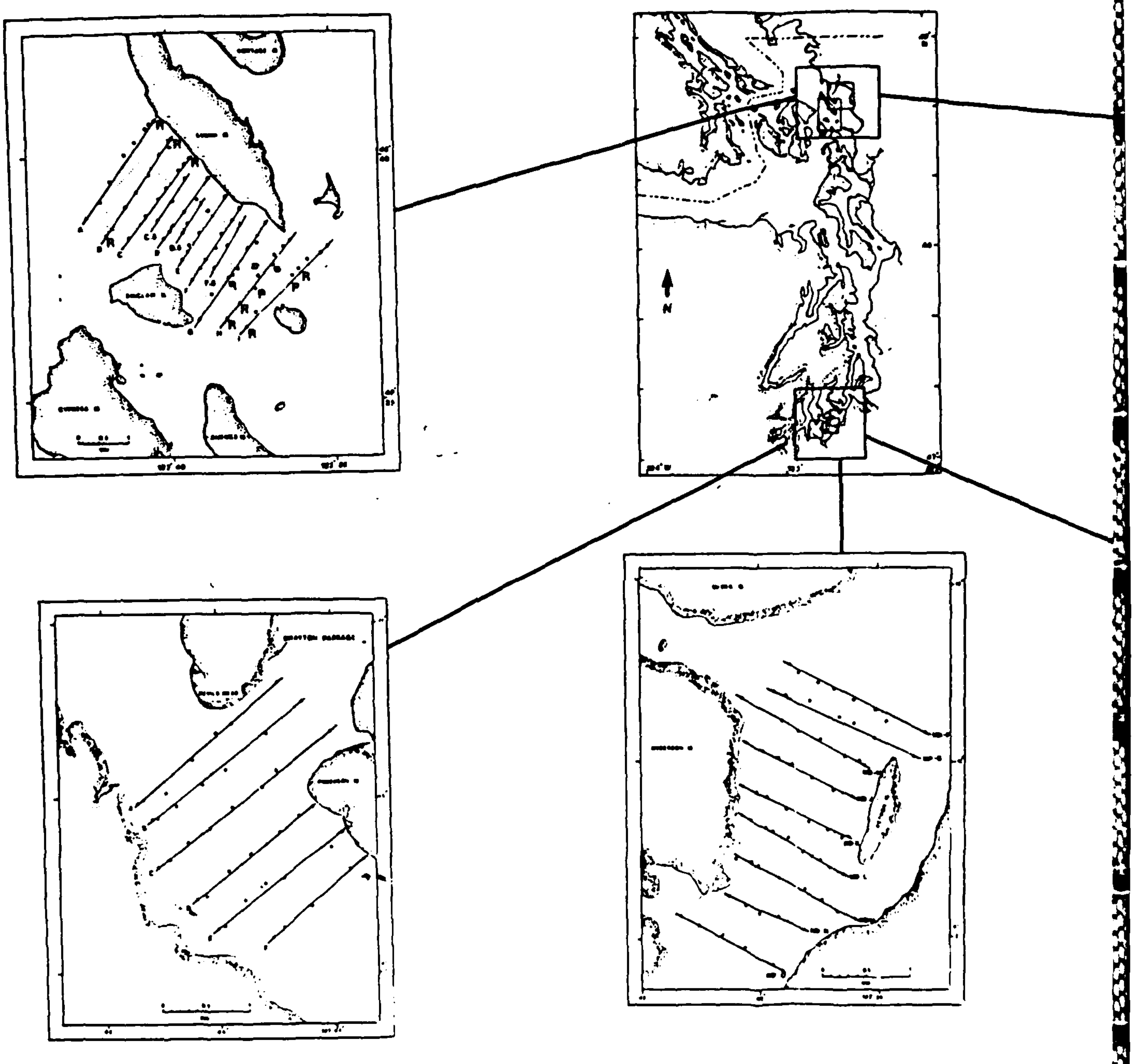

Figure 2. Transects (solid lines) and stations (•) sampl each area. Dotted line represents zones of si feasibility (ZSF). Stations that were rejecte indicated by (R).

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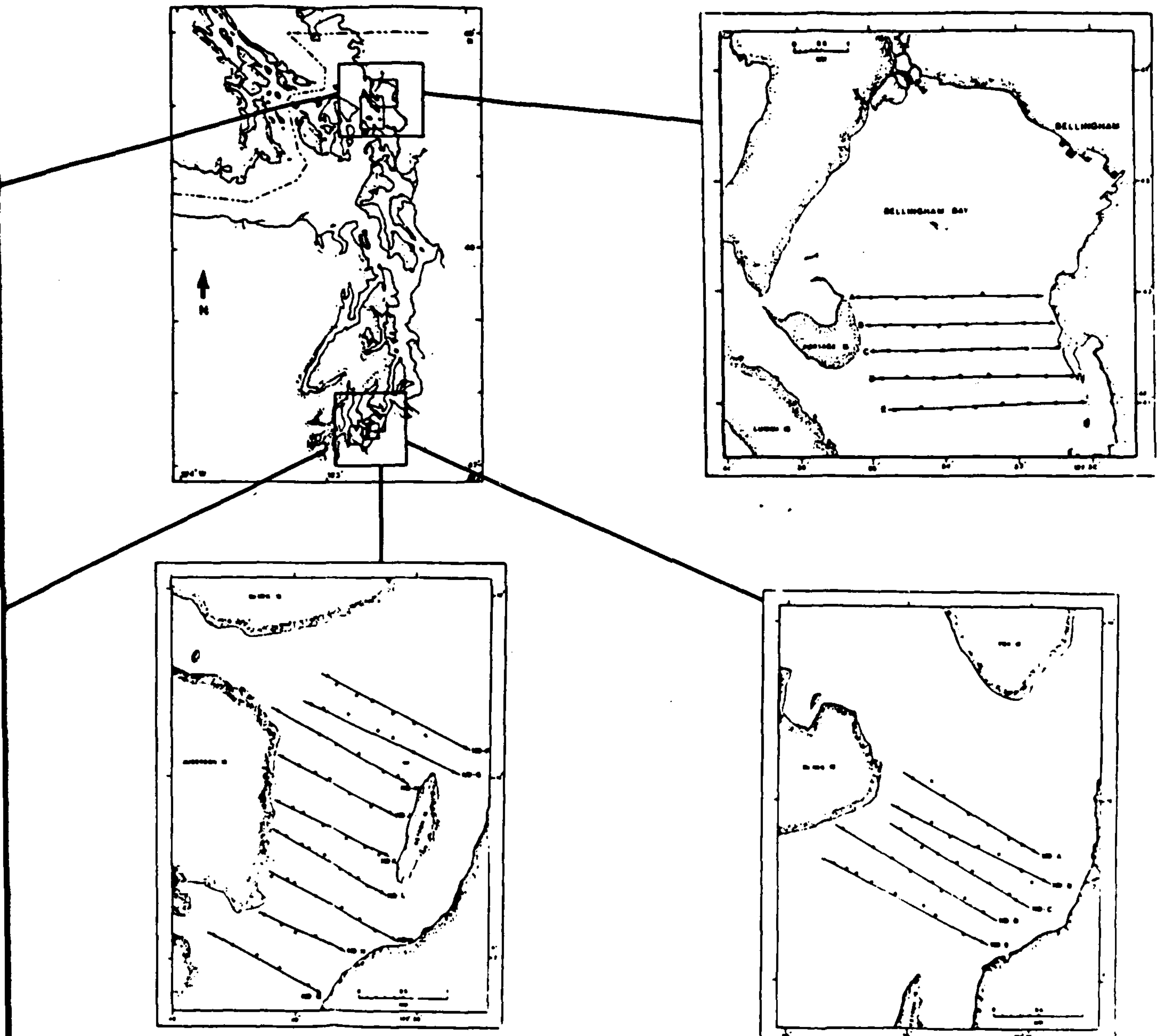

gure 2. Transects (solid lines) and stations (•) sampled in each area. Dotted line represents zones of siting feasibility (ZSF). Stations that were rejected are indicated by (*).

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as, wood debris and biological structures (e.g., shells and tubes). Samples which showed excessive disturbance of the sediment surface were rejected. In addition, sediment samples were rejected if they did not meet the following minimum penetration depths.

1) 4 cm-coarse sand and gravel
2) 5 cm-coarse to medium sand
3) 7 cm-fine sand
4) 10 cm-silt with sand or clay

FIELD METHODS FOR CHEMICAL ANALYSIS

Sediment samples for chemical analysis were handled by first removing the overlying water in the sampler using a vacuum suction device attached to the seawater system on the vessel. Since an undisturbed sediment surface was necessary, the physical description of the sediments was delayed until after the chemical samples were taken. At each station separate samples were collected for: grain size, total volatile solids, and five-day biochemical oxygen demand.

Samples were taken from the upper two centimeters of the sediments using METRO's toxicant cookie cutter. The cookie cutter, an inverted stainless steel pan, was placed on the surface of the sediment, gently pushed into the sediment, and a flat plate slid just underneath the edge of the device. Material extending outside the device was sliced away and the material within the cookie cutter was transferred to an appropriately cleaned container. The cookie cutters were rinsed between replicates at each station, and between stations, with a solution of deionized organic-free water. Handling devices for the collection of grain size, total volatile solids, and biochemical oxygen demand were cleaned as described, and sediments were placed into clean eight ounce jars.

Sediment samples for measurements of grain size and percent water were kept in a cool place until returned to the laboratory where they were refrigerated (4°C). Samples for total volatile solids and biochemical oxygen demand were stored on ice until returned to the laboratory where they were stored in freezers.

LABORATORY PROCEDURES

In 1985, the U.S. Environmental Protection Agency (Region X) established protocols for the examination of water, sediments, and benthic infauna under the Puget Sound Estuarine Program (PSEP). These protocols, when used with those established in Standard Methods for the Examination of Water and Wastewater, are an extremely valuable guide to follow when conducting research in the marine environment. All procedures used in this study are those recommended for use by the above two manuals.

Percent Volatile Solids (% VS)

Percent volatile solids were determined by combustion at 550°C, once the samples were completely thawed and homogenized. A minimum of two replicates were conducted fo~ each station.

Five-Day Biochemical Oxygen Demand (BOD_5)

The 5-day biochemical oxygen demand was determined following procedures in Standard Methods for the Examination of Water and Wastewater (1985). These procedures were modified for using seawater as the dilution water. Seawater was collected at the Seattle Aquarium and filtered through three Baker Hydro Sand Filters (Model HRV-36; #20 white silica sand), two charcoal filters, and an ultraviolet sterilizer (Model L-150). The water was then incubated at 20°C in the dark and aerated for quality improvement. The 5-day demand of the seawater dilution blank did not exceed the recommended value of 0.20 milligrams per liter throughout the study.

The microorganism seed culture was produced in the laboratory by continually aerating a three liter culture medium incubated at 20°C. The medium was initially composed of one liter of aquarium sand collected from the University of Washington School of Fisheries' saltwater aquarium gravity filter beds, and two liters of the supernatant of equal parts sand and saltwater. For the duration of the study the culture received 75 milliliters of salinity-adjusted METRO West Point Treatment Plant unchlorinated sewage effluent and 5 milligrams of Tetra-Min baby fish food every other day. Three times a week the seed culture was violently stirred and a portion transferred to a one liter glass jar where the particulates were allowed to settle and the supernatant was used in the BOD_5. A seed concentration of 1 milliliter per 0.3 liters of diluted sample was used.

In preparing the sediment sample for the 5-day test, the sample was allowed to thaw to room temperature and was homogenized. Four representative aliquots of the sample were weighed to within 10 milligrams of each other and then carefully transferred into incubation bottles. One milliliter of the seed culture was introduced into each bottle which was then filled with oxygen-saturated seawater. Care was taken when capping the bottles so that no air bubbles were introduced into the bottles. Two bottles were fixed immediately to measure the initial concentration of dissolved oxygen. The other two bottles were agitated for 10 seconds or until the sediment was completely suspended, and were placed in a darkened area and maintained at 20°C. The bottles were incubated for a period of five days, and were agitated daily to resuspend the sediments.

The 5-day BOD (milligrams of oxygen used per kilogram of sediment, dry weight) for each sample was calculated using the formula:

$$BOD_5 = \frac{(a-b) \quad .3 \times 100}{(g) \ (R)}$$

where,

a = initial dissolved oxygen concentration at time 15 minutes (mg/l)

b = dissolved oxygen concentration at time 5-day (mg/l)

g = grams of sediment added to each 0.3 liter test bottle

R = ratio of the dry to wet weight of the sediment sample (expressed as a decimal fraction)

Quality control of the dilution water, the effectiveness of the seed culture, and the technique of the analyst, were maintained by: 1) preparing dilution seawater controls (test blanks); 2) using control mixtures of glucose and glutamic acid (1:1) with a theoretical oxygen demand of 218 $\pm$ 11 mg/l; 3) preparation of several dilutions of seeded dilution seawater (seed control) with theoretical oxygen demand between 0.6 and 1.0 mg/l; and 4) duplicate determinations made using sediment samples with low and high organic loads.

Percent Water, Grain Size, and Percent Clay

The refrigerated sediment samples were warmed to room temperature and homogenized. One aliquot was weighed, oven-dried (103^{o}C $\pm$ 5^{o}C), and weighed again for computation of percent water.

A second aliquot went through a stepwise procedure for sediment grain size determination. The grain size determinations were done based on methods modified from Plumb (1981), Krumbein and Pettijohn (1938), and Buchanan (1984). The sediment was wet sieved into two size fractions. Sediment larger than 62 microns were air dried and further analyzed by dry sieving through a series of graded sieves using a Braun mechanical shaker into the following categories: cobble (156-64 mm); gravel (64-2 mm); coarse sand (2-0.5 mm); fine sand (0.5-0.062 mm). Sediments finer than 62 microns were analyzed by wet pipetting techniques, and were classified into silts (0.062-0.004 mm) and clays (less than 0.004 mm). A computer program generated the median size class and the percentages of gravel, sand, silt, and clay.

DATA ANALYSIS

A statistical method was employed to determine if individual samples indicated a station to be more depositional in nature than other stations at a similar depth. To assure that the means, variances, and confidence intervals of the data could be calculated with parametric statistics, the Kolmogorov-Smirnov test was applied using a standard normal distribution. Results of this test indicate that the data are normally distributed, and that the use of parametric statistics is justified. The mean, standard deviation, 95% confidence interval (95% CI), and 1.96 standard normal deviate (1.96 SND) were calculated for BOD, % VS, and % water for each depth contour using data from all 251 Phase II stations as well as 201 Phase I stations. In addition, the volatile solids data from the Seahurst and Duwamish Head Baseline studies were added to the analysis to broaden the database (Word et al., 1984a, b; Sokel and Roth, 1969). The original intent was to incorporate data for each parameter from the Seahurst and Duwamish Head Baseline studies. However, it became apparent during discussions with the personnel that conducted the work that protocols established in Standard Methods for the Examination of Water and Wastewater were not followed except in the analysis of volatile solids. Thus, the data used in this study incorporated only the Seahurst and Duwamish Head volatile solids data and not the BOD_5 and percent water data.

Those values falling beyond the 1.96 SND were considered outliers. They were temporarily removed from the data, and the computations performed again. Removal of the outliers decreased the variance and produced more realistic average values for the data. Once the final mean, 95% CI, and 1.96 SND were obtained for each depth contour, the individual data for each station sampled (including previously removed outliers) were then compared to the appropriate values. Individual values which fell outside of the 95% CI but inside the 1.96 SND were considered to be potentially depositional compared to other stations at that depth. Any values falling outside of the 1.96 SND were considered depositional in nature as compared to other stations at that depth.

Stations exceeding the 95% CI and 1.96 SND were placed on a chart, and areas encompassed by the two levels were shaded.

The advantage of this technique is that the values of each parameter are averaged over a large geographic region. This gives a high degree of confidence that stations with sediments that exhibit abnormally high concentrations of the measured parameters are indeed indicative of a depositional environment.

RESULTS AND DISCUSSION

LUMMI/SINCLAIR ISLAND

Field data indicated that there was a large component of sand at all but two stations in the ZSF. The northernmost transects (A, B, and C; Fig. 2) also contained large numbers of scallop shell fragments (Appendix A I). At transects A and B there were roughly three to four live scallops in each 0.1 m^2 van Veen grab sample. The obvious lack of clay/silt sediments and the presence of scallops, which are indicative of high current areas, caused this ZSF to be removed from consideration as a potential disposal site.

McNEIL ISLAND

The field data for the McNeil Island ZSF in south Puget Sound also showed it to be unsuitable for use as a non-dispersive site for the dredge material. A number of stations contained silty sediments but these sediments contained a large component of sand (Appendix A II). The majority of the stations in the central portion of the ZSF consisted of coarse sand with some gravel. For this reason the entire ZSF was removed from consideration.

BELLINGHAM BAY

The contour intervals showing the levels of organic material in Bellingham Bay are depicted in Figures 3 and 4. Both the BOD_5 and % VS show increasing concentrations from the southwest to the north and from the northeast into the center of the study area. Both measures show a high and uniform concentration throughout the center of the Bay and in the ZSF. These values exceed the 95% CI for both BOD and VS at all stations (Figs. 3 and 4; Table 1). In addition VS values exceeding the 1.96 standard normal deviate (SND) were found in the northwest, northeast, and southeast corners of the study area. BOD_5 values exceeding the 1.96 SND were located at the same stations where the % VS also exceeded that limit. The only data point that differs from the % VS is where the BOD_5 exceeds the 1.96 SND at the north edge of the study area.

