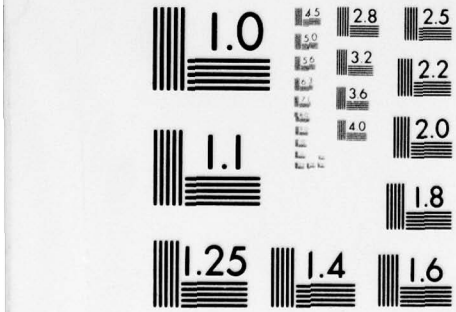
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(1) LEVEL III

MILLER SANDS MARSH AND UPLAND HABITAT
DEVELOPMENT SITE, COLUMBIA RIVER, OREGON

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APPENDIX A: PHYSICAL AND CHEMICAL INVENTORY

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(6) **Habitat Development Field Investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon. Appendix A. Physical and Chemical Inventory.**

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(10) Norman Cutshall [redacted] Vernon G. Johnson
School of Oceanography
Oregon State University
Corvallis, Oregon 97331

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ABSTRACT

Physical and chemical conditions at Miller Sands Island complex seem to control plant growth and ecosystem development. While no chemical factors have been identified that appear to retard plant growth, at several locations (particularly on the older upland portion of the existing island) fertility is marginal. In the intertidal and aquatic areas, chemical factors do not appear to limit growth, either through deficiency or retardation. Instead it appears that physical factors, specifically wave action on the sand substrate, prevent establishment of plants around much of the island, particularly on the newer beaches.

The combination of marginal fertility on the older island and severe sediment turnover on the newer island gives Miller Sands an aspect that is bleak by Oregon coastal standards. Once rooted plants are established at Miller Sands, trapping of silt follows with concomitant increases in fertility factors and development of a more diverse and active community begins. This in turn stimulates plant development and further stabilizes the system through an increased capacity for absorption of wave energy without sediment stirring. The lush areas of marshy development around the south and east portions of the island appear to have become resistant to the normal abuse of the wind waves and ship wakes. Initial establishment is difficult, though, because sediment turnover and transport leads to uprooting and destruction of the interstitial-water/root/microbial-flora characteristics of the well developed marsh vegetation.

Waves at the proposed marsh development site develop principally within the cove itself under sustained winds. The large waves that build in the Columbia River estuary during westerly and northwesterly winds are dissipated at the cove entrance. The cove waves appear to build as they travel eastward toward the proposed marsh site. Physical protection of the site from these waves during the critical period of marsh establishment may be necessary.

Fertilization of the area would probably accelerate initial plant development but would require very delicate control, lest the new marsh become dependent upon artificial supplies of nutrients. Nonetheless, in the longer course of time, the fertility of the soil, particularly where it is usually emergent, should be closely monitored. Depletion of fertility factors on the older island presumably is related to a lack of replenishment through river flooding. Where periodic inundations are sufficiently frequent, depletion is probably not as serious a problem as where submergence no longer occurs.

It appears that once a marsh is well established in the Miller Sands area subsequent destruction is not caused so much by the high energy and high frequency factors that inhibit initial establishment but rather by the longer-term changes of greater scale. For example, natural deepening of the channel along the southern side of the older island, along with migration of the channel toward the island, may soon threaten the marshy area that fringes the south shore. The processes of deepening and migration occur over a period of years, even decades, and are not substantiated by data herein, but rather through discussions with long-time residents of the area.

Long-term processes such as channel migration might be studied more successfully through longer-term programs than through short-term studies at any level of effort since natural processes occur on nature's time scale.

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PREFACE

The work described in this report was performed from June through December 1975 under Contract No. DACW 57-75-C-0280, entitled "Physical-Chemical Conditions at Miller Sands Island in the Columbia River Estuary," between the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the School of Oceanography, Oregon State University (OSU), Corvallis, Oregon. The research was sponsored by the Environmental Effects Laboratory (EEL) as part of its Habitat Development Project, Dredged Material Research Program (DMRP).

Dr. Norman Cutshall and Dr. Lawrence Small directed this project, and Vernon G. Johnson was project manager at OSU. Duane L. Higley contributed the biological data and assisted in the field work, together with Mike Christian, Norman Farrow, Russell Flegal, Dave Menzies and Mike Peters. Karla McMechan aided in preparing the bibliography and the final report. Sandy Moore, Jerry Wagner, Dave TenHulzen and Don Miller helped to analyze the samples collected. Fatu Bigsby and Kathy Heide assisted in data reduction. Gerri Riley typed the text. The OSU research vessels YAQUINA, CAYUSE, and SACAJAWEA were used to collect samples.

The following experts were consulted for advice during this project: Ed Condon (OSU Extension-Oceanography), and Hugh Gardner, Marvin Kauffman and G.H. Simonson (Soil Science Department, OSU) on soil fertility and soil analysis; Max Deinzer (OSU Agricultural Chemistry) on pesticide analysis; Bill Griffis (Environmental Protection Agency, Corvallis) on

nutrient measurements in water and sediment; Wilbur Ternyk and Dave White (other contractors on Miller Sands); I.L. Larsen and Paul Komar (Oceanography, OSU) on sediment transport; and Michael DeManche and Percy Donaghay (Oceanography, OSU) on interpretation of nutrient measurements.

The authors accept sole responsibility for all interpretations and conclusions presented herein, including those based upon information obtained from the above-mentioned persons.

The contract was monitored by Mr. David R. Parsons, Dr. Scott Boyce and Dr. John E. Byrne, DMRP, WES. Contracting officer was Mr. Adam B. Mello, U.S. Army Engineer District, Portland. The study was conducted under the direction of the following EEL personnel: Tom Wood, Chief, Natural Resources Development Branch and Dr. Conrad Kirby, Chief, Environmental Resources Division. The study was under the general supervision of Dr. John Harrison, Chief, EEL. Dr. Hanley K. Smith was Project Manager for Habitat Development Research.

The director of WES during the study and preparation of this report was Col. G.H. Hilt. Technical Director was Mr. F.R. Brown.

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI)

UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U.S. statute)	1609.344	meters
square feet	0.09290304	square meters
acres	0.40468	hectares
pounds (mass) per acre	1.1208666	kilograms per hectare
feet per second	0.3048	meters per second
miles per hour	1609.344	meters per hour
cubic feet per second	0.02831685	cubic meters per second
Fahrenheit degrees	5/9	Celsius or Kelvin degrees*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

HABITAT DEVELOPMENT FIELD INVESTIGATIONS
MILLER SANDS, COLUMBIA RIVER, OREGON
APPENDIX C: PHYSICAL AND CHEMICAL INVENTORY

PART I: INTRODUCTION

Study Site

Physical, chemical, and biological studies were made at Miller Sands and nearby regions as part of the Miller Sands Habitat Development Project, research which is investigating beneficial uses of dredged material taken from the ship channel in the lower Columbia River. The study site is situated at approximately Columbia River mile* (CRM) 24 near Astoria, Oregon. Much of the island material originated from dredged material removed from the nearby ship channel. However, it seems quite possible that some of the area was shallow and perhaps emergent prior to dredging operations (which began about 40 yrs ago), as indicated in Figure 1.

The area known as "Miller Sands Island" is actually an island complex consisting of at least two distinct islands (depending upon tidal stage). For purposes of this report, the various portions of this island complex have been designated as shown in Figure 2. The main island is the oldest and is well vegetated. The spit is composed mostly of barren dredged material, while the new fill was created during the present study. The upper reaches of the cove are shallow (exposed at

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* A table of conversion factors for dimensions can be found on page 11.

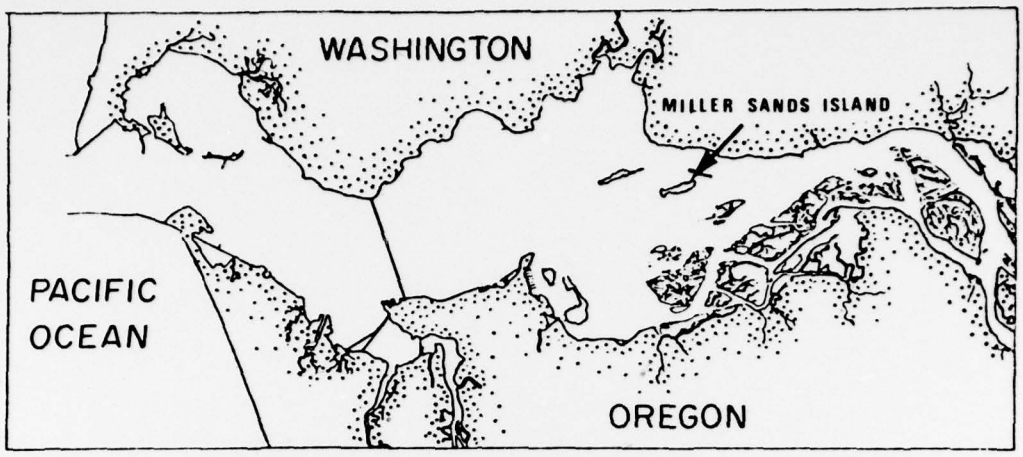


Figure 1a. Columbia River estuary, 1974 (taken from U.S. Coast and Geodetic Survey Charts 6151 and 6152).