The percent water values of the Bellingham Bay sediments are contoured in Figure 5. Percent water shows the same pattern as seen in the BOD_5 and %VS. Percent water values increase from approximately 30% at the western and northeastern edges to over 60% in the center and southeastern portions of the study area. At the northern edge of the ZSF 70% water content was encountered. Areas of elevated % water presented in Figure 5 shows the study area and ZSF to contain sediment with percent water in excess of the 95% CI. The northwest and southeast

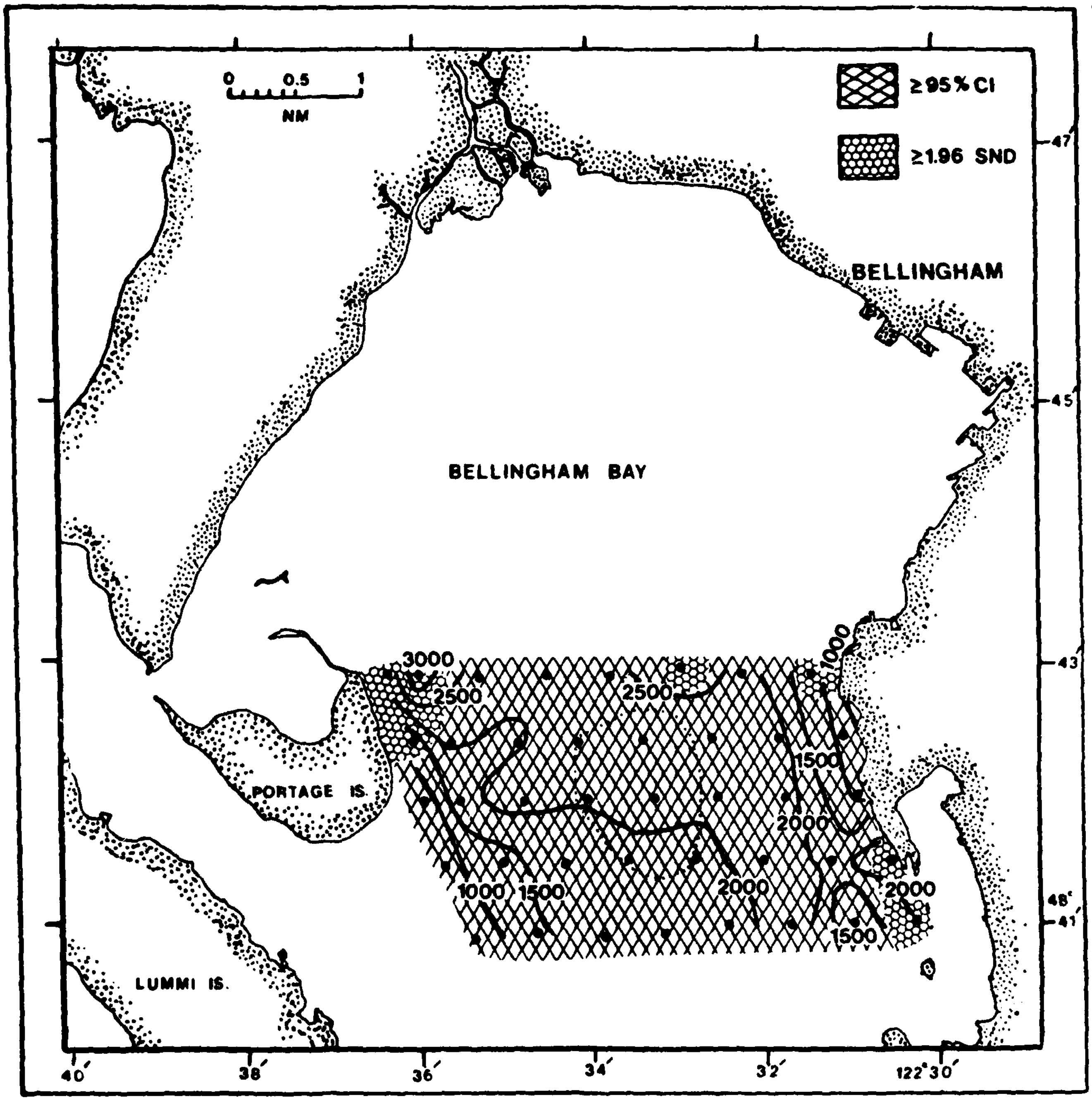

Figure 3. Contours of five-day biochemical oxygen demand (mg/kg dry weight) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Bellingham Bay. Dotted line represents preliminary ZSF boundary.

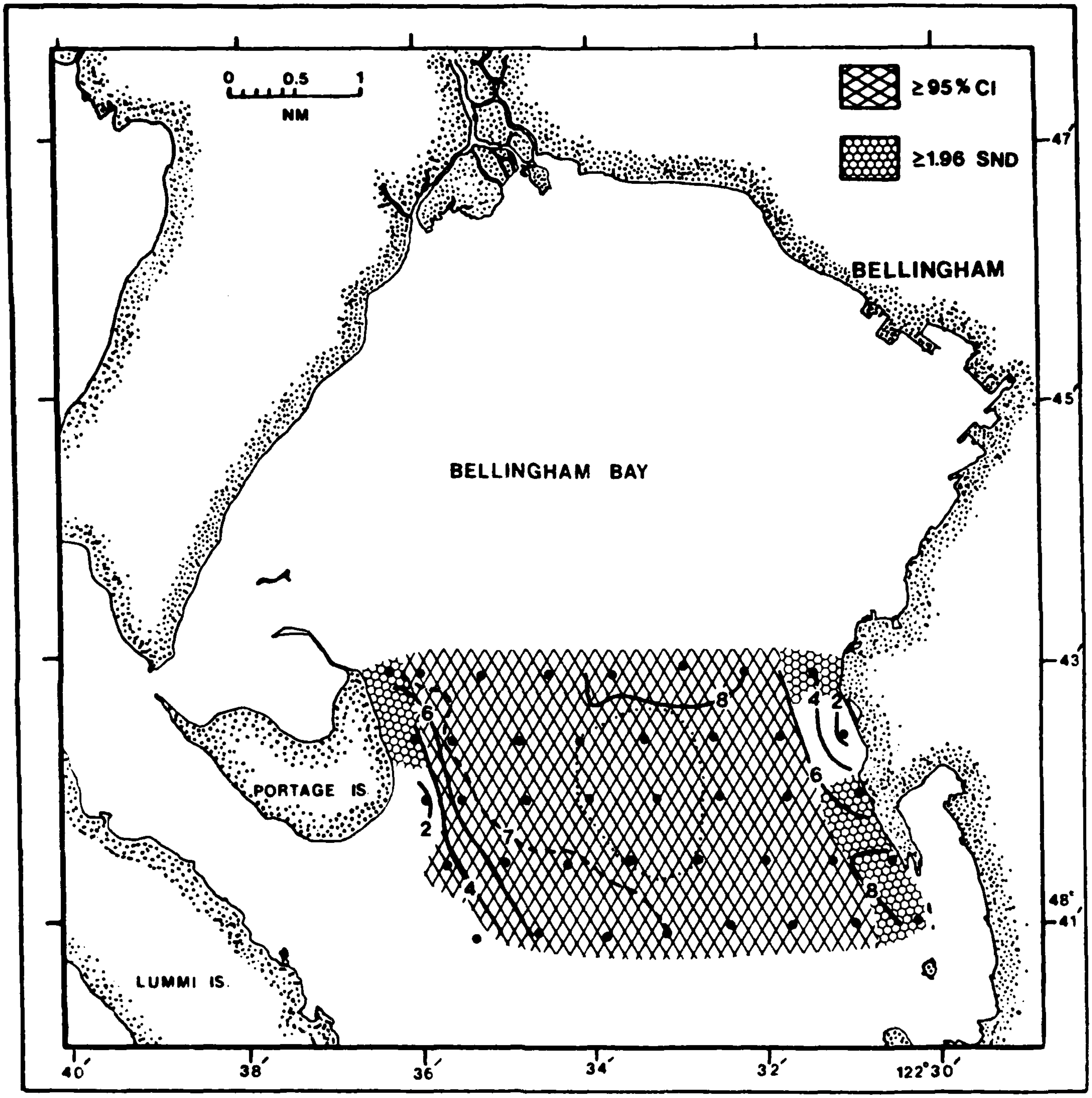

Figure 4. Contours of volatile solids content (percent) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Bellingham Bay. Dotted line represents preliminary ZSF boundary.

Table 1. Mean, standard deviation, and 95% CI and 1.96 SND intervals for conventional chemistry measures for each depth contour sampled. (n - number of samples, x - mean, S.D. - Standard Deviation, C.V. - Coefficient of Variation, SND - Standard Normal Deviate, CI - Confidence Interval).

Measurement Type	Depth (ft.) 50	100	200	300	400	500	600	700
Volatile Solids								
n	73	167	84	118	105	135	54	25
x	1.8	4.5	2	4	3.6	4.4	6.5	7.8
S.D.	1	2.8	1	2.3	2.1	2.5	2.2	1.8
C.V.	0.57	0.63	0.52	0.57	0.58	0.56	0.33	0.23
x + 95% CI	2.1	4.9	2.2	4.5	4.1	4.8	7.1	8.5
x - 95% CI	1.6	4	1.8	3.7	3.2	3.9	5.9	6.9
x + 1.96 SND	3.9	10	4	8.7	7.8	9.2	10.8	11.4
x - 1.96 SND	0	0	0	0	0	0	2.2	4.2
Biochemical Oxygen Demand								
n	72	183	85	102	98	126	45	2
x	544	1265	460	573	693	707	799	955
S.D.	272	853	242	256	257	244	240	7
C.V.	0.5	0.67	0.52	0.45	0.37	0.34	0.3	0.01
x + 95% CI	606	1388	511	623	744	750	[illegible]	964
x - 95% CI	480	1141	408	523	642	665	[illegible]	945
x + 1.96 SND	1077	2936	934	1075	1198	1186	1271	968
x - 1.96 SND	10	0	0	70	188	229	327	941
Percent Water								
n	76	172	92	116	109	145	54	2
x	30.4	45.7	33.3	45	45.3	47	57	66.2
S.D.	7.9	20.4	7.7	14	12.4	15.5	10.9	0.07
C.V.	0.26	0.44	0.23	0.31	0.27	0.32	0.19	0
x + 95% CI	32.2	48.7	34.8	47.5	47.6	49.5	59.9	66.3
x - 95% CI	28.6	42.6	31.7	42.4	42.9	44.5	54.1	66.1
x + 1.96 SND	46	85.7	48.5	72.5	69.7	77.4	78.4	66.3
x - 1.96 SND	14.8	5.7	18	17.4	20.8	16.6	35.6	66.1

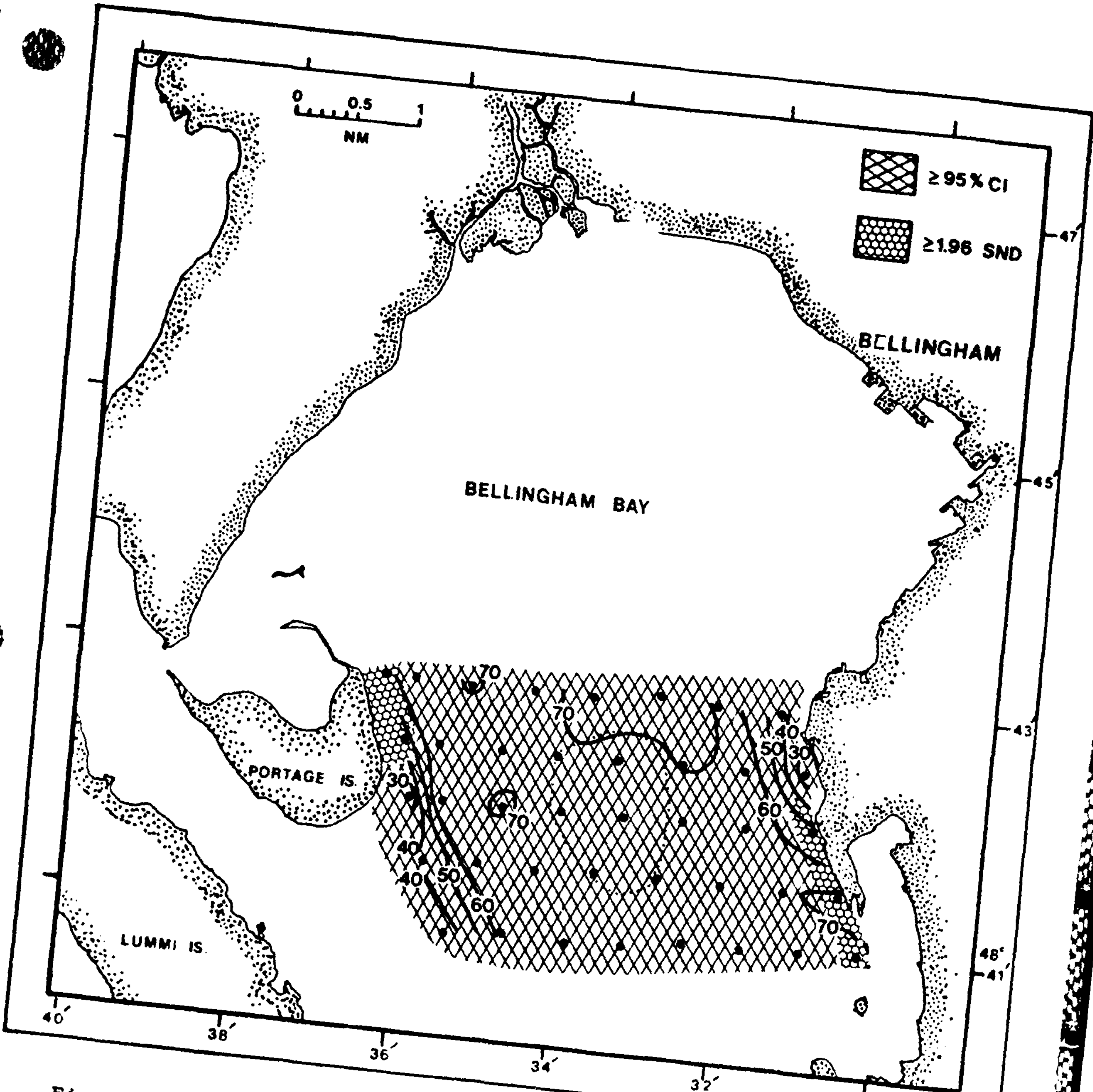

Figure 5. Contours of water content (percent) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Bellingham Bay. Dotted line represents preliminary ZSF boundary.

corners of the ZSF were significantly elevated due to their data points falling beyond the 1.96 SND range.

The median grain size characteristics of the Bellingham Bay stations are shown in Figure 6. Medium sand grading to very fine sand was located off the eastern shore and of the south end of Portage Island gradually grading into finer sediments (medium silt) in the center of the study area and ZSF. Two areas containing sediment consisting of fine silt are found in the far north and to the east of the ZSF.

The clay fraction found in this ZSF follows the grain size contour intervals (Fig. 7). The amount of clay increases from the east and west sides of the Bay towards the center of the area, and is roughly constant at 16-18% within the ZSF. Two lobes of 18%-20% clay were found northeast and northwest of the ZSF.

In reviewing the measured parameters, it is evident that the sediments in the Bellingham Bay ZSF contain a large amount of enriched organic material. BOD_5 range from 2000 to 2500 mg/kg of sediment, % VS are in excess of 8 percent and percent waters range just around 70%. The entire study area has all the attributes of a very low energy, depositional environment. The area that appears to be the most depositional in the study area is roughly 0.5 nautical miles due north of the existing ZSF. All stations in the Bay contained sediments where the BOD_5, % VS and % water were enhanced beyond the 95% CI for each parameter (Fig. 8). The grain size is predominantly silt in this area and percent clay ranges from 18 to 20 percent.

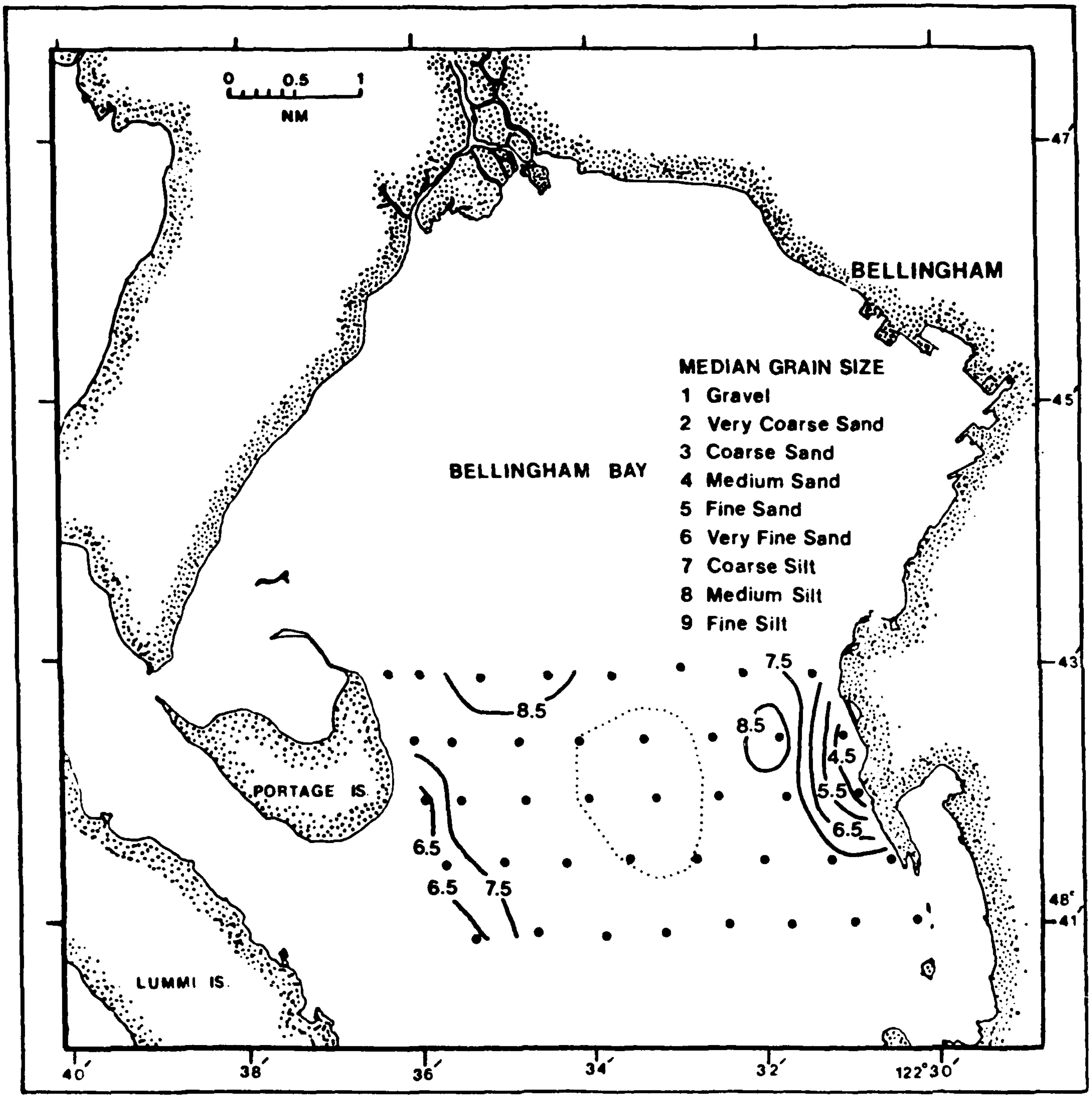

Figure 6. Contours of median grain size in Bellingham Bay. Dotted line represents preliminary ZSF boundary.

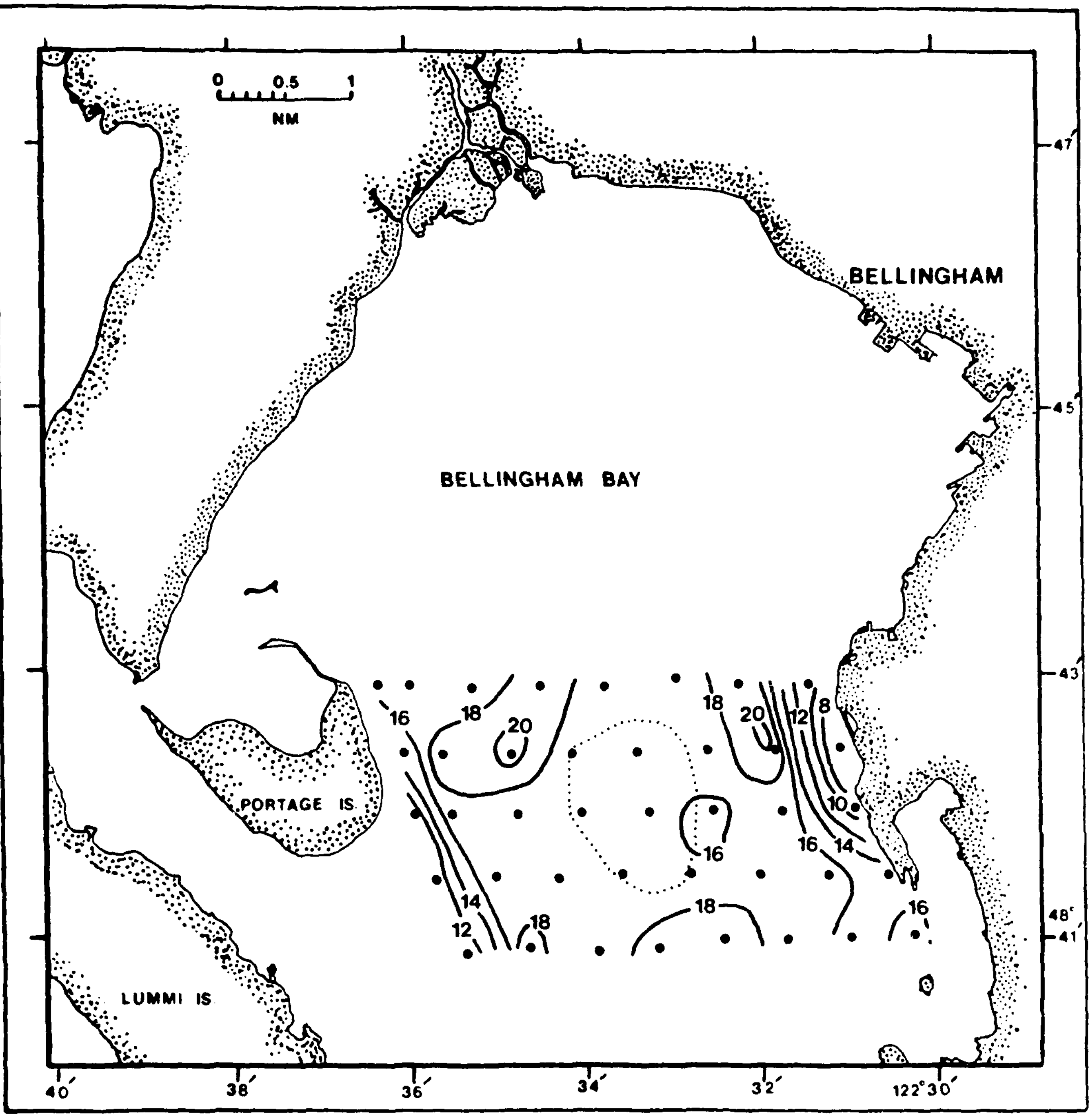

Figure 7. Contours of clay content (percent) in Bellingham Bay. Dotted line represents preliminary ZSF boundary.

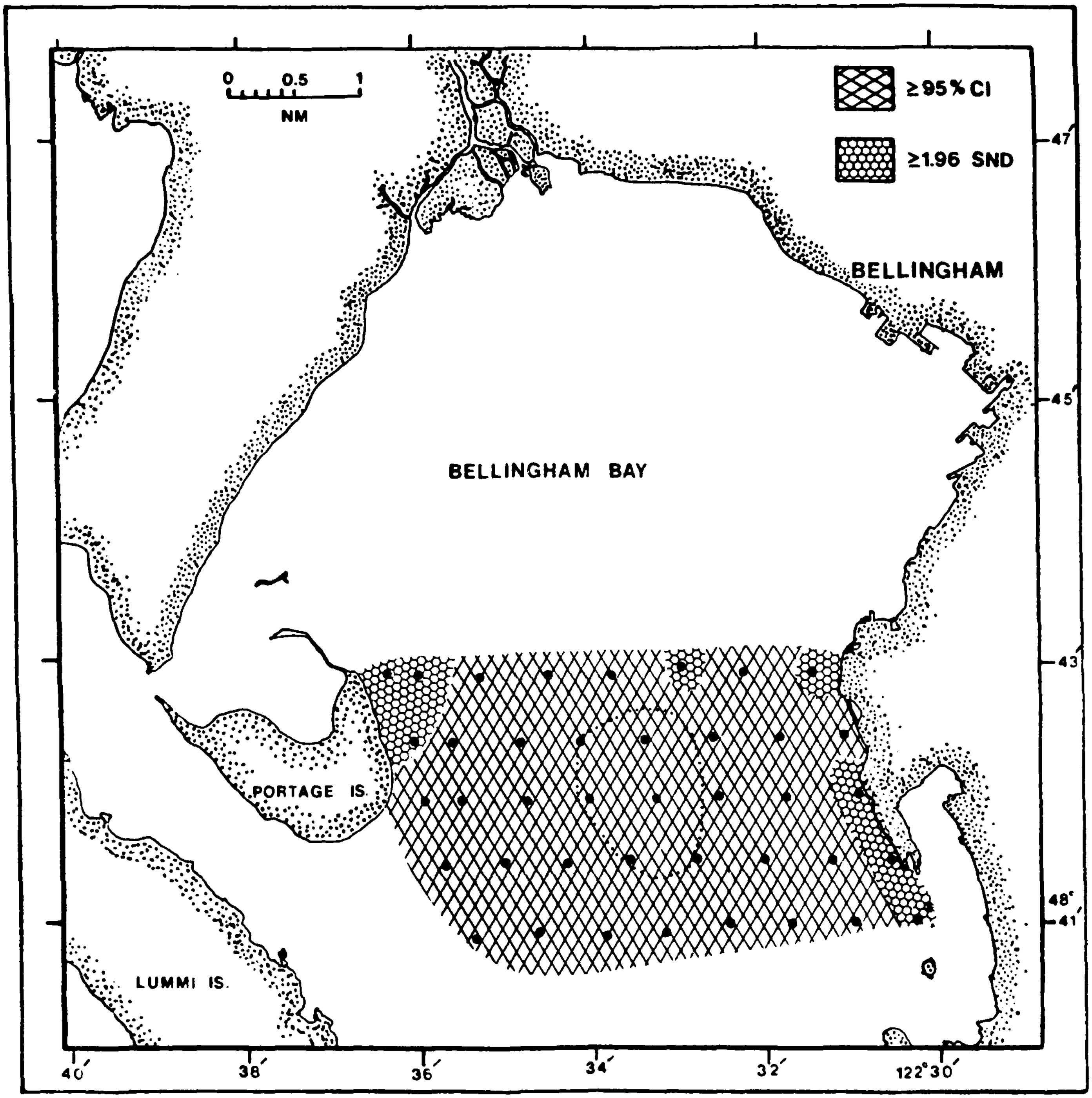

Figure 8. Areas where at least one parameter (biochemical oxygen demand, volatile solids, or percent water) exceeded the 95% confidence interval or the 1.96 standard normal deviate for Bellingham Bay. Dotted line represents preliminary ZSF boundary.

ANDERSON - KETRON ISLANDS

Results from the analysis of the biochemical oxygen demand (BOD_5) show that low BOD_5 values (< 500 mg/kg dry weight) occur at relatively shallow depths along the margin of Anderson and Ketron Islands (Fig. 9). Low values also occ[illegible] at the northern and southern margins of the ZSF. Values of 7[illegible] mg/kg dry weight were found at the base of the slopes from both islands and encompass the entire ZSF. The 1000 mg/kg contour abuts the western edge of the ZSF and extends to the north and south for a distance of about one nautical mile. Elevations in BOD_5 beyond the 95% CI are found throughout most of the ZSF and concentrations beyond the 1.96 SND were found along the western edge of the study area and ZSF within the 1000 mg/kg contour.

Percent volatile solids (% VS) ranged from less than one to four percent. The contours shown by % VS are roughly similar to those seen for the BOD_5 (Fig. 10). The greatest amount of organic material was found at the base of the slopes between the two islands. The values in the ZSF range from two to four percent with the higher values found in the central portion of the ZSF. Elevations in the amount of organic material past the 95% CI occurs at one station within the ZSF and at two additional stations; one along the shore of Anderson Island and the other south of Ketron Island near the mainland.

Contours of percent water are presented in Figure 11. Trends in percent water are relatively similar to those seen for BOD_5 and % VS. Values range from less than 30 to over 50% water. The sediments with greater than 40% water content occur at the base of the slopes between the two islands and encompass much of the ZSF. Elevations in percent water beyond the 95% CI occur at four stations in the center of the ZSF and at two stations along the shorelines surrounding the ZSF (Fig. 11).

The median grain size and percent clay content of the sediment are presented in Figures 12 and 13, respectively. The median grain size at the extreme northern and southern parts of the study area was predominantly medium to very fine sand with percentages of clay ranging from four to eight percent. The sediment along the margins of Anderson and Ketron Islands consists of fine sand with six to eight percent clay. Sediments in the central portion of the ZSF were predominantly coarse silt with percentages of clay ranging from 10 to 12 percent.

Areas containing the higher organic content and smaller grain sizes overlay much of the ZSF (Fig. 14). The highest concentrations and elevations of BOD_5 and percent water occur within the ZSF. Elevations of % VS beyond the 95% CI occurs at one station in the central portion of the ZSF at the same station where elevations of BOD_5 and percent water occur. This portion of the ZSF contains the finest sediment and the greatest percentage of clay. This combination is indicative of a low energy area where sediments are being deposited naturally. The suitability of this site for the disposal of dredge material

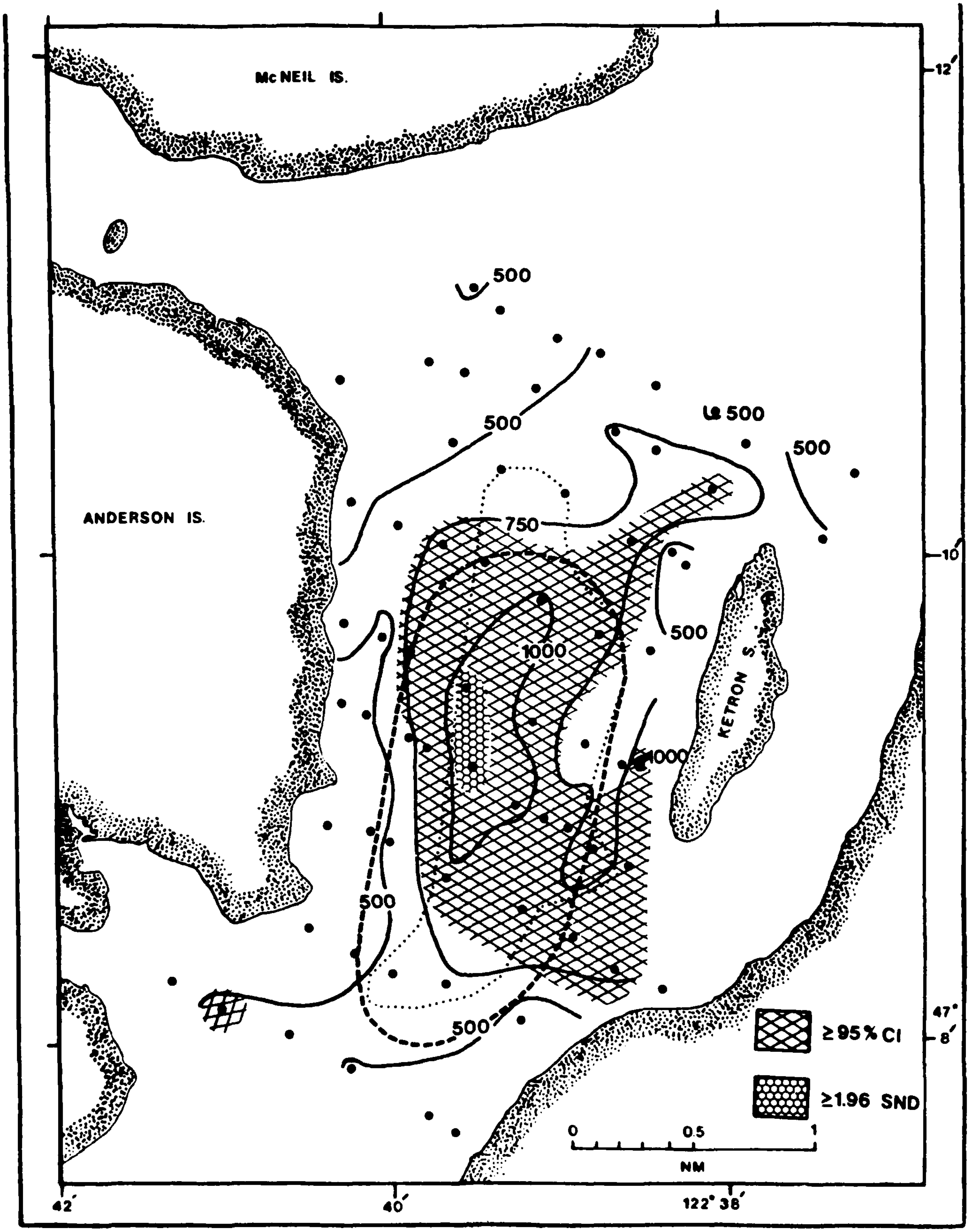

Figure 9. Contours of five-day biochemical oxygen demand (mg/kg dry weight) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Anderson/Ketron Island ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

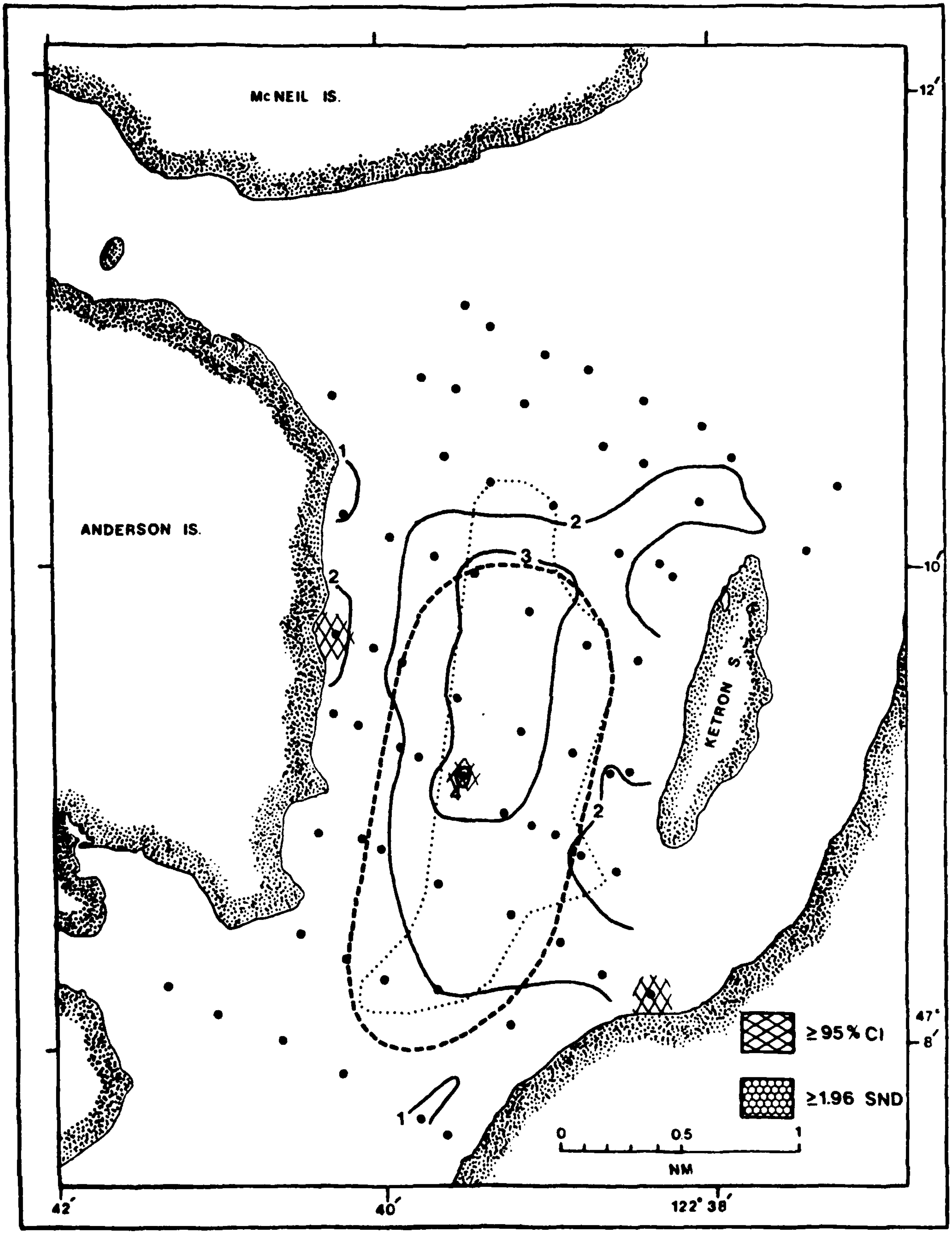

Figure 10. Contours of volatile solids content (percent) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Anderson/Ketron ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

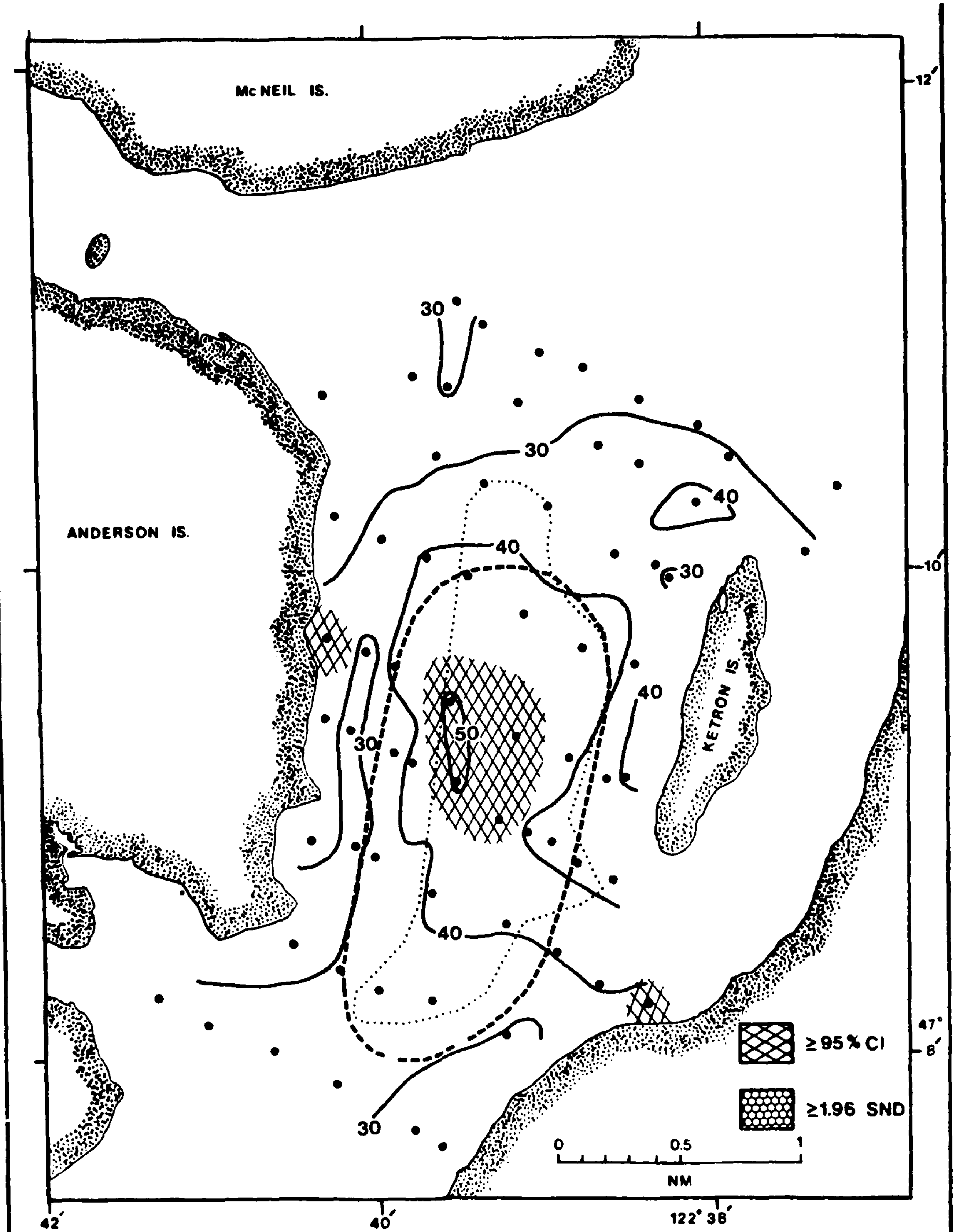

Figure 11. Contours of water content (percent) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Anderson/Ketron ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