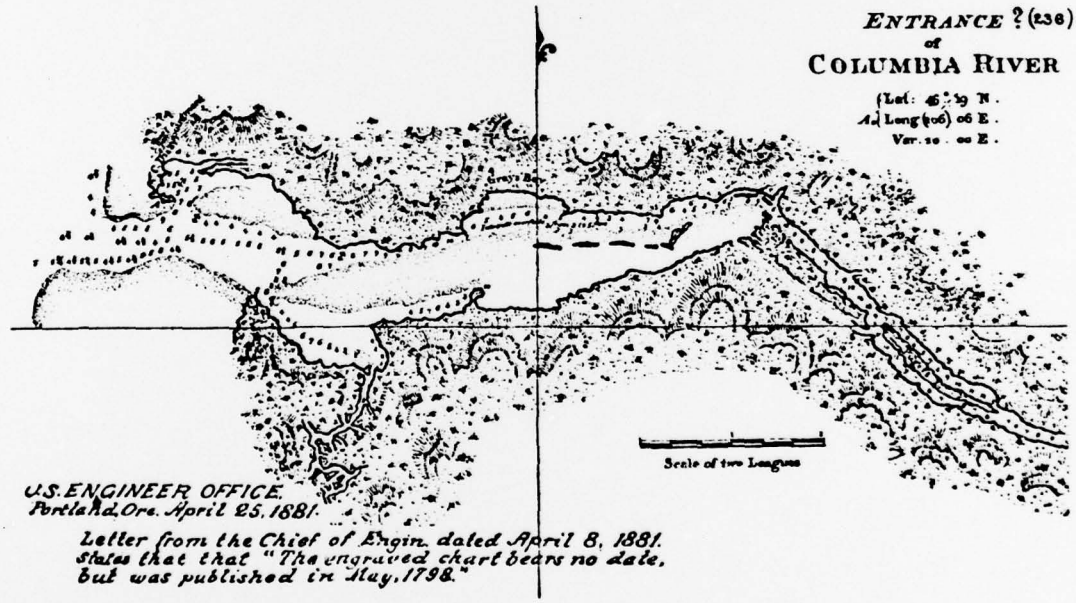


Figure 1b. Columbia River estuary, circa 1792. Note that islands appear near where Miller Sands Island is presently located. (Taken from chart prepared by Admiral George Vancouver, as presented in Lockett, 1963.)

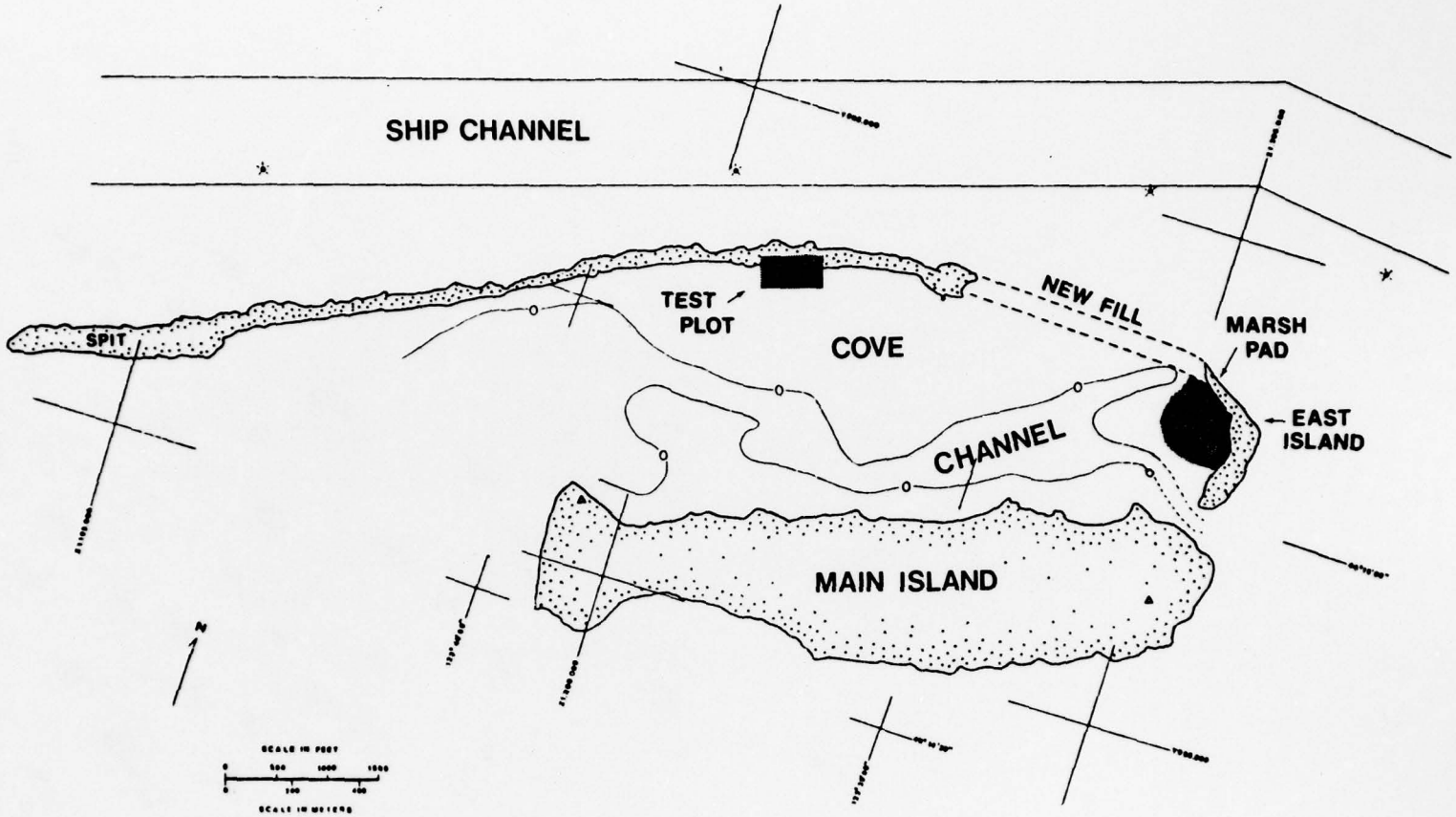


Figure 2. Miller Sands complex, 1975. Island parts have been labelled for purposes of this report only. [Based on an aerial photo taken 6 September 1974 (COE Condition Survey CL-21-142).]

extreme low tides) and have scattered silt deposits. A break between the east and the main islands allows water flow through the cove, as exhibited by a channel running along the south edge of the cove. Subaqueous and emergent vegetation lines the interior shores of the cove, as well as shallow regions upstream of the east and main islands.

Purpose and Scope

The Miller Sands study was divided into three areas concerning the use of dredged material to create wetland habitat: aquatic life, studied by the National Marine Fisheries Service; terrestrial ecology, studied by Woodward-Clyde Associates; and chemical-physical conditions, studied by the School of Oceanography, Oregon State University (OSU), and reported herein. OSU was also charged with supplying historical data and an annotated bibliography concerning physical, chemical, and biological conditions of the aquatic environment near Miller Sands. Similar studies are being conducted at other sites in the U.S., as part of the Dredged Material Research Program, which is investigating the beneficial uses of dredged material. The need for such work is evident in the fact that dredging is an ongoing modifying feature of ship channel maintenance and harbor improvement.

Physical and chemical conditions at Miller Sands are critical factors controlling plant growth and ecosystem development. Therefore, Phase I of the Miller Sands Habitat Development Project was to inventory and assess selected physical and chemical characteristics of water, sediment, and soil on and around the island, with the following objectives:

a) To prepare a baseline against which to measure changes in the study area that may occur as a result of manipulation and placement of dredged material;

b) To identify physical or chemical factors that might influence the success or failure of habitat development efforts;

c) To determine existing substrate fertility.

These objectives were somewhat compromised by the late date at which the project was initiated. Sampling did not begin until 17 June 1975, approximately 1 month prior to dredging and placement activities. Indeed, the sampling period for this work (June 1975 to January 1976) overlapped with Phase II, the operational phase originally intended to have been spent monitoring changes in water quality occurring during dredging activities. (The results of this latter work are also reported here.)

The study consisted of two parts: (1) a survey of literature and other data sources relevant to the project site, and (2) a field investigation. Data collected in Part I are referred to in this report as "historical data," no matter how recently they were collected. These data cover a range of 10 to 15 yr and provide a valuable historical perspective for this short-term study. An annotated bibliography of selected sources is included as Addendum C.

The field work concentrated on obtaining information not already available. Sampling dates, and methods and procedures used in collecting and analyzing data are given in Addendum A. Data collected are presented in Addendum B. Where desired measurements could not be made and where historical data were available, inferences were drawn from the historical data.

This report is primarily descriptive in nature. Some data interpretation and evaluation are included, but this part of the report should not be considered exhaustive. Additional statistical treatment of some of the data is desirable. These qualifications do not affect the conclusions and recommendations that are made with respect to the Habitat Development Project.

PART II: HYDROGRAPHY

Geomorphology

Miller Sands lies at CRM 24 in a geomorphic transition zone of the lower Columbia River. Above CRM 31 the river is bounded by steep valley walls 2 to 4 miles apart and occupies a main channel 0.4 to 1 mile wide [at mean lower low water (MLLW) during low upland flow]. Below CRM 31 the river broadens, attaining a maximum width of about 9 miles in the vicinity of Harrington Point, Washington (CRM 23). Extensive areas of the estuary between CRM 23 and 31 are occupied by semipermanent, diurnally inundated, vegetated islands (Figure 1). Equally large areas of non-vegetated islands appear in lower regions of the estuary at low tides (Hubbell and Glenn, 1973).

The interaction of tides, river discharge, and geomorphology produces a highly variable pattern of sediment distribution in this region.

Tides

Tides in the Columbia River are of the mixed type characteristic of the Pacific Coast and consist of two high waters and two low waters during each lunar day, all of differing heights. At the river mouth the mean tidal range is 5.5 feet and the diurnal range is 7.5 ft. Around Miller Sands Island the mean tidal range is 6.1 ft and the

diurnal range is 7.7 ft. A more detailed description of tides in the estuary is given in OSU, Ocean Engineering Program (1975).

River Discharge

The mean annual discharge of the Columbia River is 255,000 cfs, approximately twice the amount of freshwater discharge from all other rivers in California, Oregon and Washington combined. The flow is distinctly seasonal with peak discharge occurring during late spring and early summer in response to inland snow melt. Minimum flow usually occurs in September or October. However, flow conditions vary considerably from the mean. High discharge periods, equalling spring runoff, can occur in the winter as a result of large amounts of rainfall runoff from the Coast Range. Although these periods are highly irregular and are always of shorter duration than the spring freshet, they can greatly influence floodplain morphology and sedimentation patterns, as well as substrate stability.

River discharge during the study period is tabulated in Addendum B, Table B1. Exceptionally high discharge (53 percent above the 15 yr average) occurred during the 1974 spring freshet when the adjusted mean monthly flow rate exceeded 900,000 cfs (U.S. Geological Survey, 1965-1976). This period of high flow was followed by an exceptionally low October adjusted mean flow of 87,000 cfs, 33 percent below the 15 yr average. The mean monthly flow rates for 1975 were near the 15 yr average levels. Of greatest importance to the Miller Sands project are the conditions involving maximum intrusion of salt into the upper

estuary. The exact limit of such intrusion is not well defined. Several workers consider Harrington Point, at CRM 23, to be the maximum limit of salt intrusion (e.g. Neal, 1972). Simmons (1971), however, indicates that intrusion could reach as far as CRM 32 during low flows on the order of 100,000 cfs.

Stream Velocity

The most detailed study of river discharge, flow distribution and velocity in the vicinity of the study site is contained in Lutz, Hubbell and Stevens, Jr. (1975). Those authors concluded that flow reversal occurs between CRM 14 and CRM 53 during at least one of the daily flood periods whenever daily mean discharge is less than 185,000 cfs. At discharges greater than 225,000 cfs, flow reversal occurs rarely. Clark and Snyder (1969) documented the occurrence of flow reversals as far upstream as Prescott, Oregon (CRM 73). Observations made at Astoria indicate that near-surface ebb-tide velocities range up to 8 fps and flood velocities range up to 6 fps.

Near-surface velocities found near the channel northeast of the new fill on 8 September 1975 are shown in Figure 3. These measurements were made during a moderately large tidal range (9.5 ft) when the discharge was low (approximately 160,000 cfs).

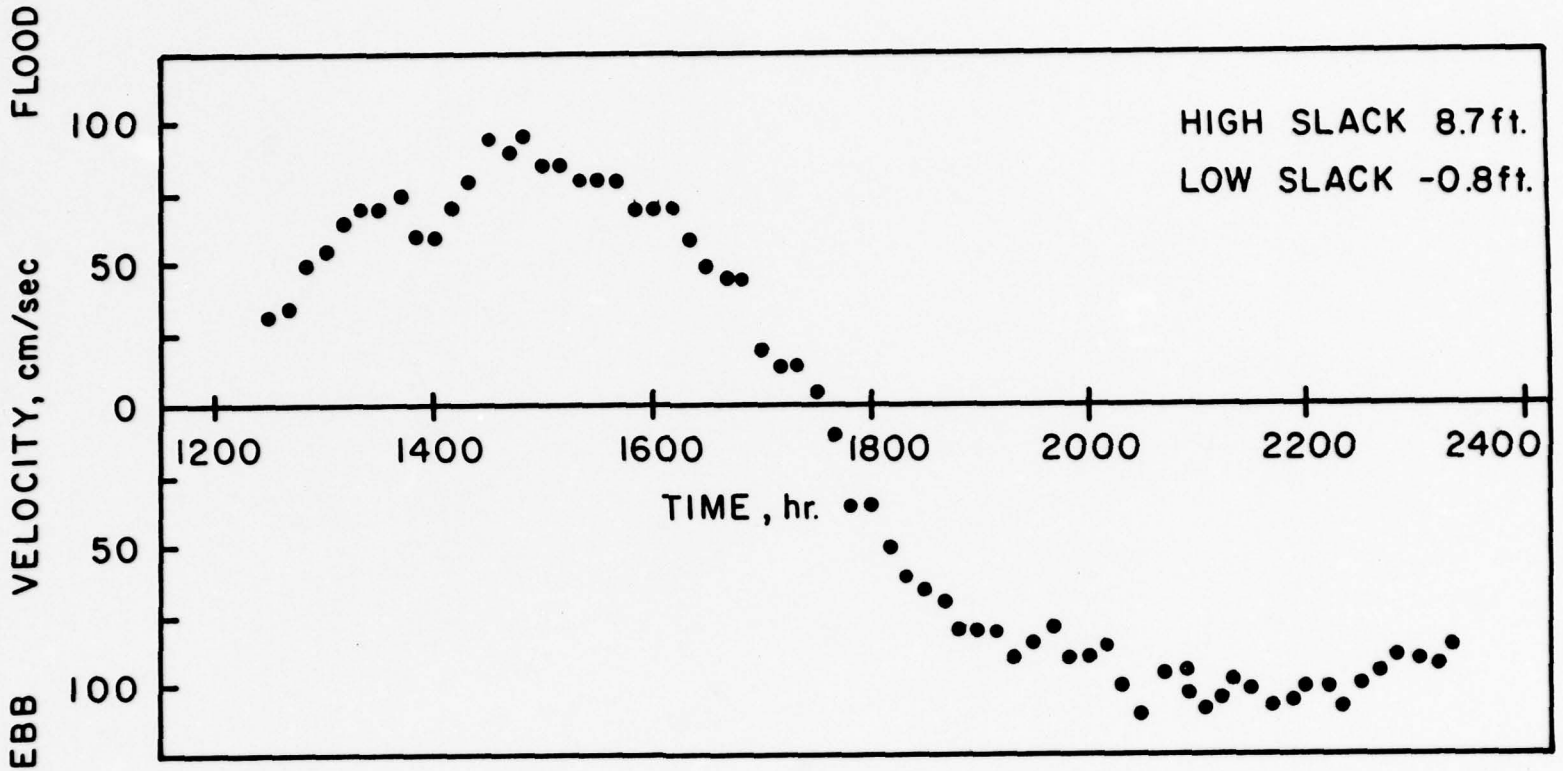


Figure 3. Near-surface velocities measured 8 September 1975

Estuarine Circulation

The general pattern of lateral circulation in the lower estuary is apparently controlled by discharge. According to measurements taken at CRM 14, when daily mean discharge is less than 165,000 cfs, a net clockwise circulation occurs; when discharge exceeds 190,000 cfs, the net circulation is counterclockwise. Thus, a net upstream flow occurs in the north channel during periods of low flow (Lutz, Hubbell and Stevens, Jr., 1973).

Current circulation patterns in the region of Miller Sands are not well known, but are probably complex due to the complexity of the deeper channel shapes (Figure 4).

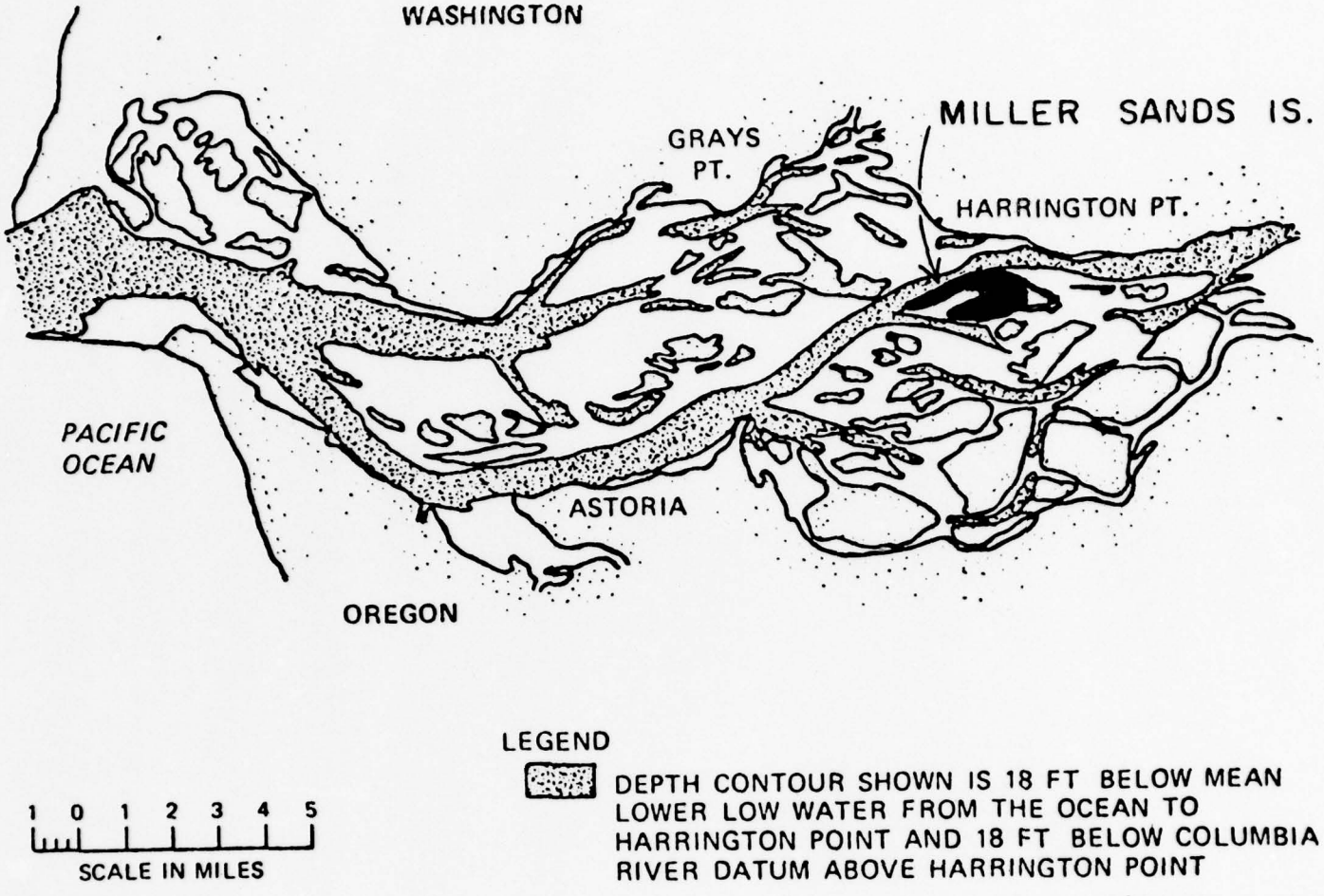


Figure 4. Eighteen-foot channel depth, Columbia River estuary (from Neal, 1972)

PART III: CLIMATOLOGY

Climatological data cited herein are given for the meteorological station at Astoria, Oregon, the nearest to the study site.