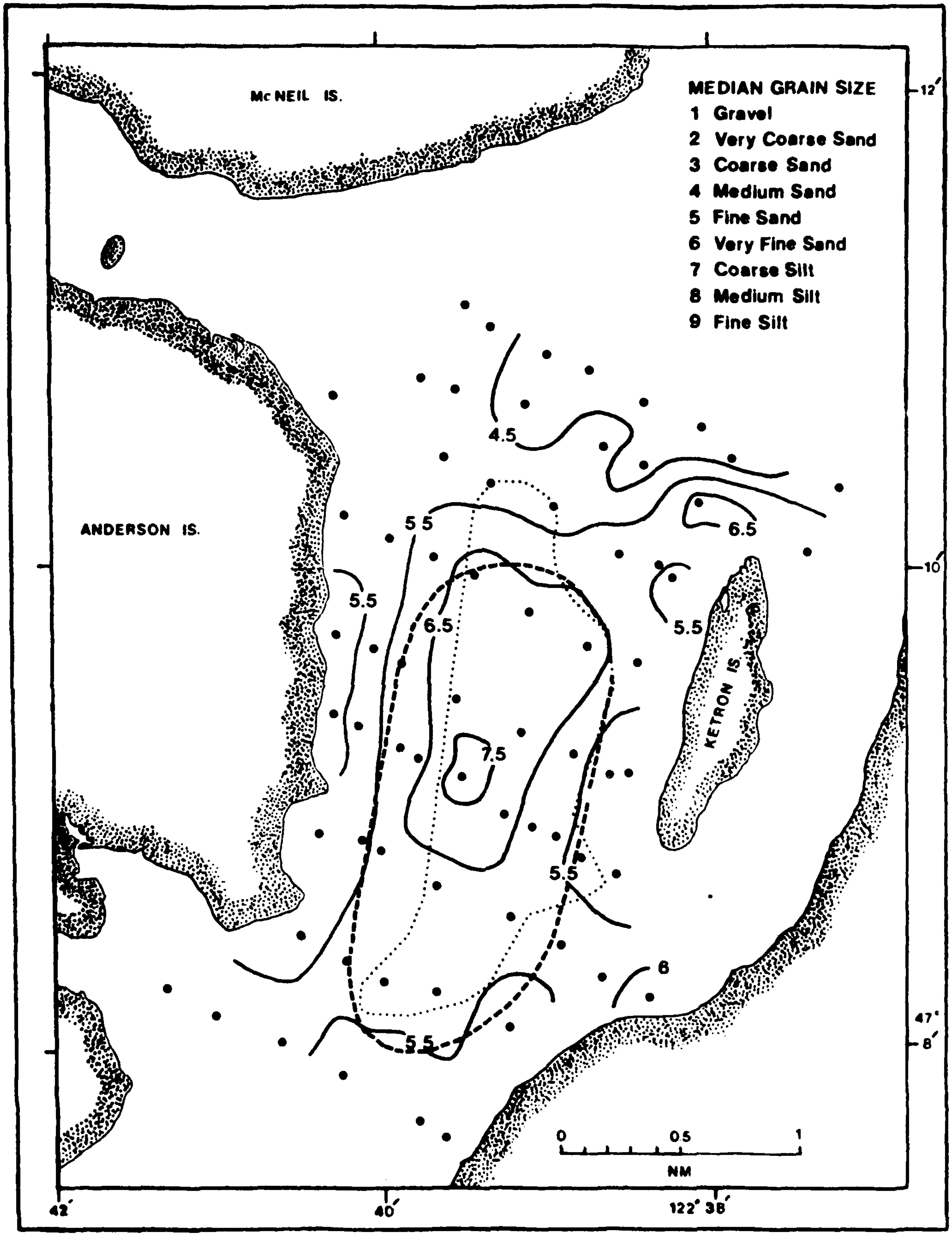

Figure 12. Contours of median grain size in Anderson/Ketron ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

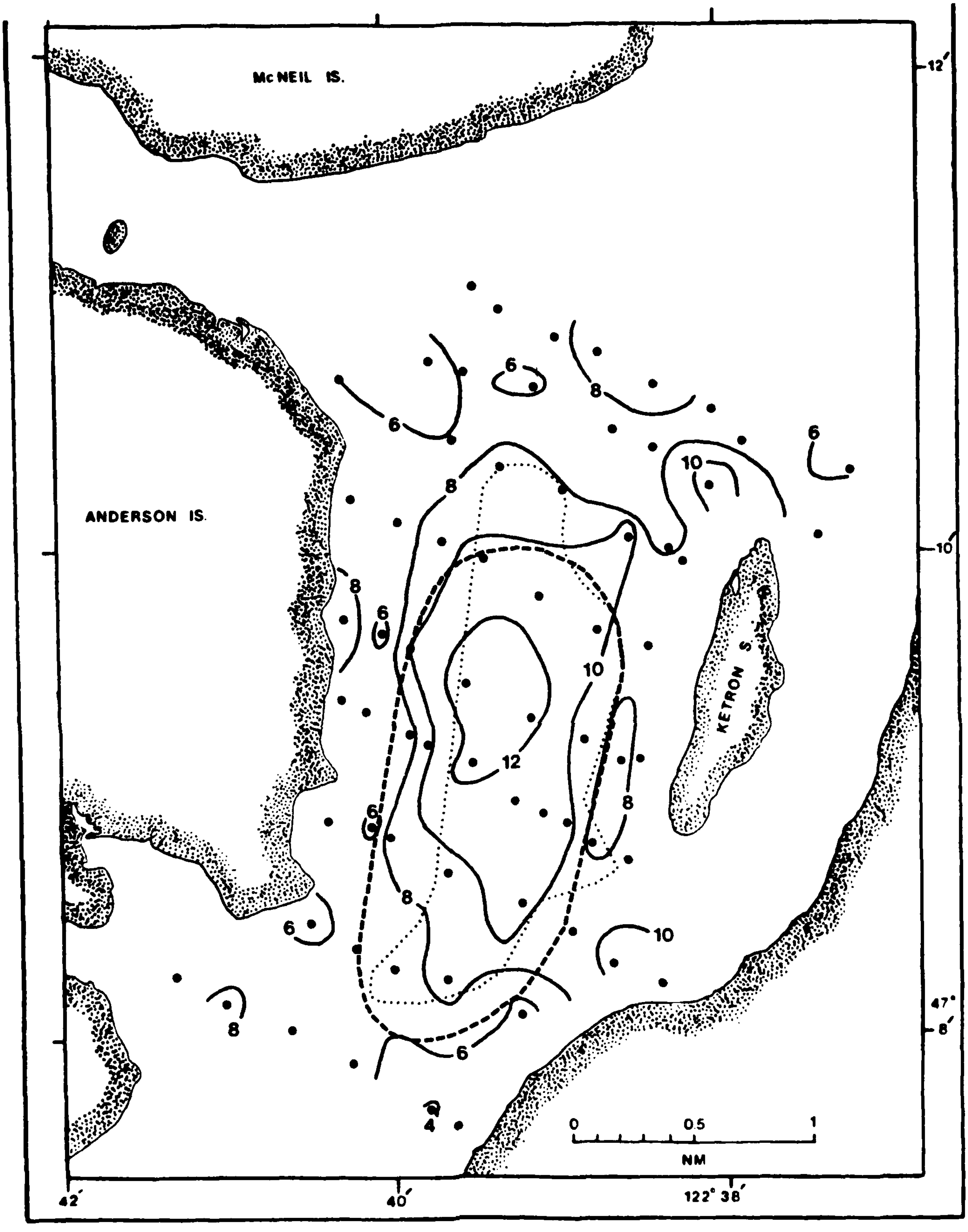

Figure 13. Contours of clay content (percent) in Anderson/Ketron ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

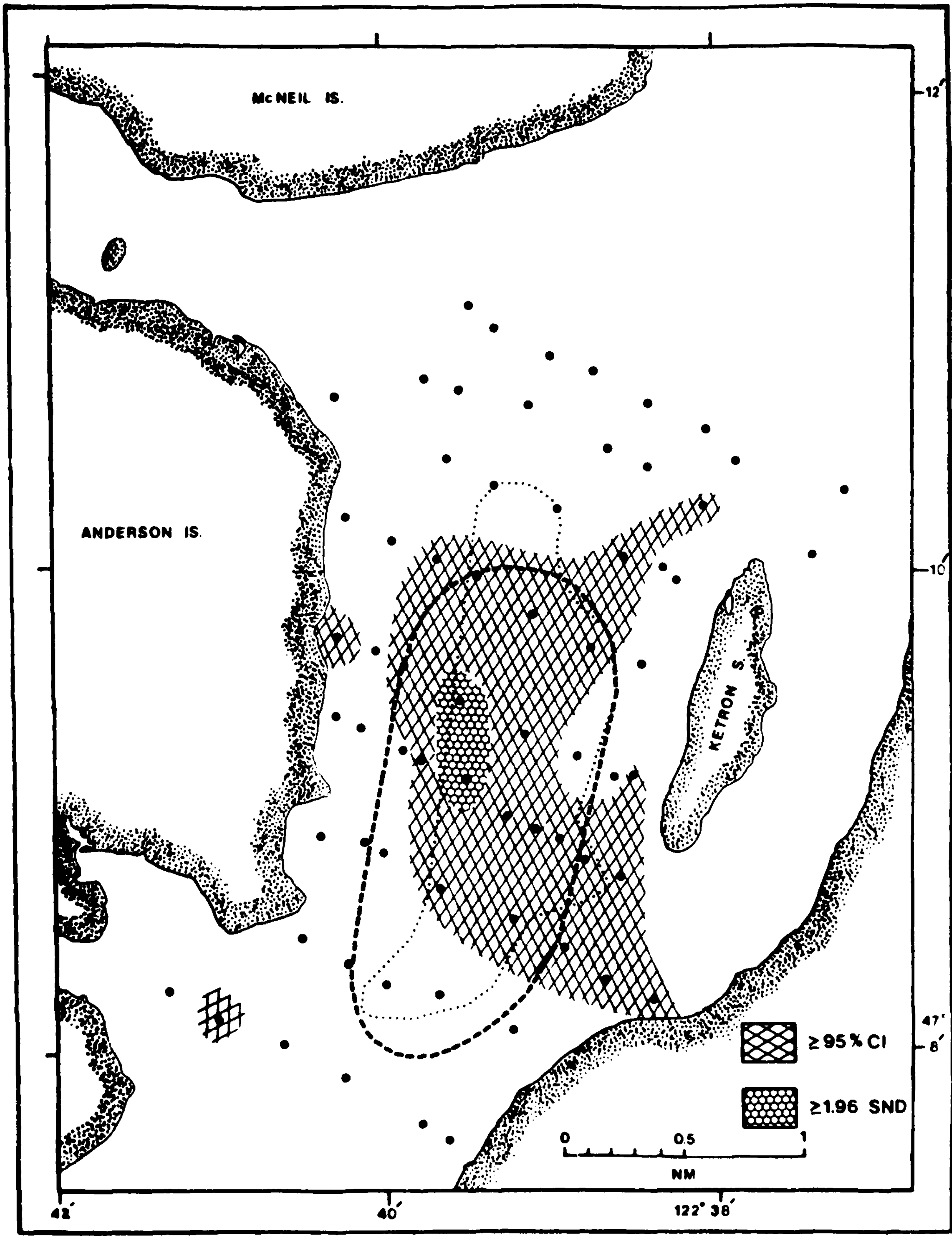

Figure 14. Areas where at least one parameter (biochemical oxygen demand, volatile solids, or percent water) exceeded the 95% confidence interval or the 1.96 standard normal deviate for Anderson/Ketron ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

appears to be very good, as long as the dredge material's erodability characteristics are similar to those of the existing bottom sediment. The area that appears to be the most depositional is situated between Anderson Island and the southern end of Ketron Island in the center of the basin.

DEVILS HEAD ZSF

The two parameters measuring the levels of organic material in the Devils Head ZSF are depicted in Figures 15 and 16. Both figures show similar trends in that low levels of BOD and VS occur in the south end of the ZSF and high va: :s occur to the northwest in the direction of Drayton Passage. Concentrations of BOD_5 in the ZSF range from 250 to 500 mg/kg dry weight, while the % VS range from one to just under two percent. The greatest concentrations in BOD_5 occurred between Anderson Island and Devils Head on the Kitsap Peninsula. These values ranged from 500 to over 1000 mg/kg dry weight. The % VS in the same region ran from one to three percent. Elevations beyond the 95% CI and 1.96 SND occurred in this area for BOD_5. Elevations in % VS beyond the 95% CI occurred in the central basin and also between Anderson Island and Devils Head.

The percentage of water in the sediments in the study area surrounding the ZSF ranged from 30 to over 50% (Fig. 17). The contour patterns shown by % water are very similar to that seen for the two measures of organic material. Low percent water content (< 30%) occurred at the southern end of the ZSF. Highest concentrations (> 50%) were found in Drayton Passage between Anderson Island and Devils Head and in the northwest corner of the study area similar to the results for BOD_5 and % VS. Elevations beyond the 95% CI for % water occur at the northwest end of the ZSF proper and in the region in Drayton Passage.

The distribution of median grain size and percent clay are presented in Figures 18 and 19. The median grain size consists of medium sand southeast of the ZSF grading to very fine sand and fine silt within the ZSF. Coarse to fine silt predominates in the two areas mentioned as having elevated amounts of organic material and a greater percent water. These two areas are the northwestern corner of the study area and in Drayton Passage. Both areas contain greater amounts of the finer sediments which can be seen in the percent clay content (Fig. 19). The percentage of clay within the study area ranges from less than 5 to over 20 percent. The areas with the greatest amount of clay overlaps areas with the finest sediment. In the ZSF the percent clay ranges from 5% at the southern end to 20% at one station.

The area of lowest energy in the study area appears to be located at the entrance to Drayton Passage. This area contains the greatest amount of organic material based on elevations beyond the 95% CI for BOD_5, % VS and percent water (Fig. 20). The median sediment grain size in the area is predominantly coarse to medium silt, and while the percent clay is not the highest encountered in the study area, it does range from 10 to 15 percent.

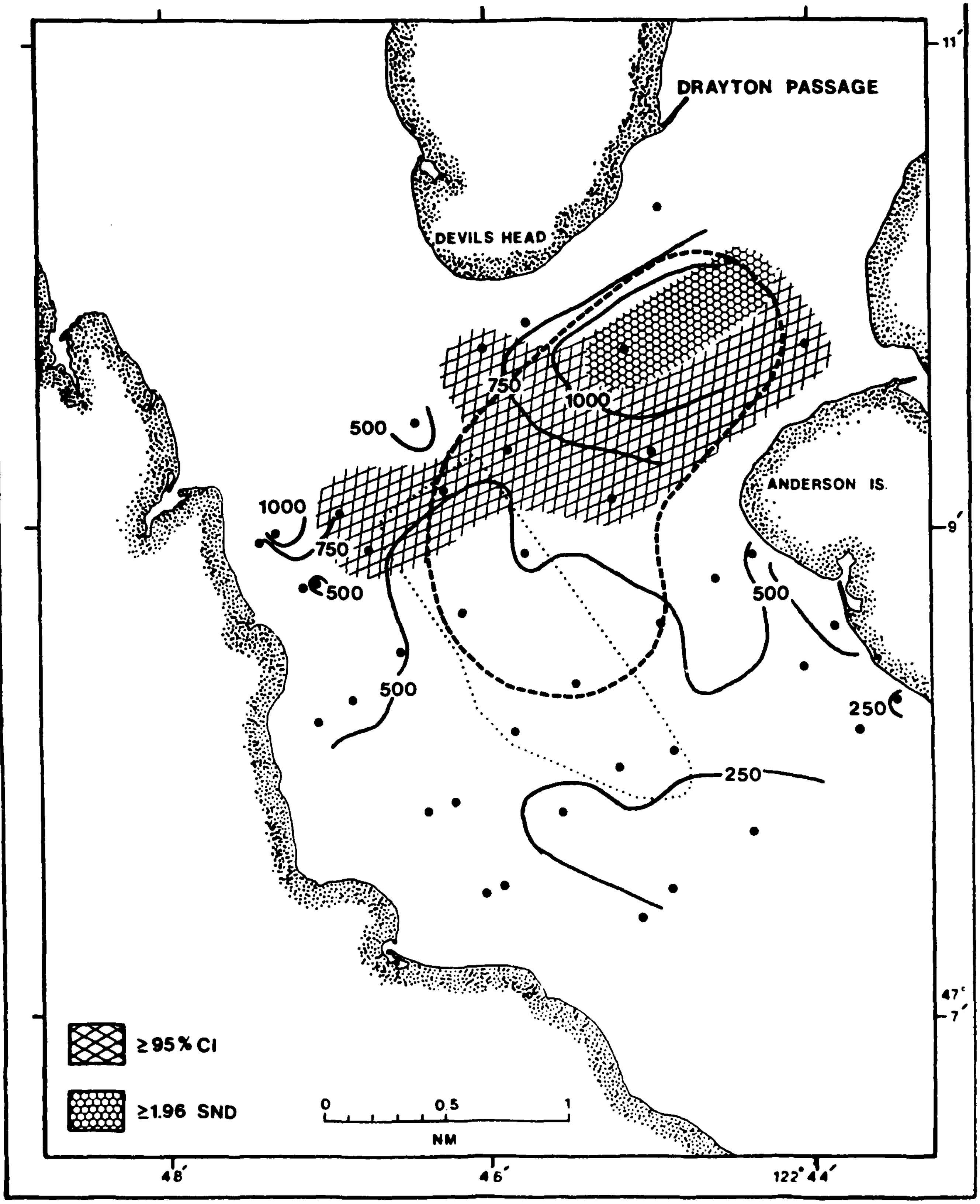

Figure 15. Contours of five-day biochemical oxygen demand (mg/kg dry weight) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Devils Head ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