Precipitation

In general, the greatest monthly rainfall in the Astoria area occurs in December and January, which average about 12 in each. However, even in late summer months over an inch of precipitation per month can be expected. The average net annual water surplus is 57.4 in. (Summarized from OSU, Ocean Engineering, 1975).

Temperature

The average annual air temperature (1956-65) for the Astoria weather station is 50.9°F. The highest average monthly temperature, 60.5°F occurs in August and the lowest in January, 41.8°F. (From OSU, Ocean Engineering, 1975). Soil temperatures for the Astoria area could not be obtained.

Winds

Wind data for the Astoria airport show that southeast winter winds predominate and summer winds are from the northwest (OSU, Ocean Engineering, 1975). However, records from an offshore weather station near the

Columbia River mouth show that the winter winds there are usually from the southwest (Barnes, Duxbury and Morse, 1972:48). Apparently a local channeling in the vicinity of the airport changes the regional winter surface winds from southwest to southeast.

This channeling effect does not appear to control very strong winds with the result that, when these occur, offshore wind patterns may prevail. The observation by local boat operators that strong southwesterly winds are a regular feature of the estuary supports this speculation. As an indication of possible strong-wind effects on Miller Sands, the offshore average monthly wind direction and speed vectors from Barnes et al. (1972:48) were superimposed on the Miller Sands site map (Figure 5). Because of the large open-water expanse southwest of the study site, considerable buildup of wind waves can occur in a relatively short time.

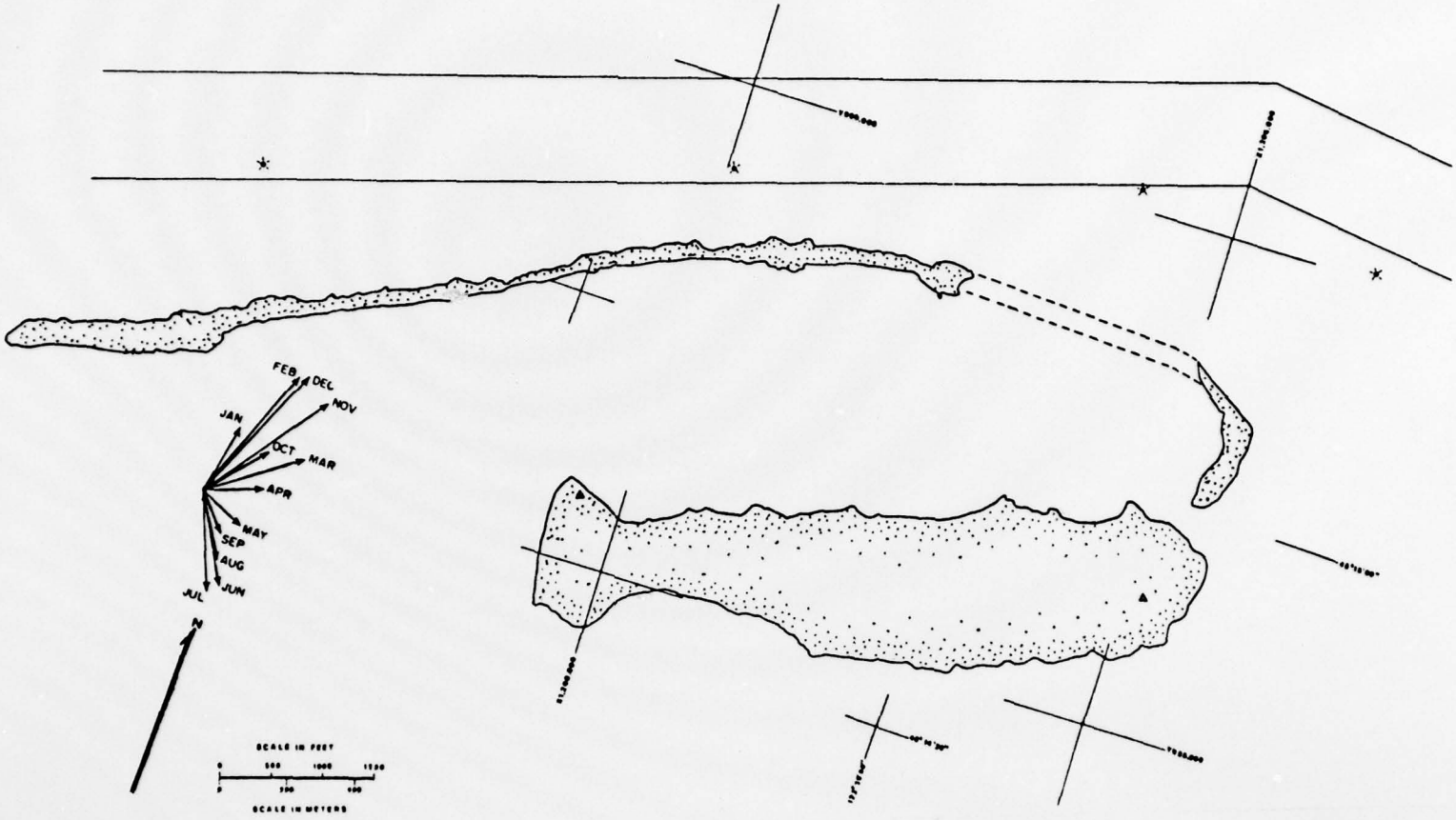


Figure 5. Offshore wind direction and speed vectors superimposed on Miller Sands site map (Vectors from Barnes, Duxbury and Morse, 1972)

PART IV: WATER QUALITY

Objectives

The primary objectives of the water-quality study were: (1) to compare water parameters from inside Miller Sands cove with those from the main channel; and (2) to compare main channel data with historical records providing measurements from nearby stations. In the analyses of samples described below dissolved oxygen, pH, suspended sediment, trace metals, and nutrients were determined in subsamples taken from the same sample bottles.

Predredging sampling was conduted on 17 and 30 June 1975. The effect of construction activities on water-quality parameters was studied during operations on 16 July 1975. In addition to these sampling trips, three visits were made by the OSU research vessel YAQUINA for *in situ* water quality measurements. These trips were made in June, August and October in conjunction with an offshore chemical baseline study. Sampling station locations are shown in Addendum B.

The following discussion presents an overview of the results and, where possible, relates the measurements taken during this study to historical records. Analytical procedures used in this study are presented in Addendum A. Values of all measurements presently available from this study are included in Addendum B.

Results

Salinity and Temperature

Salinity and temperature profiles taken during this study all showed essentially zero salinity and uniform temperature over the water column. Stratification would be expected further downstream where cold, saline water intrudes along the bottom in a typical salt wedge. Barring an extremely low discharge (less than 100,000 cfs) it does not appear likely that salt intrusion occurs in the Miller Sands area.

Haertel (1970) indicates that river water entering the estuary ranges between 4 and 22.5°C. U.S. Environmental Protection Agency (EPA) data for Bradwood, Oregon, (CRM 39) show a mean of 17.7°C, a maximum of 22.0°C, and a minimum of 5°C for 1971. Daily temperature records at Altoona, Oregon, (CRM 27) for 1972-73 show a maximum of 22.0°C in August and a minimum of 1.5°C in January, with a daily range of approximately 1°C (EPA data in U.S. Geological Survey, 1972b:34). Temperature measurements made during the present study fall within the expected range for the time of year sampled. Temperatures inside the cove did not differ significantly from those measured in the main channel. The slight differences observed, approximately 1°C, probably occurred because stations were occupied at different times during the day and stages of tide.

Dissolved Oxygen and pH

In general, oxygen levels in the lower Columbia River tend to be slightly supersaturated during spring and summer and slightly undersaturated during fall and winter, presumably in response to photosynthesis

(and perhaps turbulence from dam overflow) in the former case and biological oxidation in the latter. These conditions also cause the pH to rise and fall, although the river tends to the basic side, apparently due to the alkaline nature of the drainage basin. These oxygen and pH patterns are complicated somewhat by the winter freshets which have low pH and high oxygen content.

In the present study dissolved oxygen ranged from 8 to 11 mg/ℓ and was consistently at or slightly below 100 percent saturation (with respect to distilled water and 760 mm mercury). These values are in agreement with previous values taken at similar temperatures at the same time of year (Park, Osterberg and Forster, 1972).

The pH ranged from 7.7 to 8.5 with most of the results grouped around 8.0. High photosynthetic activity undoubtedly contributed to these high values. Park *et al.* (1972) observed similar pH values near Harrington Point. Values upstream at The Dalles routinely average about 8 the year round and are sometimes higher (U.S. Geological Survey, 1965-76).

No differences between channel and cove measurements were evident for either of these parameters.

Suspended Sediment

The suspended sediment concentration of the lower Columbia River varies with discharge. Typical annual values are 50 mg/ℓ during periods of maximum discharge and 10 mg/ℓ during low flow. The overall annual average for the Columbia River is taken as 30 mg/ℓ. In the estuary the picture is complicated by tidal flow which resuspends deposited material and temporarily may produce levels of 500 to 600 mg/ℓ (see Hubbell and Glenn, 1973). These factors must be recognized when

considering suspended sediment concentrations for a given time and location in the estuary. Periodic resuspension of deposited material is apparently a regular feature of the estuary. Whether or not resuspension influences water quality in the vicinity of Miller Sands is not definitely known.

Hubbell and Glenn (1973) observed that the turbidity maximum for low discharge conditions occurred near CRM 20. It is generally considered that the turbidity maximum occurs near the limit of salt intrusion. As pointed out elsewhere in this report, it seems unlikely that this zone would occur as far upstream as Miller Sands. However, the tidal forces that act to resuspend bottom sediment may function there.

In the present study, suspended sediment in the main channel averaged 21 and 22 mg/ℓ for 17 and 30 June, respectively. While these levels are rather low for June, they are appropriate for the river flow, which was approximately 250,000 cfs.

Suspended sediment was significantly higher, although more variable in the cove than in the main channel, presumably because of wave action in the cove. Values in the cove averaged 37 mg/ℓ on 30 June and 23 mg/ℓ on 17 June.

In addition to the regular water-quality stations occupied during the baseline study, a special suspended sediment survey was conducted in the vicinity of the dredging operation on 16 July. Locations of sampling positions in relation to the outfall from the discharge pipe are shown in Addendum Figure B5. Maximum values of 40 mg/ℓ were obtained where berm runoff mixed with water at the shoreline. By comparison, 18 mg/ℓ was measured at the control site. A turbidity plume could be

seen, but this extended no more than 1/2 mile from the outwash point, and suspended sediment levels at the plume's apparent perimeter were only 5 to 6 mg/ℓ above those at the control site. Inside the cove, levels were noticeably higher than at the control station. However, since previous cove measurements were similarly high, it cannot be concluded that this arose from dredging activities.

Trace Metals

Water samples for trace metal analysis were collected on 30 June and during dredging operations (16 July 1975).

In general, total trace metal concentrations varied with suspended sediment concentrations, as would be expected. Comparison on a per gram basis of metal concentrations in suspended sediments with fine-textured bottom sediment (median diameter: 20 μm) in the cove showed that certain metals in the suspended sediments (manganese, copper and lead) were enriched by a factor of 3-4 over those in the bottom sediment. Although no size distribution determinations were made on the suspended material sampled in this study, other data (Hubbell and Glenn, 1973; Conomos and Gross, 1972) suggest that such values would not vary significantly from those of the fine-textured bottom sample mentioned above. Thus, it seems unlikely that the apparent enrichment of these metals in suspended sediment can be attributed solely to surface area dependence, although this possibility remains. A more likely explanation is that the composition of suspended sediment differs from that of bottom sediments, as suggested by Evans and Cutshall (1973).

Metals determined in the present study were lead, iron, manganese, zinc, copper, iron, nickel, cadmium, chromium, cobalt and mercury. The

levels found generally agree with earlier data (see 1971 EPA data for Bradwood at CRM 39 and Clatskanie at CRM 54 in U.S. Geological Survey, 1972b); however, the total lead concentration for the present work was about one-tenth of that shown. Other trace elements not measured in this study, but determined in the U.S. Geological Survey study (U.S. Geological Survey, 1972b), were arsenic and selenium; concentrations for these elements were 6 and 100 mg/ℓ (total), respectively. Mercury levels were below the limit of detection, which was about 2.5 µg/ℓ. More sensitive methods used in other studies indicate that total mercury levels in lower Columbia River water are on the order of 0.02 µg/ℓ (Naidu and Cutshall, 1974). Results of other trace metal surveys made in the lower Columbia River are available in U.S. Geological Survey, 1972b, and Kopp and Kroner, *ca*. 1969. In addition to those elements already mentioned, the Kopp and Kroner survey includes boron, strontium, molybdenum and aluminum.* All trace element concentrations for the present work and those reviewed from previous work are far below the maximum concentrations of trace elements recommended for irrigation waters.

Pesticides/Chlorinated Hydrocarbons

No measurements were made in the present study of waterborn chlorinated hydrocarbons or pesticides. Previous EPA surveys of the lower Columbia River indicated that levels of BHC, DDD, DDE, DDT, Dieldrin, Endrin, HCHLR-EP, HCLR were all below 0.003 µg/ℓ (U.S. Geological Survey, 1972b).

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* It should be noted that their results were based on filtered water analyses.

strong seasonal cycles occurred. Haertel (1970) reports extremes of 0 to >30 µM for nitrate, 60 to 240 µM for silicate, and 0.01 to 1.0 µM for phosphate. These cycles are apparently due to summer conditions of decreased flows (especially the Willamette River) and increased on-river primary production. As a result of these fluctuations, the estuary changes from a nitrate-limited system (nitrate:phosphate <15:1 in summer) to a phosphate-limited system (nitrate:phosphate >15:1 in winter).

Water nutrient data collected during the 1975 Miller Sands study are presented in Addendum B. Sampling stations are shown in Figures B2 through B4.

In general, data collected from stored samples exhibit high variability among replications and this has precluded statistical testing for differences among stations located at test and control sites. On the other hand, data for 17 June 1975 provided by immediate on-site analyses aboard the R/V YAQUINA show excellent repeatability.

In order to compare 1975 data with historical data, average nitrate and phosphate concentrations for samples taken at channel stations near Miller Sands are presented in Figure 6 together with the 1966-68 data for Harrington Point (Haertel, 1970). The 1975 data correspond reasonably well with the earlier data.

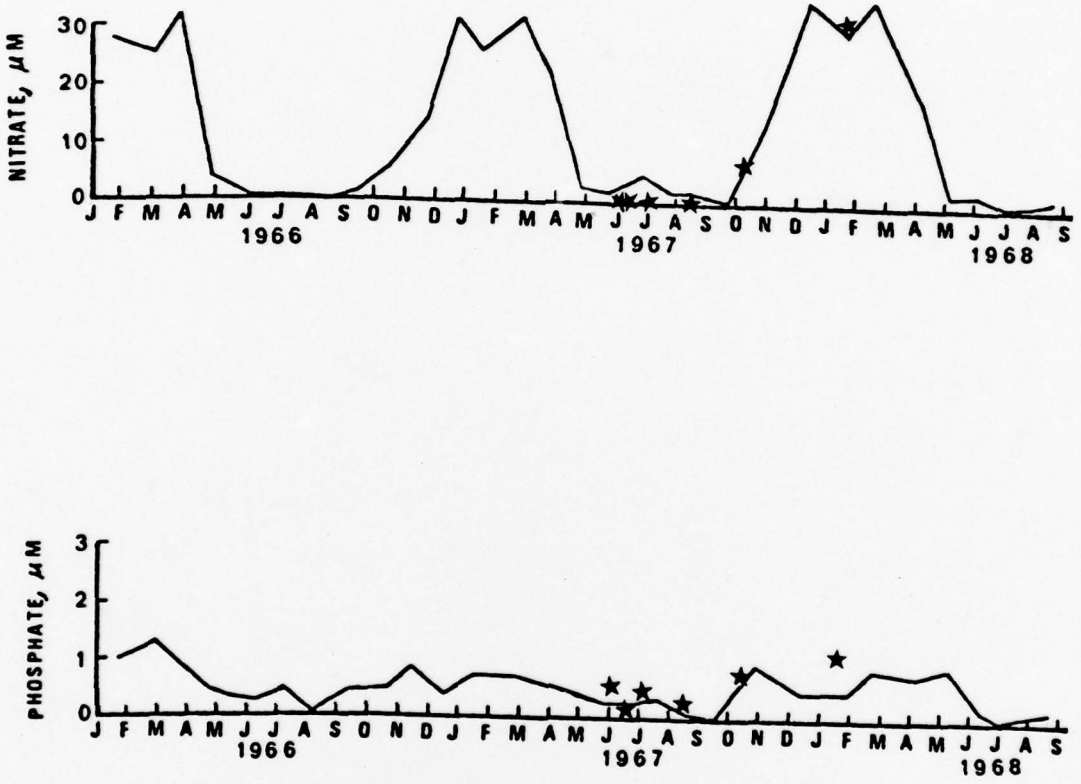


Figure 6. Comparison of 1975 nitrate and phosphate concentrations at Miller Sands (shown as stars) with seasonal data from Figure 4 (Haertel, 1970) which were taken downstream from Harrington Point. Miller Sands data points were plotted arbitrarily with the 1967 data.

Phytoplankton

Phytoplankton counts were not made in the present study; however, previous work adequately defines the expected densities and species composition. See Haertel, Osterberg, Curl and Park (1969) for tabulation of species and densities.

Haertel (1970) characterized the freshwater phytoplankton of the estuary downstream from Harrington Point as common to eutrophic lakes. The species composition of this reach closely resembled that at Clatskanie (CRM 53) and Haertel concluded that the estuary freshwater phytoplankton is a downstream extension of the river plankton.

Nutrients

The major sources of nutrients to the lower Columbia River are the Snake and Willamette Rivers. The Snake River contributes 35 percent of the nutrients and 18 percent of the water; while the Willamette River contributes 29 percent of the nitrates, 22 percent of the silicates, 21 percent of the phosphates and 13 percent of the water (Park, Catalfomo, Webster and Reid, 1970). Nitrate concentrations in the Willamette River generally exceed those in the Columbia River, while concentrations in the estuary vary between the values in the two source rivers.* The Willamette has less influence on estuary nutrients during periods of low summer flow (Haertel, 1970).

According to Park, Osterberg, and Forster (1972), in 1966 and 1967 nitrate concentrations averaged 12 micromoles (μM), silicate concentrations, 160 μM, and phosphate concentrations, 0.5 μM, in the estuary. However,

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* Nutrient concentrations in the estuary have been adjusted by the authors cited to correspond to conditions of 0 percent salinity.

PART V: SEDIMENT

Primary objectives of the sediment study were: (1) to define the existing physical and chemical characteristics of sediment before further dredged material placement occurred with its resulting modification of hydrologic characteristics, and (2) to characterize the dredged material with regard to its potential fertility for marsh grass propagation. To accomplish these objectives, sediment cores were taken in the dredging zone of the ship channel (two sites), in the cove (four sites), and near the control station (one site) for physical and chemical analysis. A few radionuclide analyses were also made on these samples in an attempt to age-date strata using residual artificial radionuclides from the Hanford reactor. In addition, surface sediment was collected at 34 sites inside the protected cove for a textural survey. Details of sampling and analytical procedures are included in Addendum A.