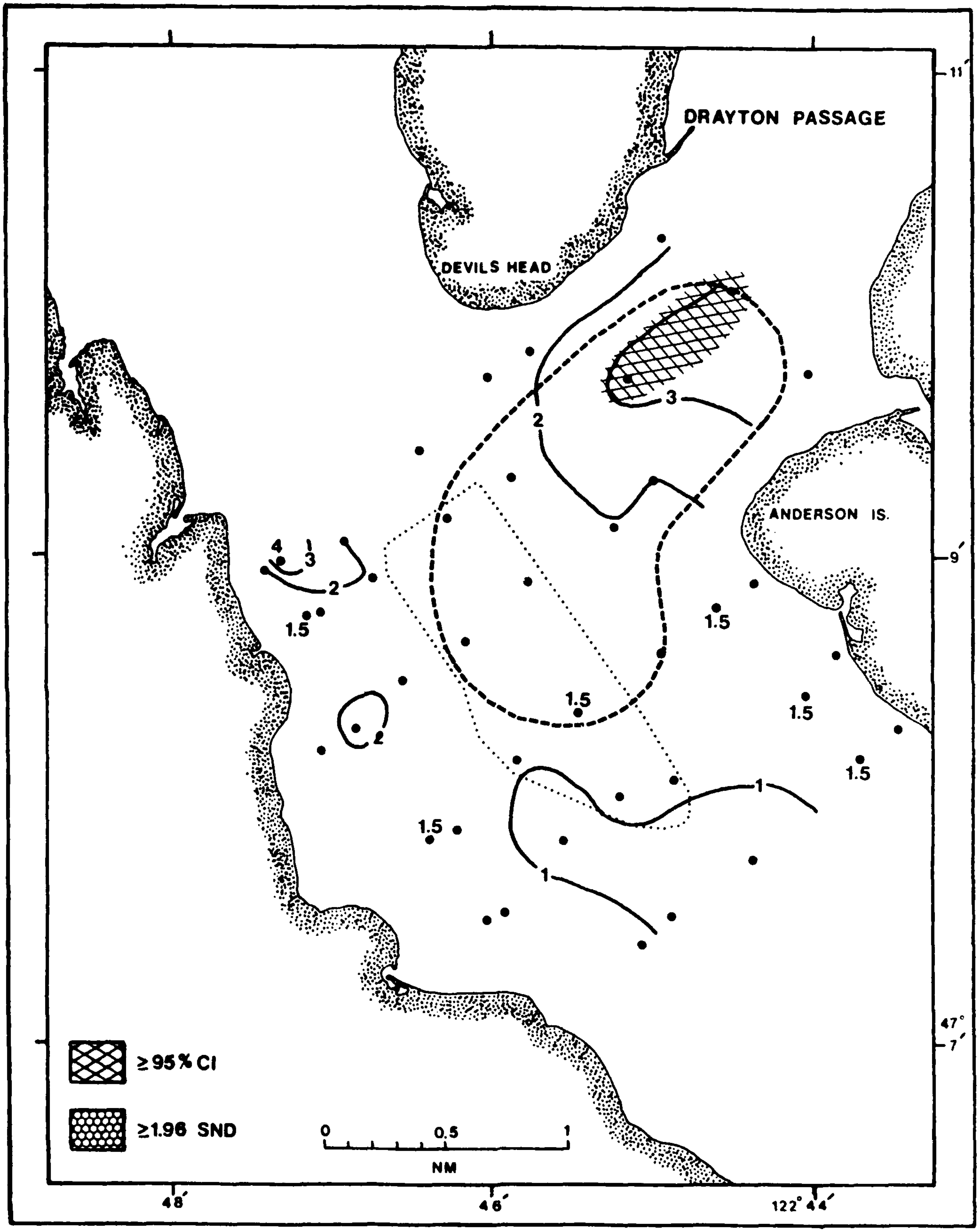

Figure 16. Contours of volatile solids content (percent) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Devils Head ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

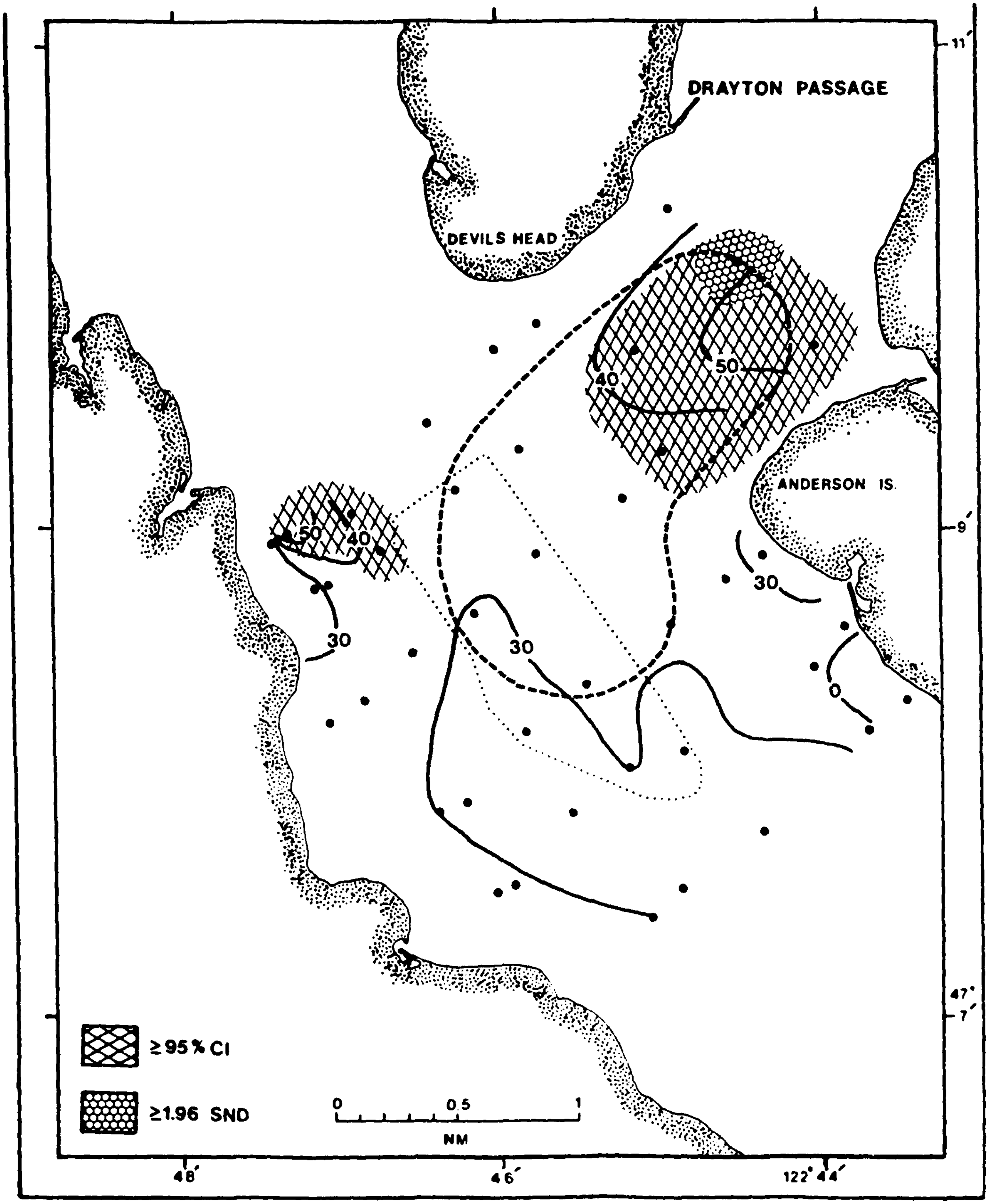

Figure 17. Contours of water content (percent) and areas which exceed the 95% confidence interval (CI) and 1.96 standard normal deviate (SND) values, in Devils Head ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

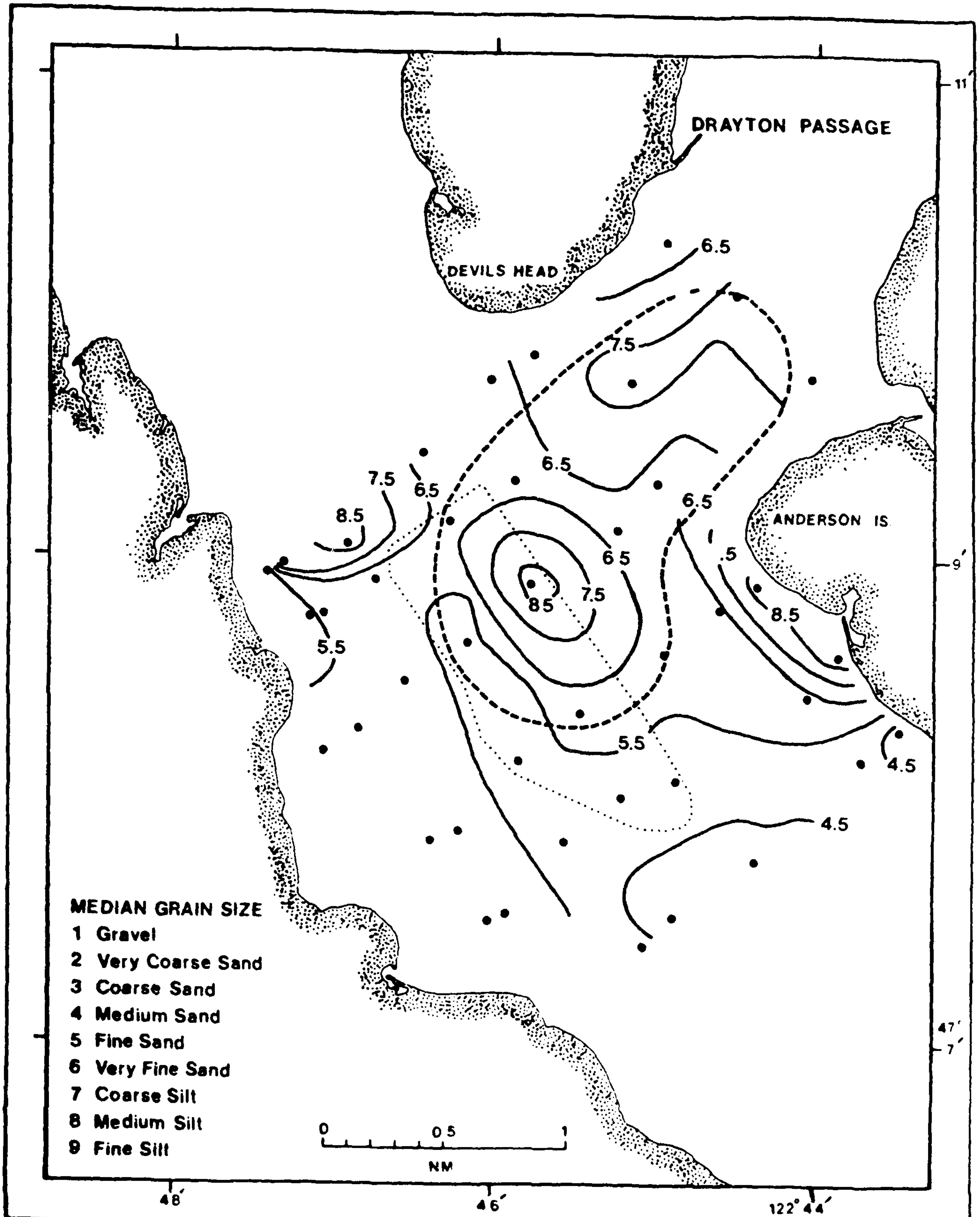

Figure 18. Contours of median grain size in Devils Head ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

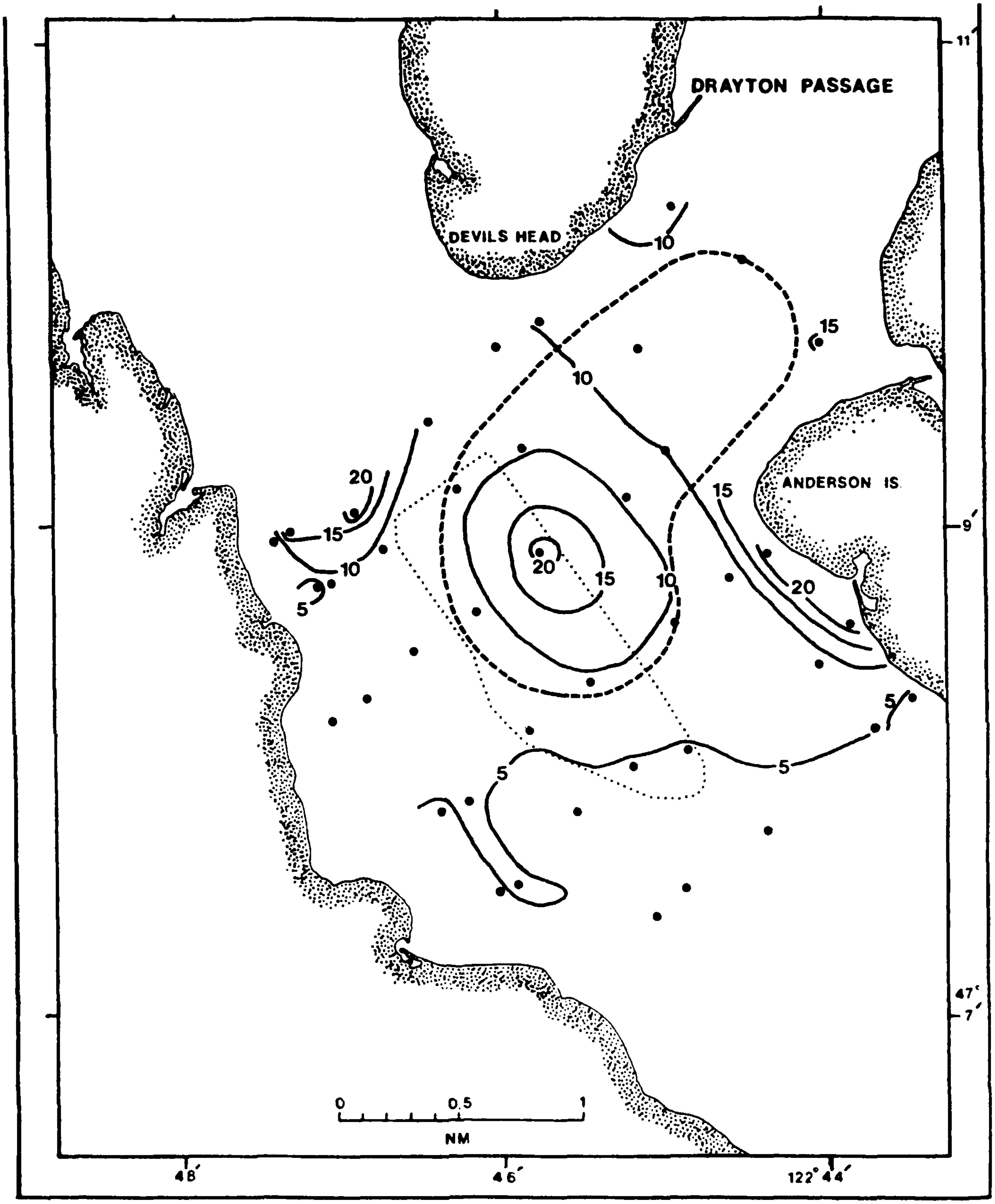

Figure 19. Contours of clay content (percent) in Devils Head ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

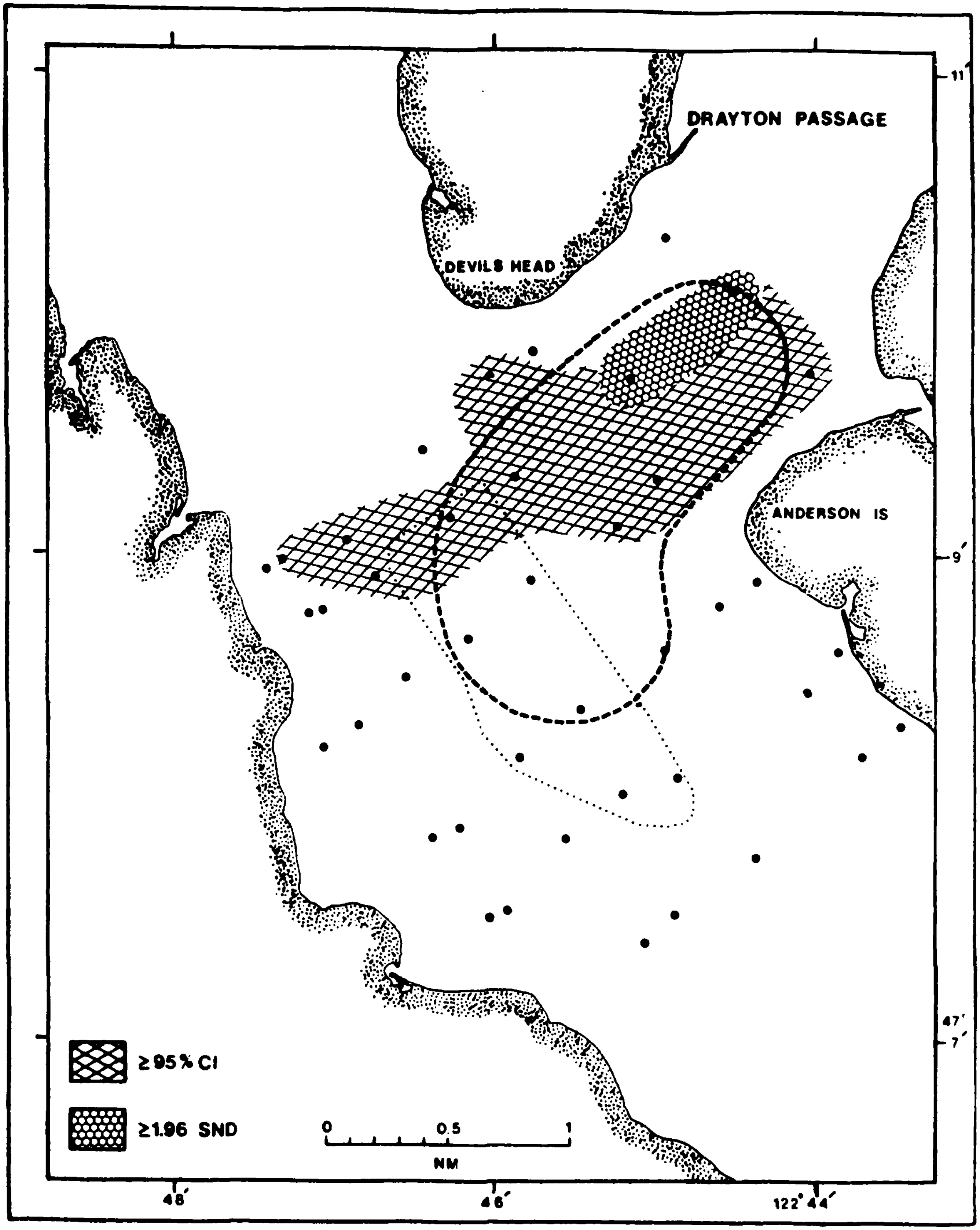

Figure 20. Areas where at least one parameter (biochemical oxygen demand, volatile solids, or percent water) exceeded the 95% confidence interval or the 1.96 standard normal deviate for Devils Head ZSF. Dotted line represents preliminary ZSF boundary. Dashed line indicates revised boundary based on deposition analysis results.

CONCLUSIONS

(Zone of Siting Feasibility)

1) The Lummi/Sinclair Island ZSF in northern Puget Sound and the McNeil Island ZSF in south Puget Sound were found to be unsuitable as non-dispersive sites for the disposal of dredged material. At both ZSF's the grain size of the sediment was much too coarse and little organic material was in evidence. In addition the macrofaunal communities at both ZSF's were characteristic of a suspension feeding community which indicate that water currents in the ZSF are relatively high.

2) Areas were located within each of the remaining ~~three~~ 3 ZSF's that are suitable non-dispersive sites.

3) In Bellingham Bay the area that appears to be the most depositional is located roughly 0.5 nautical miles north of the existing ZSF.

4) The area of greatest deposition within the Anderson/Ketron Island ZSF is located in the center of the ZSF, with the western half of the center area being slightly more depositional.