Physical Factors

Sediment Texture

Location of stations occupied in the texture survey are shown in Addendum Figure B6. All of the texture survey results are derived from a dry-sieve method and, therefore, could underestimate the silt-plus-clay fraction (<63 μm) where this fraction is appreciably large. In addition, only the top 2 to 3 cm were sampled; this undoubtedly biased the samples toward the finer texture categories, since a thin layer of

fine sediment commonly overlaid coarse sediment. Despite these considerations, the data collected provide useful estimates of fine sediment distribution and abundance (Addendum Figure B7).

The texture survey revealed regions of fine sediment accumulation in both the deeper water of the cove and on exposed flats. The distribution does not appear to be related to bathymetry. Especially surprising was the accumulation of a rather thick deposit (10 cm) of mud in the far northeast corner of the cove. This deposit seemed to be confined to the finger of deep water extending into the corner. Older charts of the area suggest that this finger is a remnant of a former shallow channel. Apparently the depression has now become a protected area where fine sediment can accumulate. It is not known whether the fine sediment accumulation in the cove is seasonal or if it has been greatly influenced by the berm buildup of the previous summer (1974).

Beyond these observations, no consistent pattern of sediment distribution was evident.

Additional textural information was obtained through the analysis of cores taken at seven core stations. For these samples, a wet sieve-pipette procedure was used. A few of the finer textured samples were subjected to both a routine dispersal analysis, which involved a mechanical and chemical dispersing treatment prior to size analysis, and to a native water treatment or non-dispersal analysis. The latter technique involved gentle agitation of the sample in water collected near Miller Sands, followed by size analysis using sieves and pipettes (Guy, 1969). The native water treatment is designed to provide information on the degree of flocculation or, conversely, the dispersability

of the sediment. Inman size statistics were used to calculate the median phi diameter (Md_ϕ), and phi deviation measure (σ_ϕ) or sorting index.

The channel samples were coarse textured and moderately well sorted. The values obtained in this study for median particle size are very near the channel sediment values of mean size for the fluvial or upper portion of the estuary reported in Hubbell and Glenn (1973). These authors reported an average mean phi diameter of 1.51 and an average sorting index of 0.69. By comparison, the average of seven samples from the channel core sections for this study yielded a median phi diameter of 1.59 and a sorting index of 0.62. It is also interesting to compare these values with the size statistics for the island soil samples, which were 1.84 median phi diameter and 0.81 sorting index (N=17). The similarities suggest a similar hydraulic regime for the channel and soil sediments.

Inside the cove the median phi diameters ranged from 1.78 to 5.65 and the sorting index from 0.74 to 2.77. These wide ranges of values reflect the highly variable accumulation of fine surface sediments, as mentioned previously.

Table 1 compares size statistics for the native water analyses with dispersed results and indicates that there is only a small difference in median phi diameter between the dispersed and nondispersed treatments. This suggests that the fine sediment deposited in the inner cove is present in a relatively nonflocculated form.

Table 1

Comparison of Sediment Size Parameters for Dispersed and Nondispersed Treatments

Station	Section cm	Native or Nondispersed Md_ϕ	Native or Nondispersed σ_ϕ	Dispersed* Md_ϕ	Dispersed* σ_ϕ
SC 3	0-5	3.30	1.42	3.30	1.66
SC 5	0-5	3.75	1.81	A 3.85	2.01
				B 3.86	2.01
				C 3.85	1.92
SC 6	0-5	5.00	2.38	5.65	2.77

* A, B, and C indicate replicate treatments.

Mineralogy

A number of investigators have examined the mineralogy of Columbia River sediment from the lower river, the estuary, and the nearby continental shelf (Whetten, Kelley and Hanson, 1969; White, 1970; Knebel, Kelley and Whetten, 1968; and Glenn, 1973). Some of these studies have focused on sand mineralogy, some on heavy mineral content, and others on clay mineralogy. The most complete work and the one most relevant to the Miller Sands Project site was done by Glenn (1973).

The station studied by Glenn (1973) that was closest to Miller Sands was near St. Helens, Oregon, at CRM 86. Since no major tributaries enter the Columbia River between St. Helens and Miller Sands, results for this station should closely represent the sediment mineralogy in the vicinity of Miller Sands. The mineralogy of the St. Helens station is summarized in Figure 7, where mineral group content is shown

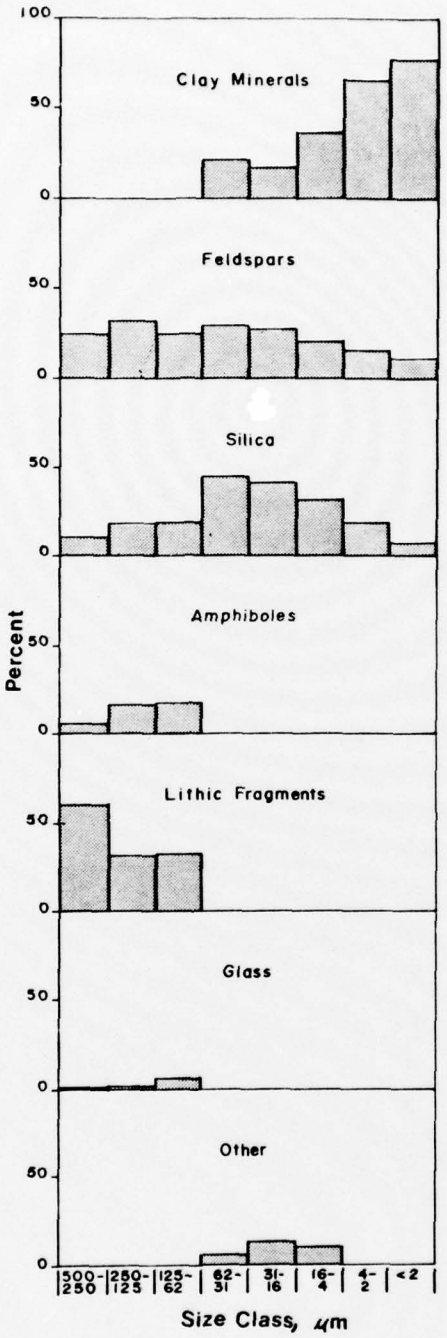


Figure 7. Distribution of major mineral groups among size classes of lower Columbia River sediment at St. Helens station. Percentages in each size class sum to 100%. (Summarized from Glenn, 1973.)

as a function of particle-size class. The dominant sand size classes for coarse material at Miller Sands correspond to 500-250 μm and 250-125 μm. Rock fragments form the single largest category in these size classes, followed by feldspars and silica. The rock fragments are primarily volcanic in origin and have an intermediate to basic composition. The feldspars are dominated by plagioclase and consist of about one-fourth potash feldspars, of which orthoclase is the most important. In the silt and clay size classes, feldspars, silica, and clay minerals account for nearly all of the mineral content. The silica and feldspar content decreases with decreasing size class, while the clay mineral group content increases. The clay mineral group is dominated by montmorillonite followed by illite and chlorite with minor amounts of kaolinite. Glenn (1973) includes a detailed discussion of variations in clay mineralogy in Columbia River sediments.

Erosion

The proximity of the island complex to the main channel of the river and its exposed position at the head end of the estuary suggest that considerable sediment erosion may occur along the perimeter of the island complex.

Wind Waves. Evidence of storm-wave erosion is apparent on the far west end of the older island. Several miles of fetch exist across the estuary and this, as well as frequent near-hurricane force winter winds from the southwest, can produce relatively large waves. The impact of these storm-driven waves on the inner portion of the island system is greatly diminished by the shallow water in the cove (approximately 1.5 m at high tide). However, evidence of storm-wave activity

was noted at the marsh grass test plot, which is located in the cove about midway along the spit. At this position, sand waves were observed moving through the planted rows of test grass. Since the waves come from the southwest, sand transport in the upstream direction is probable. A detailed inspection of the inner cove at low tide to check for position and size of sand waves, ripple marks, etc., would allow stronger inferences to be made about the character of wave dynamics there.

The observations of higher suspended sediment concentrations inside the cove than outside are attributed to resuspension of bottom sediment by wind induced waves. In theory, waves generated by westerly winds would increase in height and energy toward the eastern end of the cove. For a 5-ft constant water depth at high tide and strong wind gusts (greater than 60 mph), wave heights of 2 ft would be attained within the cove. The wave period for this wind velocity and depth is about 3-4 sec. Calculations based on simple Airy wave theory for shallow water predict bottom orbital velocities of greater than 50 cm/sec, more than sufficient to cause movement of sand particles of the average size (0.3 mm) of the dredged material (Komar and Miller, 1975). Such bottom velocities could easily resuspend the uncompacted silt and clay layers in the cove and allow the removal of fine silt and clay by tidal flushing.

Postma (1967) indicates that velocities of 10 to 15 cm/sec are adequate to transport suspended particles in the fine-silt to clay size range, but velocities greater than 100 cm/sec are required for erosion or resuspension. Water content of the fine textured material in the core

sampled in the far northeast end of the cove was approximately 50 percent for the top 5-cm section. It seems unlikely that such highly consolidated material would be resuspended. Presumably only a shallow surface layer (<1 cm) of sediment is subject to resuspension, however, and samples used were 5 cm in thickness.

Tidal currents might also be suspected to contribute to sediment motions within the cove. Tidal current velocities in the main channel near the northeast corner of Miller Sands approach 100 cm/sec. In studies of European estuaries, Postma (1967) found that channel velocities adjacent to tidal flats were only about one-fifth of those in the channel proper. If this relationship holds for the Miller Sands area, velocities of about 20 cm/sec probably occur on the receding tide. This is adequate to retain the fine silt-clay size material in suspension but not to induce erosion. These considerations are compatible with the water quality data for the cove, which show sporadic but significantly higher suspended sediment concentrations for water samples collected from inside the cove than for those taken in the ship channel. This relationship held true even during the relatively quiet summer period. Thus, it appears that wind waves may be significant in scour and resuspension in the protected inner cove, as well as along the more exposed outer perimeter of the island complex. Tidal flows may be important in sediment transport but do not appear likely to cause erosion.

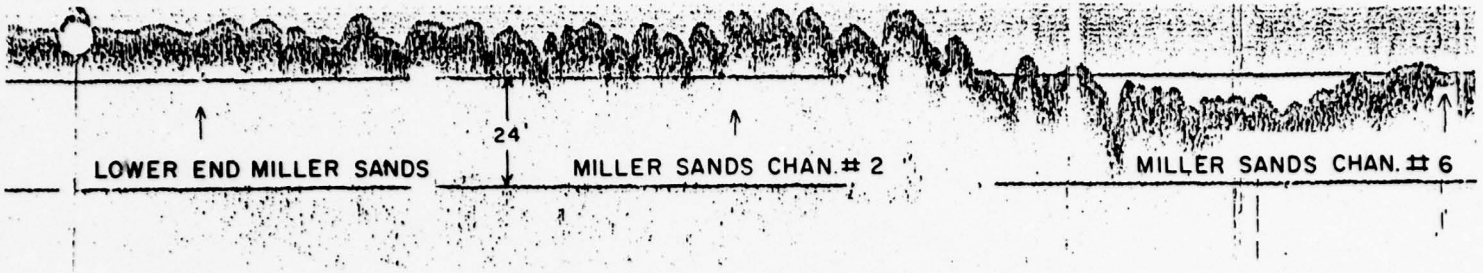
These shallow water, fine sediment accumulation/suspension phenomena warrant further investigation.

Stream Erosion. The transport power of the Columbia River has been well documented. The occurrence of migrating sand waves along the main channel, such as were found near Miller Sands (Figure 8), are a dominant feature all along the lower river (Whetten, 1969). Because the outer northeast corner of the island appeared to be especially vulnerable to stream erosion, sediment stakes were placed at several locations in that critical zone.

The first stakes were placed on 2 July and consisted of 61 cm lengths of reinforcement bar. Each stake was inserted into the sand leaving a 15 cm section exposed above the bed surface. Stakes were placed at near-high water line, at mid-beach face and at near-low water line. On 16 July, just after the new fill was placed, additional stakes were added at several sites including the new fill.

No significant changes occurred in the exposure of the stakes located at the head end of the island. However, most of the stakes placed in the vicinity of the new fill zone were gone within three weeks. Probable causes are vandalism, accidental removal by gill netters, or erosion. A single set remained, showing that near the upper or high water line an additional 38 cm of stake was exposed, at mid-beach face 30 cm, and near low water approximately 8 cm. Thus, over 30 cm of the newly placed sand fill had apparently eroded away in a three week period. While the sediment stake method of monitoring erosion in this highly active zone leaves much to be desired, the results made periodic observation of the new fill desirable.

A new set of stakes was placed along the new fill on 8 August 1975 and the site was visited again on 8 September. The stakes had all



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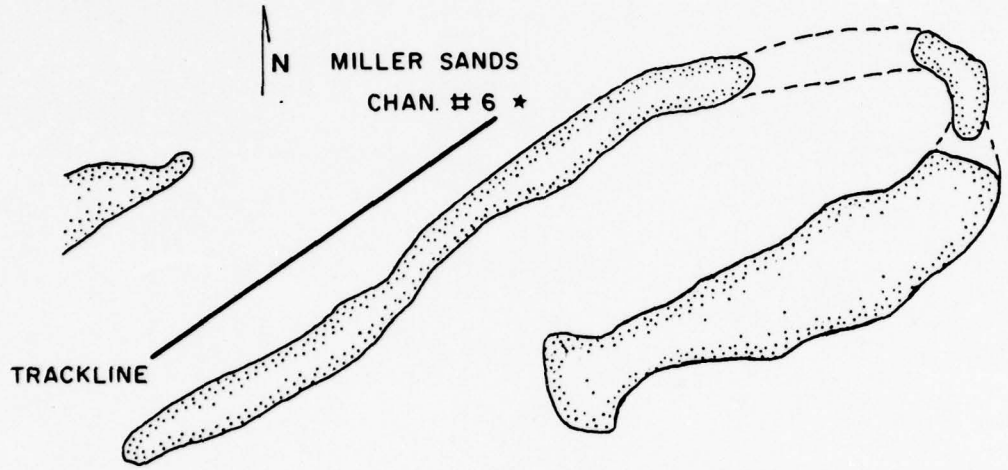


Figure 8. Sand wave patterns along the ship main channel near Miller Sands, 21 June 1975

disappeared. The appearance of the shoreward side of the new fill left little doubt that considerable erosion had occurred during the intervening period of approximately one month (Figure 9). All along the new fill a sharp cliff topped the berm. The cliff height indicated that nearly 1 m had been removed near the top of the fill. Further down the face, a number of mud clumps with intact root mats had been exposed. These were part of the outer marsh that had been buried in the process of completing the fill.

Current velocities were measured in the vicinity of the new fill on 8 September 1975. Maximum velocity at the surface was about 100 cm/sec and decreased to a maximum of approximately 30 to 40 cm/sec just off the bottom (20 feet MLLW). Upstream flood velocities equalled ebb velocities in magnitude. It appears unlikely that these current velocities could have accounted for the rather severe erosion that occurred. A more plausible explanation presented itself when a large ship passed by the island producing a large wake that hit the beach with nearly explosive force. All along the beach where the ship waves were striking, the turbulent water was grey with suspended sand. It appears that such a mechanism is the most likely cause of sand erosion from the new fill material. Wakes from passing ships must occur frequently since the Columbia River serves as a major waterway for worldwide shipping.

Sediment stake information in the zone of new fill suggests that the sand being removed from the portion of the fill lying between high and low tide is transported beyond the low water line, since even the low water line stake indicated some evidence of erosion rather than accretion.



Figure 9. Eroded shoreward side of new fill at Miller Sands, 8 September 1975

The subsequent disposition of the tremendous amount of sand eroded is not known. However, it appears likely that it was returned to deeper water before settling again, perhaps into the channel from which it was dredged. In addition to ship-wave erosion, it is conceivable that unusually high river stages in the Columbia River could contribute significantly to erosion at the site. Attempts to use marsh grasses to stabilize dredged material along the channel may require protection from these types of erosion during the critical stages of initial root development.

Sediment Deposition

Cores taken in the inner cove revealed the presence of fine-grained sediment to a depth of 10 cm, a surprising result. Based on an accretion rate of 2 to 4 cm/yr found in a protected Youngs Bay mud flat (Johnson and Cutshall, 1975), the 10-cm layer might represent 5 yr of accumulation. The fine sediment deposition, then, could have begun well before the construction of the 1974 berm. These and similar observations prompted the study of selected core sections for radionuclide content in an attempt to estimate the recent age and (hopefully) the sediment accumulation rate for those cores containing fine sediment. The techniques for using Hanford radionuclides to estimate sedimentation rates and/or relative ages of recent sediment strata are described by Hubbell and Glenn (1973). In more recent work (Johnson and Cutshall, 1975), longer lived radioisotopes such as cobalt-60 (Co-60) and europium-152 (Eu-152) have been used.

In the present study two cores were selected for radioanalysis: SC 5, collected about mid-cove and found to contain a considerable amount

of silt and clay sized material mixed with sand; and SC 6, collected in the tidal channel in the far northeast corner of the cove and containing very fine textured material underlain by coarse sand. Radionuclide concentration data for these cores are presented in Addendum B. In both cores Hanford radionuclides were found in the upper 15 cm but were undetectable below this level. In the SC 6 core, this could be explained by the lack of silt and clay in the lower layers, since fine-grained sediment fractions tend to accumulate the greatest radioactivity levels due to their greater surface area. This explanation does not hold for the SC 5 core, however, since a significant amount of silt-clay sized material was present over the entire length of the core. Nonetheless, Hanford radioactivity was present only in the top 10 cm layer.

Estimations of sediment accumulation rate and strata age are aided by Figure 10, where results for a McNary reservoir core are plotted along with the Miller Sands data. The McNary data* are quite regular, showing a progressive decline with depth, which is expected since Co-60 has a shorter half life than Eu-152 (5.3 versus 12.7 yr). The different slopes can be interpreted as changes in sedimentation rate. The complete McNary core profile represents approximately 30 yr. The unexpected aspect of the Miller Sands data for SC 5 when evaluated in this manner is that the upper 10 cm yield only very contemporary radionuclide ratios, while the lower strata, having a similar texture, show no evidence of Hanford radioactivity.

It is implied by the above observations that the deeper strata

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*Unpublished data, V.G. Johnson, OSU School of Oceanography, Corvallis, Oregon.