5) The region at the entrance to Drayton Passage has the greatest potential to be depositional. Concentrations of all measured parameters exceed the 95% CI and 1.96 SND in this region.

6. A comparison of all three ZSF's indicate that the amount of organic material in the sediment at Bellingham Bay is almost an order of magnitude greater than found in the south Puget Sound ZSF's. The median grain size and percent clay in the depositional regions of the south Puget Sound ZSF'S are roughly comparable to that found in Bellingham Bay.

LITERATURE CITED

Buchanan, J.B. 1984. Sediment Analysis. In: Methods for the Study of Marine Benthos. N.A. Holme and A.D. McIntyre (eds). Blackwell Scientific Publications, Boston, Massachusetts. pp. 41-65.

Krumbein, J.I., and F.J. Pettijohn. 1938. Manual of Sedimentary Petrography. Appleton-Century Crafts, N.Y. 549 pp.

McConkey-Sparks, P.J. and C.A. Coomes. 1986. Literature Review of Tidal Currents and Marine Sediment Studies in regard to the Proposed Phase II Disposal Sites. Final Report. U.S. Army Corps of Engineers, Seattle, WA.

Plumb, R.H. 1981. Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Technical Report EPA/CE 81-1. U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Standard Methods for the Examination of Water and Wastewater. 16th Edition. 1985. pp. 97-98, 418-419, 525-532.

Striplin, P.L., P.J. Sparks-McConkey, and M.E. Day. 1986. Puget Sound Sediment Deposition Analysis: Phase I. Final Reports. U.S. Army Corps of Engineers, Seattle, WA.

Word, J.Q., P.L. Striplin, J. Ward, and P.J. Sparks. 1984a. Subtidal Benthic Ecology. *Final Report. Vol. V. Sect.* 6, in J. Stober and K.K. Chew. Principal Investigators. Renton Sewage Treatment Plant Project: Seahurst Baseline Study. Fisheries Research Institute, University of Washington, FRI-UW-8413.

Word, J.Q., P.L. Striplin, J. Ward, and P.J. Sparks. 1984b. Subtidal Benthic Ecology. Final Report Chapter 6, pp. 134-189. In J. Stober and K.K. Chew. Principal Investigators. Renton Sewage Treatment Plant Project: Duwamish Head Baseline Study. Fisheries Research Institute, University of Washington, FRI-UW-8417.

Appendix A I.

PSDDA phase II sediment sampling at Lummi/Sinclair Island ZSF in north Sound was conducted on 22, 25, and 26 September 1986. At that time 60 stations were established and a sediment sample was obtained to determine the grain size, percent water, percent volatile solids, and biochemical oxygen demand (5 days). In addition, the sediment samples collected at each station were qualitatively defined by their physical characteristics (see Table 1 for explanation of terms). Table 2 presents the information for each station as taken from the field notes.

Seventeen stations were rejected on site in the field due to an inability to collect an adequate grab sample that held a minimum amount of sediment (as based on penetration depth). Table 3 presents data which shows whether the topography of the bottom and/or the sediment composition prevented the collection of a suitable sample.

A decision was made to halt evaluation of the sediment samples pertaining to the Lummi/Sinclair Island ZSF for the following reasons:

- North end of Lummi/Sinclair Island ZSF (transects A & B) large numbers of live scallops and clams found (4-5 per 0.1 m^2 or 100,000/acre).
- Towards the center of ZSF (transects C, C.5, D, D.5 and F.5) large size shell fragments were found.
- South end transects (G, H, and I) consisted of rock, gravel, cobble, and coarse sand.
- Qualitative observations of the large infauna indicated that suspension feeding polychaetes were more prevalent than the deposit feeding types.
- Some stations did contain silt (<50%) but there was always sand present and sometimes cobble and shell fragments.

Table 1. Qualitative descriptive information for subtidal 0.1 m^2 van Veen grab samples. REP#: R = Rejected station.

CODE:
G =GRAIN SIZE
V =VOLATILE SOLIDS
B =BIOCHEMICAL OXYGEN DEMAND

SEDIMENT TYPES		MODIFIERS	>50%
Rock :		RCKY	RCK
Cobble :		CBLY	CBL
Gravel :		GVLY	GVL
Sand :		SY	S
	Coarse		C
	Medium		M
	Fine		F
Silt :		SLTY	SLT
Clay :		CLY	CL

EXAMPLE : SY(M)-SLT

The modifier is listed first: SY = Sandy, and the type of sand is (M) medium. The last component: SLT, exceeds 50% of the sediment's composition.

COLOR
D.O. = Drab Olive
G = Green
GRY = Grey
B = Black
BRN = Brown

ODOR
H2S = Hydrogen Sulfide

Table 2. Qualitative sediment characteristics for stations in ZSF 6.

STATION	REP	CODE	LATITUDE	LONGITUDE	DEPTH M	TIME	DATE	SED TYPE	COLOR	ODOR	PEN DEPTH CM	COMMENTS
A-1(247)	2	GVB	48 38 07	122 42 05	75	1139	25 SEP 86	SLTY-S(C)	D.O.	NONE	4	SCALLOP SHELLS & URCHIN
A-1.5	3	GVB	48 39 01	122 42 01	80	1119	"	SLTY-S(C)	D.O.	NONE	10	SHELL FRAGS.
A-2(248)	1	GVB	48 39 05	122 41 08	75	1101	"	SY(C)-SLT	D.O.	NONE	9	SCALLOP(SHELL FRAGS)
A-3(222)	1	GVB	48 40 01	122 41 03	67	1049	"	S(C,M)	D.O.	NONE	6	SHELL FRAGS.
A-4(221)	1	GVB	48 40 03	122 41 00	67	1039	"	SLTY-S(F)	D.O.	NONE	7	SHELL FRAGS.
A-5(185)	1	GVB	48 40 06	122 40 07	56	1030	"	SY(F)-SLT	D.O.	NONE	10	SHELL FRAGS.
A-6(102)	2	GVB	48 40 07	122 40 06	32	1017	"	SLTY-S(C)	D.O.	NONE	9	LARGE COBBLE MIXED
B-2(190)	3	GVB	48 38 06	122 41 07	50	1222	"	SLTY-S(C)	D.O.	NONE	9	
B-3(203)	1	GVB	48 39 00	122 41 03	62	1235	"	SY(F)-SLT	D.O.	NONE	9	
B-4(199)	1	GVB	48 39 03	122 41 00	60	1245	"	SLTY-S(M)	D.O.	NONE	12	FULL OF SHELLS
B-5(228)	1	GVB	48 39 06	122 40 06	70	1256	"	SLTY-S(M)	D.O.	NONE	11	FEW SHELLS
B-6(258)	1	GVB	48 40 01	122 40 03	78	1306	"	SLTY-S(M)	D.O.	NONE	10	COBBLE & SHELL FRAGS.
C-1(64)	1	GVB	48 38 03	122 41 03	20	1513	"	SLTY-S(M)	D.O.	NONE	8	
C-2(154)	1	GVB	48 38 08	122 40 07	47	1503	"	SLTY-S(M)	D.O.	NONE	12	SHELL FRAGS.
C-3(190)	1	GVB	48 39 02	122 40 03	55	1444	"	SY(M)-SLT	D.O.	NONE	12	SHELL FRAGS.
C-4(271)	1	GVB	48 39 04	122 40 01	82	1406	"	SY(M)-SLT	D.O.	NONE	15	FEW SHELL FRAGS.
C-5(195)	1	GVB	48 39 07	122 39 07	56	1356	"	SLTY-S(M)	D.O.	NONE	9	SHELL FRAGS.
C-6(185)	1	GVB	48 39 08	122 39 05	56	1347	"	SLTY-S(C)	D.O.	NONE	8	FEW SHELLS
D-1(61)	2	GVB	48 38 04	122 40 02	20	1526	"	SLTY-S(C)	D.O.	NONE	6	ROCK & SHELLS (FRAGS)
D-2(116)	1	GVB	48 38 05	122 40 00	35	1535	"	SLTY-S(M)	D.O.	NONE	9	Phyllochaetopterus(ANNELID)
D-3(239)	1	GVB	48 38 06	122 39 09	73	1544	"	SLTY-S(F)	D.O.	NONE	11	LARGE CLAM SHELLS
D-4(237)	1	GVB	48 38 09	122 39 06	72	1553	"	SY(F)-SLT	D.O.	NONE	10	
D-5(225)	1	GVB	48 39 01	122 39 02	69	1505	"	SY(F)-SLT	D.O.	NONE	9	SCALLOP & CLAM SHELLS
D-6(101)	1	GVB	48 39 06	122 38 08	30	1616	"	SY(F)-SLT	D.O.	NONE	10	
E-1(67)	3	GVB	48 37 09	122 39 06	21	1716	"	SY(C)-GVL	D.O.	NONE	5	ROCK (2") & SHELL FRAGS
E-2(125)	1	GVB	48 37 09	122 39 05	38	1706	"	SY(F)-GVL	D.O.	NONE	10	ROCK & SILT(5%)
E-3(180)	1	GVB	48 38 02	122 39 05	55	1659	"	SY(F)-SLT	D.O.	NONE	10	ROCK (1") & SHELL FRAGS
E-4(235)	1	GVB	48 38 04	122 39 01	71	1651	"	SY(F)-SLT	D.O.	NONE	14	
E-5(180)	1	GVB	48 38 09	122 38 09	55	1641	"	SY(F)-SLT	D.O.	NONE	11	
E-6(189)	1	GVB	48 39 01	122 38 05	57	1633	"	CLY&SLT	D.O.	NONE	14	
E-7(109)	1	GVB	48 39 02	122 38 03	33	1625	"	CLY&SLT	D.O.	NONE	14	Phyllochaetopterus(ANNELID)
F-1(65)	2	GVB	48 37 05	122 39 04	20	1745	"	SY(M)-SLT	D.O.	NONE	9	ROCKS
F-2(154)	1	GVB	48 37 07	122 39 01	47	1754	"	SY(F)-SLT	D.O.	NONE	10	ROCKS
F-3(183)	1	GVB	48 37 09	122 39 00	56	1801	"	SY(F)-SLT	D.O.	NONE	10	FEW ROCKS
F-4(230)	1	GVB	48 38 02	122 38 06	70	1809	"	SY(F)-SLT	D.O.	NONE	11	DRIFT CARD #41-50 RELEASED
F-4.5	1	GVB	48 38 04	122 38 04	57	0846	26 SEP 86	SLTY-S(M)	D.O.	NONE	12	LARGE SHELLS
F-5(188)	1	GVB	48 38 07	122 38 01	57	1823	25 SEP 86	SLTY-S(M)	D.O.	NONE	12	
F-6(175)	1	GVB	48 38 09	122 38 01	53	1844	"	CLY&SLT	D.O.	NONE	9	
G-1(55)	2	GVB	48 36 07	122 39 02	17	1637	22 SEP 86	SY(C)-CBL	D.O.	NONE	6	LEAKAGE & ROCKS
G-2(85)	2	GVB	48 37 02	122 38 08	26	1649	"	SY(C)-CBL	D.O.	NONE	4.5	LEAKAGE & ROCKS
G-4(187)	1	GVB	48 37 06	122 38 01	57	1713	"	SY(C)-CBL	D.O.	NONE	7	ROCKS & SHELL FRAGS
G-5(287)	1	GVB	48 37 08	122 38 00	87	1725	"	SLTY-S(C)	D.O.	H2S-SLIGT	11	COBBLE & SHELL FRAGS
G-6(308)	2	GVB	48 38 01	122 37 07	94	1743	"	SHELL-FRG	-	NONE	7	SILT(10%)
G-7(307)	1	GVB	48 38 03	122 37 03	94	1757	"	SLTY-S(C)	DO(B-1CM)	NONE	10	SHELLS(WHOLE)
G-8(208)	1	GVB	48 38 07	122 37 01	63	1809	"	SY(C)-SLT	D.O.	NONE	9	SHELL FRAGS
H-(1)N	1	GVB	48 38 00	122 36 08	93	1515	"	SY(F)-SLT	D.O.	NONE	8	FEW SHELL FRAGS
H-320N	1	GVB	48 38 02	122 36 06	100	1500	"	SLTY-S(M)	D.O.	NONE	7	SHELL FRAGS(80%)
I-250N	1	GVB	48 38 02	122 35 02	82	1324	"	SILT	D.O.	NONE	13	GRAVEL(20%)
I-300N	1	GVB	48 38 00	122 35 04	92	1343	"	SY(F)-SLT	D.O.	NONE	9	GRAVEL(20%) & SHELL FRAGS

Table 2. Qualitative sediment characteristics for stations in ZSF 6.

I-380M	1	GVB	48 37 09	122 35 08	118	1353	"	SY(M)-GVL	DO(B-1CM)	NONE	9	LEAKAGE & COBBLE
C.5B1	1	GVB	48 38 07	122 40 03	40	0947	26 SEP 86	SY(F)-SLT	D.O.	NONE	10	ROCK & SHELL FRAGS
C.5B2	1	GVB	48 39 01	122 39 09	74	0939	"	SY(F)-SLT	D.O.	NONE	9	SHELL FRAGS
C.5B3	1	GVB	48 39 06	122 39 05	57	0928	"	SY(F)-SLT	D.O.	NONE	11	SHELL FRAGS
D.5B1	1	GVB	48 38 05	122 39 06	56	0859	"	SLTY-S(M)	D.O.	NONE	6	ROCKS & SHELL FRAGS
D.5B2	1	GVB	48 38 06	122 39 05	77	0909	"	SLTY-S(M)	D.O.	[illegible]	12	LARGE SHELLS(WHOLE)
D.5B3	1	GVB	48 39 01	122 39 00	55	0921	"	SLTY-S(F)	D.O.	NONE	11	SHELL FRAGS
F.5B1	1	GVB	48 37 07	122 38 07	57	0820	"	SLTY-S(M)	D.O.	NONE	13	SHELL FRAGS
F.5B2	1	GVB	48 38 02	122 38 03	62	0829	"	SLTY-S(M)	DO(GY6CM)	NONE	11	SHELL FRAGS & CRAB SP.(?)
F.5B3	1	GVB	48 38 07	122 37 08	58	0838	"	SLTY-S(M)	D.O.	NONE	13	SCALLOP (SHELL FRAGS)

Table 3. Qualitative sediment characteristics for stations in ZSF 6.

STATION	REP	CODE	LATITUDE	LONGITUDE	DEPTH M	TIME	DATE	SED TYPE	COLOR	ODOR	PEN DEPTH CM	COMMENTS
A-7(68)	3	GVB	48 40 07	122 40 04	19	1007	25 SEP 86	CBL			<4	
B-1(131)	4	GVB	48 38 04	122 41 09	39	1152	"	RCK				WASHED OUT
B-7(100)	4	GVB	48 40 04	122 39 09	30	1317	"	RCK				WASHED OUT
C-7(142)	4	GVB	48 40 00	122 39 04	43	1339	"	RCK				WASHED OUT
F-6(107)	4	GVB	48 39 00	122 37 09	32	1834	"	CBL				WASHED OUT
G-3(122)	4	GVB	48 37 05	122 38 03	37	1703	22 SEP 86	RCK				WASHED OUT
H-144N	4	GVB	48 36 07	122 38 03	44	1619	"	RCK				WASHED OUT
H-185N	2	GVB	48 37 00	122 37 09	56	1606	"	RCK/CBLE			<4	
H-283N	4	GVB	48 37 06	122 37 04	86	1541	"	RCK				WASHED OUT
H-300N	2	GVB	48 38 03	122 36 03	90	1435	"	RCK/CBL			<4	
H-310	4	GVB	48 37 08	122 36 09	95	1528	"	RCK				WASHED OUT
H-343N	2	GVB	48 37 03	122 37 04	105	1554	"	RCK/CBL			<4	
I-120S	3	GVB	48 36 05	122 37 08	37	1036	"	CBL			<4	
I-240S	3	GVB	48 36 09	122 37 03	73	1100	"	CBL/GVL			<4	
I-380	4	GVB	48 37 06	122 36 03	115	1300	"	RCK				WASHED OUT
I-380C	4	GVB	48 37 07	122 36 00	115	1412	"	RCK				WASHED OUT

Appendix A II.

PSDDA phase II sediment sampling at McNeil Island ZSF was conducted on 23 and 24 October 1986. Forty stations were established at that time to determine grain size, biological oxygen demand (5 days), percent water, and percent volatile solids values for each station. Field observations were made at each station qualitatively characterizing the physical properties of each sediment sample (see Table 1 for an explanation of terms).

Four stations were rejected on location in the field. The rocky substrate and/or bottom topography prevented the grab from penetrating to a depth adequate to retrieve a minimum amount of sediment. Table 2 presents data which shows rejected stations, penetration depths, sediment properties, and depth for each station sampled.

As in case of the Lummi/Sinclair Island ZSF, the sediments from the McNeil Island ZSF were obviously not representative of a depositional area. For this reason, no laboratory analysis of the McNeil Island ZSF sediments was carried out, and the ZSF was dropped from further consideration.

Table 1. Qualitative descriptive information for subtidal 0.1 m^2 van Veen grab samples. REP#: R = Rejected station.

CODE:
G =GRAIN SIZE
V =VOLATILE SOLIDS
B =BIOCHEMICAL OXYGEN DEMAND

SEDIMENT TYPES		MODIFIERS	>50%
Rock :		RCKY	RCK
Cobble :		CBLY	CBL
Gravel :		GVLY	GVL
Sand :		SY	S
	Coarse		C
	Medium		M
	Fine		F
Silt :		SLTY	SLT
Clay :		CLY	CL

EXAMPLE : SY(M)-SLT

The modifier is listed first: SY = Sandy, and the type of sand is (M) medium. The last component: SLT, exceeds 50% of the sediment's composition.

COLOR
D.O. = Drab Olive
G = Green
GRY = Grey
B = Black
BRN = Brown

ODOR
H2S = Hydrogen Sulfide

Table 2. Qualitative sediment characteristics for stations in ZSF 1.

STATION	REP#	CODE	LAT	LONG	DEPTH (ft)	TIME	DATE	SED. TYPE	COLOR	ODOR	PEN. DEPTH (cm)
ND-A1E	R	GVB	47 11 27	122 35 55	398	1115	23 OCT 86	-			
ND-A2E	3	GVB	47 11 30	122 36 08	490	1104	"	CBLY-S(C)	/BRN	NONE	3
ND-A3C	R	GVB	47 11 35	122 36 20	478	1030	"	-			
ND-A4C	1	GVB	47 11 44	122 36 40	525	956	"	SY(M)-SLT	D.O.(B-1cm)	NONE	9
ND-A5C	1	GVB	47 11 51	122 36 58	542	940	"	SLTY-S(M)	D.O.	H2S-slight	12
ND-A6W	1	GVB	47 12 02	122 37 24	527	925	"	SY(F)-SLT	D.O.(GRY-1cm)	H2S-slight	14
ND-A7W	1	GVB	47 12 12	122 37 35	537	911	"	SLTY-S(M)	GRY	H2S-slight	14.5
ND-A8W	1	GVB	47 12 14	122 37 56	527	852	23 OCT 86	SY(M)-SLT	D.O.	NONE	7
ND-B1E	1	GVB	47 11 05	122 35 57	300	1158	23 OCT 86	SLTY-S(C)	D.O.	NONE	9.5
ND-B2C	R	GVB	47 11 13	122 36 08	420	1210	"	-			
ND-B3C	R	GVB	47 11 24	122 36 30	478	1244	"	-			
ND-B4C	2	GVB	47 11 29	122 36 50	522	1327	"	CBLY-S(C)	D.O.	NONE	4
ND-B5C	1	GVB	47 11 36	122 37 17	531	1340	"	SLTY-S(M)	D.O.	H2S-slight	12
ND-B5W	1	GVB	47 11 45	122 37 35	517	1357	"	SY(M)-SLT	D.O.	H2S-slight	9.5
ND-B7W	1	GVB	47 11 49	122 37 55	502	1410	"	SY(M)-SLT	D.O.	H2S-slight	9
ND-B8W	1	GVB	47 11 54	122 38 10	475	1421	23 OCT 86	SLTY-S(M)	D.O.	NONE	1.5
ND-C1E	1	GVB	47 10 54	122 36 13	309	1647	23 OCT 86	SLTY-S(M)	D.O.	NONE	8.5
ND-C2C	2	GVB	47 10 58	122 36 18	350	1637	"	S(M)	D.O.	NONE	10
ND-C3C	2	GVB	47 11 04	122 36 38	424	1619	"	MIX	D.O.	NONE	6
ND-C4C	3	GVB	47 11 12	122 36 55	480	1543	"	CBLY-S(C)	D.O.	NONE	3
ND-C5C	1	GVB	47 11 18	122 37 10	528	1513	"	GVLY-S(C)	D.O.	NONE	5
ND-C6C	1	GVB	47 11 24	122 37 29	535	1501	"	SLTY-S(M)	D.O.	NONE	12
ND-C7W	1	GVB	47 11 28	122 37 44	520	1447	"	SLTY-S(M)	D.O.	NONE	13.5
ND-C8W	1	GVB	47 11 40	122 38 06	519	1435	23 OCT 86	SY(M)-SLT	D.O.	NONE	10
ND-D0E	1	GVB	47 11 06	122 35 46	165	1127	24 OCT 86	SLTY-S(F)	D.O.	H2S-slight	11
ND-D1E	1	GVB	47 10 45	122 36 46	309	1116	"	S(C)	GRY	NONE	16
ND-D2E	1	GVB	47 10 54	122 37 03	343	1105	"	CBLY-S(C)	D.O.	NONE	6
ND-D3C	4	GVB	47 11 00	122 37 26	520	1048	"	CBLY-S(C)	BRN	NONE	10
ND-D4C	1	GVB	47 11 05	122 37 35	546	956	"	GVLY-S(C)	BRN	NONE	12
ND-D5W	1	GVB	47 11 12	122 37 55	544	944	"	SLTY-S(F)	D.O.	H2S-slight	9
ND-D6W	1	GVB	47 11 20	122 38 14	528	930	"	SLTY-S(F)	D.O.	H2S-slight	10
ND-D7W	1	GVB	47 11 28	122 38 34	531	915	"	SLTY-S(F)	D.O.	H2S-slight	11
ND-D8W	1	GVB	47 11 40	122 39 04	66	904	24 OCT 86	SY(M)-SLT	GRN	H2S-slight	9
ND-E0E	1	GVB	47 10 25	122 36 46	223	1137	24 OCT 86	SLTY-S(F)	D.O.	NONE	11
ND-E1E	1	GVB	47 10 31	122 37 05	266	1147	"	SLTY-S(F)	D.O.	NONE	9
ND-E2C	1	GVB	47 10 43	122 37 32	528	1200	"	CBLY-S(M)	D.O.	NONE	7
ND-E3C	1	GVB	47 10 50	122 37 44	560	1217	"	SLTY-S(C)	D.O.	NONE	8
ND-E4W	1	GVB	47 10 57	122 38 12	545	1319	"	SY(C)-SLT	BRN	NONE	9
ND-E5W	1	GVB	47 11 04	122 38 35	536	1333	"	SY(M)-SLT	D.O.	NONE	10
ND-E6W	1	GVB	47 11 10	122 38 51	518	1344	"	S(F)-SLT	D.O.	H2S-slight	11
ND-E7W	1	GVB	47 11 13	122 39 00	522	1356	"	SY(C)-SLT	D.O.	H2S-slight	13
ND-E8W	1	GVB	47 11 16	122 39 13	320	1408	24 OCT 86	SLTY-S(F)	D.O.	NONE	8

APPENDIX B. Station locations, date, time, and type of samples collected for the sediment depositional analysis.

STATION	REP	CODE	LAT	LONG	DEPTH (ft)	TIME	DATE
Bellingham Bay ZSF							
BB A1-E	1	G/VS	48 42 55	122 31 29	62	0930	15 OCT 86
BB A2-E	1	G/VS	48 42 55	122 32 13	97	0946	"
BB A3-E	1	G/VS	48 42 58	122 32 56	96	0957	"
BB A4-C	1	G/VS	48 42 55	122 33 46	94	1010	"
BB A5-W	1	G/VS	48 42 55	122 34 30	90	1020	"
BB A6-W	1	G/VS	48 42 55	122 35 14	84	1027	"
BB A7-W	1	G/VS	48 42 55	122 36 00	78	1035	"
BB A8-W	1	G/VS	48 42 57	122 36 20	63	1040	15 OCT 86
BB B1-E	1	G/VS	48 42 26	122 31 09	65	1202	15 OCT 86
BB B2-E	1	G/VS	48 42 26	122 31 49	97	1155	"
BB B3-E	1	G/VS	48 42 25	122 32 35	99	1143	"
BB B4-C	1	G/VS	48 42 25	122 33 23	98	1130	"
BB B5-C	1	G/VS	48 42 25	122 34 11	94	1120	"
BB B6-W	1	G/VS	48 42 24	122 34 51	90	1113	"
BB B7-W	1	G/VS	48 42 24	122 35 37	92	1104	"
BB B8-W	1	G/VS	48 42 25	122 36 03	64	1055	15 OCT 86
BB C1-E	1	G/VS	48 42 00	122 30 54	62	1237	15 OCT 86
BB C2-E	1	G/VS	48 41 58	122 31 45	95	1248	"
BB C3-E	1	G/VS	48 41 58	122 32 31	98	1256	"
BB C4-C	1	G/VS	48 41 58	122 33 15	99	1305	"
BB C5-C	1	G/VS	48 41 57	122 34 02	97	1313	"
BB C6-W	1	G/VS	48 41 58	122 34 48	96	1320	"
BB C7-W	1	G/VS	48 41 58	122 35 30	98	1329	"
BB C8-W	1	G/VS	48 41 58	122 35 54	66	1336	15 OCT 86
BB D1-E	1	G/VS	48 41 30	122 30 33	67	1436	15 OCT 86
BB D2-E	1	G/VS	48 41 30	122 31 17	89	1428	"
BB D3-E	1	G/VS	48 41 30	122 32 00	91	1421	"
BB D4-C	1	G/VS	48 41 30	122 32 48	92	1414	"
BB D5-C	1	G/VS	48 41 28	122 33 33	94	1407	"
BB D6-W	1	G/VS	48 41 28	122 34 18	98	1400	"
BB D7-W	1	G/VS	48 41 29	122 35 01	99	1354	"
BB D8-W	1	G/VS	48 41 29	122 35 42	65	1345	15 OCT 86
BB E1-E	1	G/VS	48 41 00	122 30 18	67	1446	15 OCT 86
BB E2-E	1	G/VS	48 40 59	122 31 03	81	1453	"
BB E3-E	1	G/VS	48 40 59	122 31 45	82	1500	"
BB E4-C	1	G/VS	48 41 00	122 32 25	84	1507	"
BB E5-C	1	G/VS	48 40 57	122 33 12	88	1515	"
BB E6-W	1	G/VS	48 40 54	122 33 54	97	1521	"
BB E7-W	1	G/VS	48 40 57	122 34 41	106	1529	"
BB E8-W	1	G/VS	48 40 54	122 35 24	68	1537	15 OCT 86

McNeil Island ZSF

ND A-1E R	1	G/VS	47	1127	122	3555	428	1115	23 OCT 86
ND A-2E	2	G/VS	47	1130	122	3608	490	1104	"
ND A-3C R	1	G/VS	47	1135	122	3620	478	1030	"
ND A-4C	1	G/VS	47	1144	122	3640	525	0956	"
ND A-5C	1	G/VS	47	1151	122	3658	542	0940	"
ND A-6W	1	G/VS	47	1202	122	3724	[illegible]	0926	"
ND A-7W	1	G/VS	47	1212	122	3735	537	0911	"
ND A-8W	1	G/VS	47	1214	122	3756	527	0852	23 OCT 86
ND B-1E	1	G/VS	47	1105	122	3557	300	1158	23 OCT 86
ND B-2C R	1	G/VS	47	1113	122	3608	415	1230	"
ND B-3C R	1	G/VS	47	1124	122	3630	478	1244	"
ND B-4C	2	G/VS	47	1129	122	3650	522	1327	"
ND B-5C	1	G/VS	47	1136	122	3717	531	1340	"
ND B-6W	1	G/VS	47	1145	122	3735	517	1357	"
ND B-7W	1	G/VS	47	1149	122	3755	502	1410	"
ND B-8W	1	G/VS	47	1154	122	3810	479	1421	23 OCT 865
ND C-1E	1	G/VS	47	1054	122	3613	309	1647	23 OCT 86
ND C-2C	2	G/VS	47	1058	122	3618	350	1637	"
ND C-3C	2	G/VS	47	1104	122	3638	424	1619	"
ND C-4C	2	G/VS	47	1112	122	3655	480	1543	"
ND C-5C	1	G/VS	47	1118	122	3710	528	1513	"
ND C-6C	1	G/VS	47	1124	122	3729	535	1501	"
ND C-7W	1	G/VS	47	1128	122	3744	520	1447	"
ND C-8W	1	G/VS	47	1140	122	3806	519	1435	23 OCT 86
ND D-0E	1	G/VS	47	1106	122	3546	165	1127	24 OCT 86
ND D-1E	1	G/VS	47	1045	122	3646	309	1116	"
ND D-2E	1	G/VS	47	1054	122	3703	343	1105	"
ND D-3C	1	G/VS	47	1100	122	3726	520	1048	"
ND D-4C	1	G/VS	47	1105	122	3735	546	0956	"
ND D-5W	1	G/VS	47	1112	122	3755	544	0944	"
ND D-6W	1	G/VS	47	1120	122	3814	528	0930	"
ND D-7W	1	G/VS	47	1128	122	3834	531	0915	"
ND D-8W	1	G/VS	47	1140	122	3904	66	0904	24 OCT 86
ND E-0E	1	G/VS	47	1025	122	3646	223	1137	24 OCT 86
ND E-1E	1	G/VS	47	1031	122	3705	266	1147	"
ND E-2C	1	G/VS	47	1043	122	3732	528	1200	"
ND E-3C	1	G/VS	47	1050	122	3744	560	1217	"
ND E-4W	1	G/VS	47	1057	122	3812	545	1319	"
ND E-5W	1	G/VS	47	1104	122	3835	536	1333	"
ND E-6W	1	G/VS	47	1110	122	3851	518	1344	"
ND E-7W	1	G/VS	47	1113	122	3900	522	1356	"
ND E-8W	1	G/VS	47	1116	122	3913	320	1408	24 OCT 86

Anderson/Ketron Island ZSF

ND F-0E	1	G/VS	47	1020	122	3716	215	1541	22 OCT 86
ND F-1E	1	G/VS	47	1026	122	3755	540	1554	"
ND F-2C	1	G/VS	47	1035	122	3807	569	1606	"

ND F-3W	1	G/VS	47 1041	122 3829	556	1619	"
ND F-4W	1	G/VS	47 1047	122 3848	532	1632	"
ND F-5W	1	G/VS	47 1053	122 3904	516	1643	"
ND F-6W	1	G/VS	47 1059	122 3923	504	1700	"
ND F-7W	1	G/VS	47 1103	122 3934	350	1708	22 OCT 86
ND G-1E	1	G/VS	47 09 56	122 37 13	189	1532	22 OCT 86
ND G-2E	1	G/VS	47 10 03	122 37 28	219	1522	"
ND G-3E	1	G/VS	47 10 16	122 38 08	546	1508	"
ND G-4E	1	G/VS	47 10 25	122 38 28	557	1454	"
ND G-5E	1	G/VS	47 10 30	122 38 43	521	1442	"
ND G-6C	1	G/VS	47 10 40	122 39 12	513	1428	"
ND G-7W	1	G/VS	47 10 44	122 39 38	511	1414	"
ND G-8W	1	G/VS	47 10 46	122 39 51	308	1359	22 OCT 86
ND H-1E	1	G/VS	47 09 52	122 38 13	307	1113	22 OCT 86
ND H-2E	1	G/VS	47 09 57	122 38 18	433	1138	"
ND H-3E	1	G/VS	47 10 00	122 38 23	486	1156	"
ND H-4E	1	G/VS	47 10 02	122 38 38	478	1243	"
ND H-5E	1	G/VS	47 10 14	122 39 01	468	1255	"
ND H-6C	1	G/VS	47 10 20	122 39 24	481	1305	"
ND H-7W	1	G/VS	47 10 26	122 39 41	514	1316	"
ND H-8W	1	G/VS	47 10 42	122 40 22	68	1345	22 OCT 86
ND J-1E	1	G/VS	47 09 35	122 38 31	407	1102	"
ND J-2C	1	G/VS	47 09 39	122 38 49	429	1053	"
ND J-3C	1	G/VS	47 09 47	122 39 09	442	1040	"
ND J-4C	1	G/VS	47 09 57	122 39 30	459	1030	"
ND J-5W	1	G/VS	47 10 01	122 39 44	488	1018	"
ND J-6W	1	G/VS	47 10 05	122 40 00	484	1007	22 OCT 86
ND J-7W	3	G/VS/B	47 10 11	122 40 17	68	1426	24 OCT 86
ND K-1E	1	G/VS	47 09 06	122 38 33	311	0835	22 OCT 86
ND K-2E	1	G/VS	47 09 06	122 38 40	394	0846	"
ND K-3E	1	G/VS	47 09 12	122 38 54	377	0858	"
ND K-4C	1	G/VS	47 09 17	122 39 12	421	0908	"
ND K-5C	1	G/VS	47 09 25	122 39 35	445	0919	"
ND K-6W	1	G/VS	47 09 34	122 39 56	460	0929	"
ND K-7W	1	G/VS	47 09 38	122 40 05	396	0941	22 OCT 86
ND K-8W	3	G/VS/B	47 09 42	122 40 20	70	0954	24 OCT 86
ND L-1E	1	G/VS	47 08 43	122 38 38	306	1584	21 OCT 86
ND L-2E	1	G/VS	47 08 46	122 38 50	386	1605	"
ND L-3E	1	G/VS	47 08 51	122 39 00	354	1617	"
ND L-4C	1	G/VS	47 08 54	122 39 08	360	1627	"
ND L-5C	1	G/VS	47 08 57	122 39 18	408	1636	"
ND L-6C	1	G/VS	47 09 05	122 39 34	427	1650	"
ND L-7W	1	G/VS	47 09 10	122 39 50	440	1700	"
ND L-8W	1	G/VS	47 09 13	122 39 57	444	1709	"
ND L-9W	1	G/VS	47 09 18	122 40 11	310	1719	21 OCT 86
ND L-10W	3	G/VS/B	47 09 21	122 40 20	68	1522	24 OCT 86
ND M-1E	1	G/VS	47 08 11	122 38 25	70	1539	21 OCT 86
ND M-2E	1	G/VS	47 08 15	122 38 43	303	1530	"
ND M-3E	1	G/VS	47 08 24	122 38 57	324	1521	"

ND M-4C	1	G/VS	47 08 30	122 39 16	365	1511	"
ND M-5C	1	G/VS	47 08 39	122 39 43	407	1500	"
ND M-6W	1	G/VS	47 08 47	122 40 02	424	1450	"
ND M-7W	1	G/VS	47 08 50	122 40 10	400	1430	"
ND M-8W	1	G/VS	47 08 52	122 40 25	68	1428	21 OCT 856
ND N-1E	1	G/VS	47 08 04	122 39 16	300	1332	21 OCT 86
ND N-2C	1	G/VS	47 08 11	122 39 43	[illegible]	1345	"
ND N-3C	1	G/VS	47 08 14	122 40 02	[illegible]	1401	"
ND N-4W	1	G/VS	47 08 19	122 40 16	405	1410	"
ND N-5W	1	G/VS	47 08 25	122 40 33	68	1419	21 OCT 86
ND O-1E	1	G/VS	47 07 35	122 39 38	288	1314	21 OCT 86
ND O-2E	1	G/VS	47 07 40	122 39 49	307	1301	"
ND O-3C	1	G/VS	47 07 50	122 40 16	365	1250	"
ND O-4W	1	G/VS	47 07 59	122 40 38	398	1238	"
ND O-5W	1	G/VS	47 08 04	122 41 03	156	1154	"
ND O-6W	1	G/VS	47 08 11	122 41 20	96	1145	"
ND O-7W	1	G/VS	47 08 16	122 41 27	70	1135	21 OCT 86

Devils Head ZSF

NR A-OE	1	G/VS	47 10 16	122 44 55	66	1340	20 OCT 86
NR A-1E	1	G/VS	47 09 50	122 45 42	102	1029	"
NR A-2E	1	G/VS	47 09 45	122 45 58	314	1042	"
NR A-3C	1	G/VS	47 09 26	122 46 23	248	1053	"
NR A-4C	1	G/VS	47 09 04	122 46 50	248	1111	"
NR A-5W	1	G/VS	47 08 59	122 47 11	135	1125	"
NR A-6W	1	G/VS	47 08 57	122 47 19	71	1132	20 OCT 86
NR B-OE	1	G/VS	47 10 06	122 45 30	170	1333	20 OCT 86
NR B-1E	1	G/VS	47 09 44	122 45 07	183	1324	"
NR B-2E	1	G/VS	47 09 20	122 45 50	239	1314	"
NR B-3C	1	G/VS	47 09 10	122 46 13	228	1216	"
NR B-4C	1	G/VS	47 08 56	122 46 40	249	1203	"
NR B-5W	1	G/VS	47 08 53	122 46 58	103	1153	"
NR B-6W	1	G/VS	47 08 54	122 47 04	72	1142	20 OCT 86
NR C-OE	1	G/VS	47 09 55	122 44 04	130	1352	20 OCT 86
NR C-1E	1	G/VS	47 09 20	122 44 59	185	1406	"
NR C-2E	1	G/VS	47 09 09	122 45 13	258	1417	"
NR C-3C	1	G/VS	47 08 55	122 45 44	218	1430	"
NR C-4C	1	G/VS	47 08 42	122 46 08	218	1440	"
NR C-5W	1	G/VS	47 08 30	122 46 29	188	1448	"
NR C-6W	1	G/VS	47 08 18	122 46 46	96	1457	"
NR C-7W	1	G/VS	47 08 13	122 46 58	65	1505	20 OCT 86
NR D-1E	1	G/VS	47 08 54	122 44 23	68	1621	20 OCT 86
NR D-2E	1	G/VS	47 08 48	122 44 37	251	1613	"
NR D-3C	1	G/VS	47 08 37	122 44 57	219	1603	"
NR D-4C	1	G/VS	47 08 22	122 45 26	219	1551	"
NR D-5C	1	G/VS	47 08 10	122 45 50	184	1542	"
NR D-6W	1	G/VS	47 07 54	122 46 10	97	1533	"
NR D-7W	1	G/VS	47 07 52	122 46 20	65	1516	20 OCT 86

NR E-1E	1	G/VS	47	08	36	122	43	53	69	0920	21 OCT 86
NR E-2E	1	G/VS	47	08	27	122	44	05	242	0928	"
NR E-3C	1	G/VS	47	08	05	122	44	53	212	0942	"
NR E-4C	1	G/VS	47	08	01	122	45	11	193	0950	"
NR E-5W	1	G/VS	47	07	50	122	45	31	183	0959	"
NR E-6W	1	G/VS	47	07	33	122	45	53	100	1010	"
NR E-7W	1	G/VS	47	07	31	122	46	00	69	1019	21 OCT 86
NR F-1E	1	G/VS	47	08	18	122	43	32	70	1109	21 OCT 86
NR F-2E	1	G/VS	47	08	11	122	43	45	245	1102	"
NR F-3C	1	G/VS	47	07	46	122	44	23	169	1049	"
NR F-4W	1	G/VS	47	07	32	122	44	53	122	1036	"
NR F-5W	1	G/VS	47	07	24	122	45	04	70	1028	21 OCT 86

APPENDIX C. Grain Size Data for Phase II Depositional Analysis

STATION	%GRAVEL	%SAND	%SILT	%CLAY
BELLINGHAM BAY ZSF				
A1E	5.071	30.166	52.831	11.932
A2E	0	1.469	78.737	19.794
A3E	0.069	1.583	81.67	16.678
A4C	0.044	1.01	82.048	16.898
A5W	0.061	1.36	79.162	19.417
A6W	0.401	1.733	80.905	16.961
A7W	0.085	2.075	81.615	16.225
A8W	0.042	1.141	81.67	17.147
B1E	0.079	76.883	18.643	4.394
B2E	0	1.194	78.731	20.075
B3E	0	1.525	81.369	17.106
B4C	0.007	0.988	81.888	17.116
B5C	0.005	0.995	81.769	17.231
B6W	0	1.188	78.768	20.044
B7W	0.006	0.946	79.998	19.05
B8W	0.142	24.02	61.433	14.404
C1E	21.972	31.159	38.659	8.209
C2E	0	1.104	81.545	17.351
C3E	0.068	1.267	82.91	15.755
C4C	0.405	1.102	81.302	17.191
C5C	0	1.465	81.546	16.989
C6W	0.041	1.348	82.013	16.598
C7W	0.007	1.491	81.597	16.906
C8W	0.077	49.687	38.519	11.717
D1E	0.055	2.575	81.681	15.689
D2E	0.056	1.581	81.947	16.417
D3E	0	1.389	81.51	17.101
D4C	0.013	1.499	82.111	16.376
D5C	0.007	1.824	81.037	17.131
D6W	0.05	1.763	81.215	16.972
D7W	0.02	2.589	80.078	17.312
D8W	0.072	37.252	51.138	11.538
E1E	0.027	1.781	81.988	16.204
E2E	0	1.88	82.378	15.742
E3E	0	1.285	81.715	16.999
E4C	0.411	1.236	78.843	19.51
E5C	0.078	1.293	78.866	19.764
E6W	0.042	1.651	82.009	16.298
E7W	0.088	2.371	79.079	18.462
E8W	0.118	51.725	38.545	9.612
Anderson/Ketron Island ZSF				
F0E	0	78.506	15.608	5.886
F1E	24.28	47.785	21.5	6.436
F2C	1.798	65.483	25.217	7.502
F3W	2.09	58.842	29.933	9.135

STATION	%GRAVEL	%SAND	%SILT	%CLAY
Anderson/Ketron Island ZSF				
F4W	0.201	61.486	29.332	8.98
F5W	0.142	70.364	21.973	7.521
F6W	0.073	69.732	22.316	7.88
F7W	0.024	69.997	22.09	7.909
G1E	0.189	48.178	40.761	10.872
G2E	0.996	67.702	24.621	6.681
G3E	0.658	45.973	42.233	11.136
G4E	13.27	47.64	31.931	7.16
G5E	9.27	53.691	29.705	7.334
G6C	0.103	72.7	21.637	5.56
G7W	0.074	72.665	21.259	6.002
G8W	0.573	76.793	17.365	5.269
H2E	18.9	42.822	29.849	8.429
H3E	0.073	66.105	27.839	5.984
H4E	0.131	52.715	37.025	10.129
H5E	0.104	62.17	29.719	8.008
H6C	0.008	61.467	29.457	9.068
H7W	0.027	73.772	20.166	6.034
H8W	0.115	74.871	18.983	6.031
J1E	0.08	56.128	35.213	8.58
J2C	0.014	49.791	39.787	10.408
J3C	0.019	42.482	46.043	11.457
J4C	0.024	43.483	45.549	10.944
J5W	0.046	54.776	36.369	8.809
J6W	0.183	69.593	22.883	7.341
J7W	0.037	77.687	16.341	5.935
K1E	10.52	43.208	37.034	9.239
K2E	0	63.09	29.572	7.338
K3E	0.028	58.442	33.06	8.469
K4C	0.054	38.708	48.356	12.882
K5C	0.012	35.238	51.52	13.23
K6W	0.009	51.448	38.57	9.973
K7W	0.169	77.114	17.489	5.228
K8W	0.243	51.84	38.317	9.6
L1E	0.027	60.025	31.464	8.484
L2E	0.008	65.951	26.185	7.857
L3E	0.017	53.396	36.24	10.347
L4C	0.062	56.279	33.563	10.095
L5C	0.024	43.671	45.907	10.397
L6C	0.112	29.958	56.917	13.013
L7W	0.061	53.859	36.606	9.474
L8W	0.026	62.686	29.788	7.5
L9W	0.188	71.949	21.413	6.45
L10W	1.834	63.946	27.422	6.798
M1E	0.091	47.762	41.15	10.997
M2E	0.009	50.337	38.77	10.88
M3E	0.002	56.106	35.206	8.66[illegible]
M4C	0.022	52.728	37.152	10.098
M5C	0.074	51.486	38.501	9.939
M6W	0.125	59.793	31.473	8.609
M7W	4.965	68.926	20.2	5.909

STATION	%GRAVEL	%SAND	%SILT	%CLAY
Anderson/Ketron Island ZSF				
M8W	0.019	64.856	27.412	7.712
N1E	0.02	75.741	19.044	5.195
N2C	0.005	60.27	30.777	8.949
N3C	0.047	65.579	27.471	6.904
N4W	0.021	73.564	19.595	6.82
N5W	1.465	76.129	16.982	5.425
O1E	1.306	75.503	17.49	5.701
O2E	0.028	83.584	12.412	3.976
O3C	0.007	67.047	25.756	7.19
O4W	0.546	68.643	24.077	6.734
O5W	0.034	61.015	30.423	8.529
O6W	1.781	64.937	26.52	6.762
O7W	0.608	68.214	24.907	6.272
Devils head ZSF				
A0E	0.242	54.683	35.954	9.121
A1E	5.076	30.198	52.789	11.936
A2E	0	67.78	25.127	7.092
A3C	0	66.112	26.814	7.073
A4C	0.096	2.208	74.703	22.993
A5W	0	20.024	64.333	15.643
A6W	0.174	68.714	24.661	6.451
B0E	0	25.758	59.998	14.244
B1E	0	26.269	60.356	13.374
B2E	0	71.523	21.818	6.659
B3E	0.059	63.087	28.731	8.124
B4C	0.026	59.233	32.035	8.705
B5W	0	56.381	34.282	9.337
B6W	0.203	75.136	19.991	4.669
C0E	0	19.032	66.103	14.864
C1E	0	54.972	35.165	9.863
C2E	0.003	56.494	33.969	9.534
C3C	0.166	3.121	74.829	21.884
C4C	0.026	74.28	20.026	5.667
C5W	0.052	66.757	26.11	7.08
C6W	0	59.246	32.255	8.499
C7W	0.014	60.503	31.773	7.71
D1E	0.11	5.125	74.529	20.237
D2E	0	67.353	25.104	7.544
D3C	0.162	71.951	21.569	6.318
D4C	0.09	59.052	32.873	7.985
D5C	0	77.388	16.621	5.992
D6W	0	75.239	19.326	5.435
D7W	0.009	79.316	16.099	4.576
E1E	0.071	4.735	72.342	22.852
E2E	0.053	65.996	26.372	7.579
E3C	0.07	79.02	16.013	4.897
E4C	0.073	79.926	15.11	4.891
E5W	5.668	94.332	0	0

STATION	%GRAVEL	%SAND	%SILT	%CLAY
Devils head ZSF				
E6W	0	74.723	19.649	5.627
E7W	0.224	74.66	20.207	4.91
F1E	7.017	74.974	14.642	3.367
F2E	0	74.418	20.252	5.33
F3C	0.005	95.564	3.156	1.275
F4W	0	100	0	0
F5W	0.01	81.055	14.533	4.403

APPENDIX D. CONVENTIONAL CHEMISTRY DATA FOR PSDDA PHASE II

STATION	VS	BOD	H2O
BELLINGHAM BAY			
A1E	4.12	1195	39.7
	4.07	1206	40.6
A2E	8.25	1944	70.3
	7.87	1898	69.4
		2795	
		2468	
A3E	8.51	3164	72.6
	8.47	3106	72.7
		2605	
		2634	
A4C	8.19	2396	72.5
	8.29	2572	72.4
		2030	
		2299	
A5W	7.35	2309	67.6
	7.96	1691	68.8
		2212	
		2264	
A6W	7.73	2095	70.7
	8.03	2220	70.6
	7.06	2185	69.1
	7.42	1837	70.8
A7W	7.48	3379	67.9
	7.54	3460	67.9
		3690	
		3810	
A8W	6.85	2384	58.9
	6.6	2422	59.1
		2339	
		2290	
B1E	1.47	500	25.4
	1.75	564	25.9
B2E	8.19	2135	69.7
	7.99	1911	70.2
	7.74	2386	70.3
	7.77	2055	69.2
B3E	7.81	1940	70.4
	7.33	1797	70.8
	7.59	2424	70.8
	7.78	2264	69
B4C	7.59	2055	67.3
	7.58	1883	68.3
		2057	
		2203	
B5C	7.72	2000	68.7
	7.81	1928	69.3
		2550	

STATION	VS	BOD	H2O
BELLINGHAM BAY			
B6W	7.67	1850	68
	7.71	1925	68.2
		2108	
		2018	
B7W	6.81	2284	67
	7.28	2222	67
	7.5	1771	66.8
	7.37	1765	66.3
B8W	3.62	1291	46.2
	3.35	1374	46.5
C1E	3.95	1043	49.7
	4.61	930	51.6
C2E	7.99	2015	68.1
	8.09	1920	68.1
		2486	
		2455	
C3E	7.63	2138	68.4
	7.42	1817	68.3
		2266	
		2236	
C4C	7.49	1974	68.8
	7.24	2194	68.8
		2157	
		2299	
C5C	7.3	1777	67.6
	7.41	1820	67.7
		2352	
		2313	
C6W	7.99	2465	70.9
	7.66	2214	70.5
C7W	7.26	1734	67
	6.66	1612	66.9
	6.71	2034	66.4
	7.1	1978	67.2
C8W	0.43	448	27.8
	1.73	706	27.9
D1E	8.65	2143	71.8
	8.95	2193	71.3
		2672	
		2684	
D2E	7.81	1797	68.9
	7.82	1997	70.2
D3E	7.38	2369	69.4
	7.83	2052	69.5
D4C	7.13	1857	68.2
	7.46	1832	68.6
D5C	7.43	1899	68.9
	7.59	1900	68.8
D6W	6.37	1858	67
	6.94	1813	66.6

STATION	VS	BOD	H2O
BELLINGHAM BAY			
D7W	7	1287	65
	6.38	1278	65
D8W	3.12	941	41.5
	3.29	900	42.1
E1E	8.26	2080	69.1
	8.34	1930	68.6
E2E	7.45	1379	69
	7.36	1848	69.3
E3E	7.61	2199	67.8
	7.67	2171	67.7
	7.61	2626	68.1
	7.53	2393	67.6
E4C	6.82	1468	64.3
	6.86	1573	63.7
		2057	
		2113	
E5C	7.03	1846	67
	6.94	1895	67
E6W	6.77	1496	62.1
	6.35	1585	62.1
	6.51	1523	60.9
	5.92	1660	61.9
E7W	6.66	1429	61.4
	6.61	1538	61.4
E8W	1.94	466	33.4
	1.86	520	32.9
Anderson/Ketron Island ZSF			
F0E	1.25	335	26.1
	1.22	284	24.5
F1E	1.83	672	30.3
	1.91	573	29.6
F2C	1.43	460	28.1
	1.28	480	27.5
F3W	1.79	572	29.1
	1.73	615	27.7
F4W	1.4	553	25.7
	1.34	525	25.3
F5W	1.25	390	26.2
	1.3	410	25.9
F6W	1.43	400	29.4
	1.37	375	29.4
F7W	1.71	452	31.6
	1.6	620	31.8
	1.64		
G1E	2.74	1030	43.5
	2.8	1110	43.8
	2.74		

STATION	VS	BOD	H2O
Anderson/Ketron Island ZSF			
G2E	1.86	577	32.2
	1.78	455	31.9
G3E	2.33	995	43.2
	2.16	995	44.9
G4E	1.85	750	34.1
	1.84	814	34.1
	1.9		
G5E	1.66	765	32.6
	1.61	740	32.9
G6C	1.24	476	26.4
	1.18	460	26.2
G7W	1.55	442	30.8
	1.35	413	30.8
G8W	1.11	320	26.4
	1.21	360	26.1
H1E	1.5	375	33.7
	1.49	408	33.1
H2E	1.51	406	31.2
	1.57	407	28.2
H3E	1.44	379	31.2
	1.45	325	31.2
H4E	2.22	830	38.9
	2.35	805	38.6
H5E	1.86	505	35.9
	1.75	560	35.7
H6C	1.58	548	32.3
	1.65	517	32.3
H7W	1.52	500	28.6
	1.53	475	28.3
H8W	1.16	450	25.7
	1.16	390	25.7
J1E	2.21	627	39.6
	2.06	506	38.6
J2C	2.67	846	43.2
	2.67	839	42.3
J3C	3.39	1090	43.7
	3.22	1055	43.9
J4C	3.11	969	43.6
	3.01	952	45.3
J5W	2.4	845	41
	2.55	870	40.8
J6W	1.68	650	32.9
	1.7	665	32.3
J7W	0.99	411	25.8
	0.89	395	25.1
K1E	2.38	1015	42.2
	2.41	1010	41.5
	2.33	935	
		1063	
K2E	1.36	685	34.6
	1.42	724	34.7

STATION	VS	BOD	H2O
Anderson/Ketron Island ZSF			
K3E	2.29	557	40
	2.16	552	40.1
K4C	3.12	855	48.7
	2.82	835	46.7
K5C	3.61	1374	51
	3.71	1259	49.8
K6W	2.58	856	40
	2.4	857	41.1
K7W	1.47	253	29.5
	1.39	321	29.6
K8W	2.34	590	34.5
	2.58	595	34.3
		605	
L1E	1.56	823	39
	1.7	776	38.7
L2E	1.74	540	37
	1.71	560	35.6
L3E	2.09	780	40.7
	2.24	770	37.9
L4C	2.33	920	39.2
	2.35	800	39.6
L5C	3.21	1127	47.5
	3.04	993	46.1
L6C	3.87	1227	53.6
	3.95	1285	53
L7W	2.26	860	41.3
	2.51	847	41
	2.53		41.5
	2.36		
L8W	1.78	673	35.7
	1.92	761	35.4
L9W	1.5	402	28.8
	1.48	434	28.3
L10W	1.78	416	32.4
	1.83	330	30.7
		376	
M1E	2.33	600	38.7
	2.41	585	39.2
M2E	2.24	850	41.5
	2.15	942	40.2
M3E	2.49	905	44.2
	2.46	944	42.5
M4C	2.04	856	40.8
	2.15	820	39.8
M5C	2.51	1000	42.5
	2.4	948	41.3
	2.47	965	
		940	
M6W	1.93	617	34.9
	1.9	619	34.8

STATION	VS	BOD	H2O
Anderson/Ketron Island ZSF			
M7W	1.47	406	28.2
	1.35	405	28.7
M8W	1.71	390	32.9
	1.72	415	33.2
N1E	1.08	412	28.7
	1.05	400	27.9
N2C	2	748	35.2
	2.03	712	37.0K
N3C	1.63	710	35.8
	1.66	677	35.8
N4W	1.37	323	30.4
	1.35	304	29.7
N5W	1.16	285	23.9
	1.12	263	24.2
O1E	1.22	283	28.2
	1.3	242	28.3
O2E	0.92	225	27.7
	0.95	220	27.8
O3C	1.57	482	33.5
	1.54	508	33.6
O4W	1.65	590	34
	1.59	555	34.5
O5W	1.75	640	34.5
	1.64	675	33.9
O6W	1.5	375	31.2
	1.55	366	31.2
O7W	1.59	640	31.8
	1.5	525	32.1
Devils head ZSF			
A0E	1.8	508	34.2
	1.79	505	34.5
A1E	1.77	542	30.7
	1.87	606	30.9
A2E	1.74	734	35.3
	1.73	708	35
A3C	1.58	390	34.5
	1.58	410	33.9
A4C	1.99	644	36.1
	1.95	657	36.3
A5W	4	1336	55.2
	3.92	1280	55.2
A6W	1.46	555	29.8
	1.38	500	28.8
B0E	3.25	982	50.3
	3.2	930	48.6
B1E	3.22	1428	47.8
	3.36	1343	47.4
B2E	1.53	658	34.1
	1.7	590	34

STATION	VS	BOD	H2O
Devils head ZSF			
B3E	1.56	550	34.5
	1.67	580	33.8
B4C	1.98	636	37
	1.98	638	36.5
B5W	1.44	440	30.7
	1.37	480	30.5
		436	
B6W	1.24	495	25.6
	1.32	535	24.3
C0E	3.75	1521	54.7
	3.75	1430	54.3
C1E	1.86	796	38
	1.91	770	35.9
C2E	1.94	670	36.9
	2.06	715	36.7
C3C	1.71	570	31.1
	1.67	490	31.2
C4C	1.27	260	29
	1.33	315	29.5
		267	
C5W	1.79	520	34
	1.75	504	33.6
C6W	2.22	660	38.5
	2.23	662	37.6
C7W	1.85	665	34.3
	1.88	680	34.5
D1E	1.33	452	28.4
	1.3	468	28.6
D2E	1.49	530	32.8
	1.43	641	33
D3C	1.48	385	30.7
	1.52	405	30.4
D4C	1.53	424	31.3
	1.52	462	31.3
D5C	1.05	303	27.1
	1.05	311	26.7
D6W	1.37	370	29.2
	1.39	400	29
D7W	1.2	250	29.8
	1.18	350	30.2
E1E	1.4	634	30.8
	1.45	715	30.9
E2E	1.55	484	33.2
	1.6	458	33.6
E3C	1.04	320	28.7
	1.06	311	27.9
E4C	1.17	379	30.2
	1.16	396	29.7
E5W	0.63	86	28
	0.62	90	27.1

STATION	VS	BOD	H2O
Devils head ZSF			
E6W	1.38	445	30.2
	1.38	423	30.5
E7W	1.3	368	31.3
	1.34	327	30.8
F1E	1.09	225	23
	1.01	238	23.4
F2E	1.5	416	31.1
	1.48	424	31.7
F3C	0.33	62	24.1
	0.39	65	23.4
F4W	0.57	70	25.3
	0.59	53	24.6
F5W	1.14	415	30.1
	1.24	396	29.9

END

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DTIC