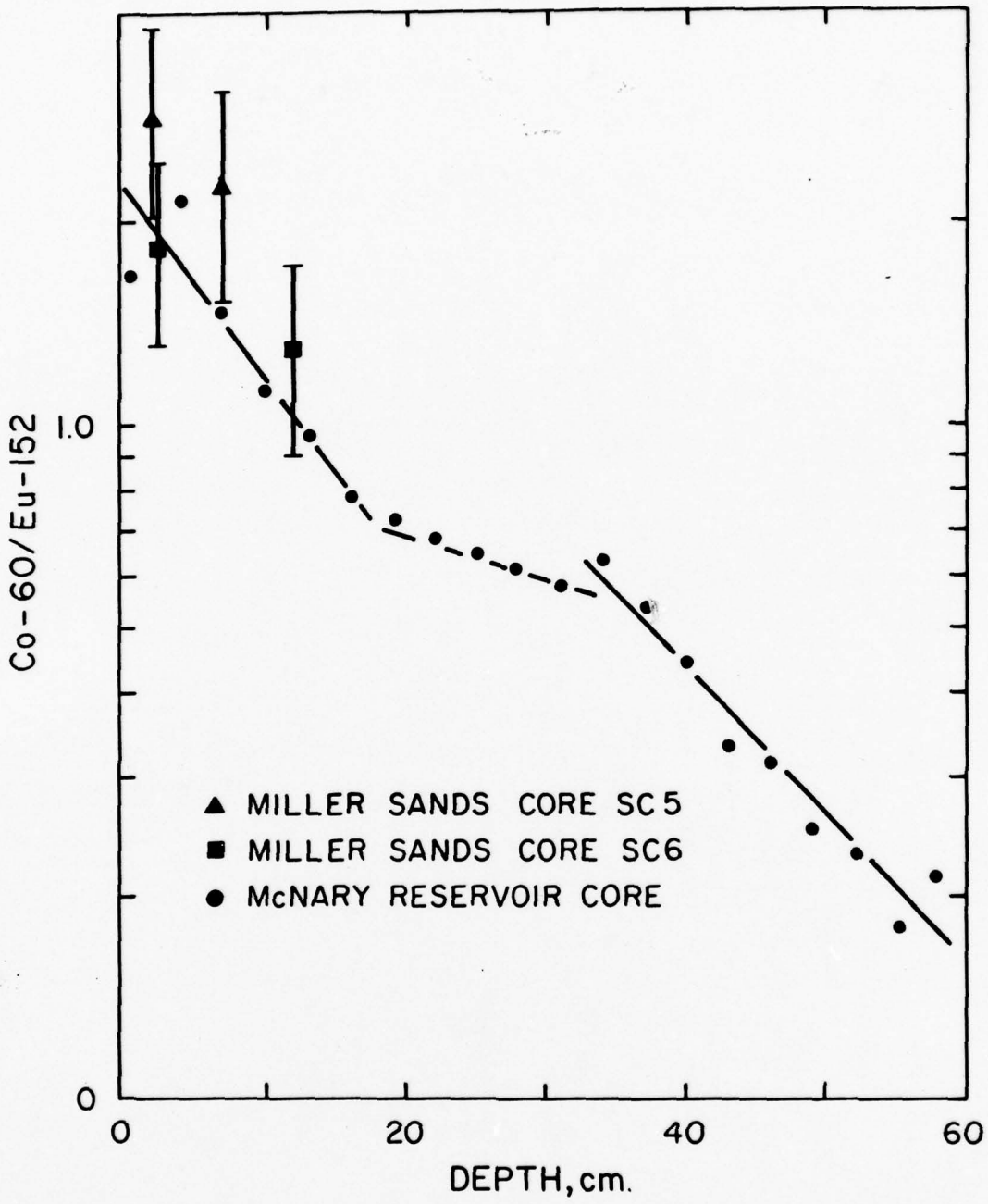


Figure 10. Co-60/Eu-152 ratios versus depth in a McNary Reservoir core (collected 16 January 1975) and two Miller Sands cores (collected 1 July 1975)

accumulated prior to the occurrence of Hanford activity in the Columbia River system, i.e., before 1944. This implies that accumulation of some very fine sediment in shallow water adjacent to the main channel(s) of the river occurred even before a significant fill had been built up. The proximity of these stations to the main channel and the occurrence (prior to flow regulation) of periodic flooding in the lower Columbia make this highly surprising.

The fate of the missing radionuclide record in core SC 5 is uncertain. One possibility is that a scour event removed the entire Hanford-tagged portion of the sediment column and that the high ratio in the upper 10-cm strata represents subsequent deposition. In 1974 high snow-melt runoff occurred in the Columbia River. Before this, a major flood occurred in the lower Columbia in December 1964 and produced major scour at various locations in the estuary, including areas near the Miller Sands site (Forster, 1972; see also Jennings, 1966). (It is significant to note that the 1964 flood occurred primarily downstream of all Columbia River reservoirs.) Perhaps the 1964 flood stripped away all the radioactively tagged sediment layers, while subsequent accumulations were removed during the moderately high waters in 1971 and 1974 and these events were followed by new deposition reflecting only the contemporary radionuclide ratio.

Radionuclide ratio data from the SC 6 core show a slope similar to the McNary core data (Figure 10). The portion of the SC 6 data representing the stratum just above the transition to coarse sand suggests an age of 7 to 8 yr. This might be interpreted as the result

of more or less continuous sediment accumulation following the 1964 flood. The implied net accumulation rate is about 2 cm/yr.

It should be cautioned that the above interpretations are tentative. They are the best interpretation allowed by present methods and are subject to change as more information concerning the use of Co-60 and Eu-152 as an age-dating tool develops.

To summarize, the large areal and vertical variability in sediment texture in the inner cove, combined with tentative age assignments and radionuclide profiles, suggest that a highly complex history involving periodic scour and depositional periods has prevailed in the vicinity of Miller Sands.

Chemical Factors

Chemical characterization of sediments involved both field and lab analyses. Eh, pH, and pS (free sulfur) were measured in the field immediately after collection and extrusion of the core in order to avoid changes that would occur during storage. Subsamples of core sections were squeezed in the field to obtain interstitial water samples for nutrient and heavy metal analysis. Sampling and analytical procedures used are discussed in Addendum A.

Sample site locations for core analyses are shown in Addendum B, Figure B8. These locations correspond primarily with the water quality sample locations and approximately with some of the National Marine Fisheries Service nekton and benthos sampling sites.

The 0 to 5 cm and 25 to 30 cm sections of each core were analyzed. These sections were chosen in order to study the chemistry of near surface sediment, the layer which is the most ecologically active, as well as the sub-surface chemistry where reducing conditions are likely to prevail.

It was necessary to take two cores at each cove and control station in order to obtain enough material for all the subsamples required. Eh, pH, cation exchange capacity, particle size, sulfide, and heavy metal content were determined on subsamples of a core collected with a fiber-glass barrel. Chlorinated hydrocarbons and nutrient samples were taken from a core collected with an all aluminum barrel.

Redox Conditions

The Eh, pH and sulfide results indicate that sediments from the main channel were well oxygenated. Samples from inside the cove on the other hand, showed that at least mild reducing conditions exist in the areas where fine sediment had accumulated. Very little total sulfide was found in the cove samples, the highest value being 16 mg/kg; this supports the assumption that salt intrusion is insignificant here. The lowest Eh value, +70 mV, was obtained in the surface section at station SC 6, located in the far northeast corner of the cove. Apparently the presence here of very fine sediment (median diameter of 20 μm) in the surface layers permits exclusion of oxygen and this allows reducing conditions to exist even in the 0 to 5 cm layer. It is also noteworthy that where the Eh is substantially lower than the +400 mV characteristic of well oxygenated sediments, interstitial manganese (Mn) and iron (Fe) contents increase dramatically from levels of 0.01 to 30 μg/mℓ and 0.1 to 60 μg/mℓ, respectively. These responses of interstitial Mn and Fe to the lowered redox potential have been

observed elsewhere (Windom, 1972, as cited in Lee and Plumb, 1974). The observation that interstitial Mn and Fe increase as redox potential decreases is not unexpected. However, the presence of well developed reducing conditions and high concentrations of reduced species in the interstitial water of the 0 to 5 cm layer is quite surprising, given the high energy conditions that presumably exist in the core area. In addition, the sediment age estimates discussed previously indicate that this condition began to develop even before manipulation of dredged material was begun for the Miller Sands project.

Heavy Metals

With the exception of mercury, heavy metal concentrations of total or unfractionated sediment were determined using flame atomic absorption (AA) methods after dried samples were leached with a reducing acid. Addendum A contains details on the procedure.

Mercury was determined by the cold vapor AA analysis of digested wet sediment that had been stored frozen.

Acidified interstitial water was analyzed directly by aspiration in the flame of the AA unit or by the carbon rod AA method. No pretreatment other than acidification with dilute nitric acid was necessary.

Total Sediment. In general the metal concentrations agree with levels found in other areas of the estuary (Johnson and Cutshall, 1975). Specific comparisons with studies at other locations are difficult to make, however, because extraction techniques often vary. Different extraction methods may not dissolve the same fractions of the elements. In addition, metal concentrations are generally sensitive to particle size, presumably because of surface area effects.

Bearing these factors in mind, it may be interesting to contrast the Miller Sands results with those from other areas. Concentrations of heavy metals such as lead (Pb), copper (Cu), and zinc (Zn) in sediments from highly industrialized bays range between 50 and 200 ppm, while cadmium (Cd) and mercury (Hg) range between 0.1 and 5 ppm (Serne and Mercer, 1975). At Miller Sands the extractable heavy metal levels ranged from 20 to 179 µg/g for Zn; 2 to 21 µg/g for Cu; and 0.5 to 22 µg/g for Pb. Cadmium ranged from less than 0.01 to 1.3 µg/g and Hg from 0.01 to 0.1 µg/g. In all cases the lower values are for the sandy textured samples and the high values represent the very fine textured sediment. It would appear from this overview that the Miller Sands concentrations are below those normally found in the highly industrialized river and bay sediments summarized by Serne and Mercer (1975). The possible exception to this is Zn which appears to fall within the range indicated for industrialized bays. Columbia River sediments are generally rich in Zn from natural sources.*

The results of heavy metal analyses for the channel and cove sediments and the marsh and island soils are displayed together in Figure 11 in which each metal is plotted as a function of the median particle diameter of the sample. These plots illustrate deviations from the linear response expected for surface-area-dependent metal concentrations.

The most striking result apparent from Figure 11 is the occurrence of at least two distinct populations of metal concentrations for Zn. The

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*Unpublished data from J. Wagner and N.H. Cutshall, OSU School of Oceanography, Corvallis, Oregon.

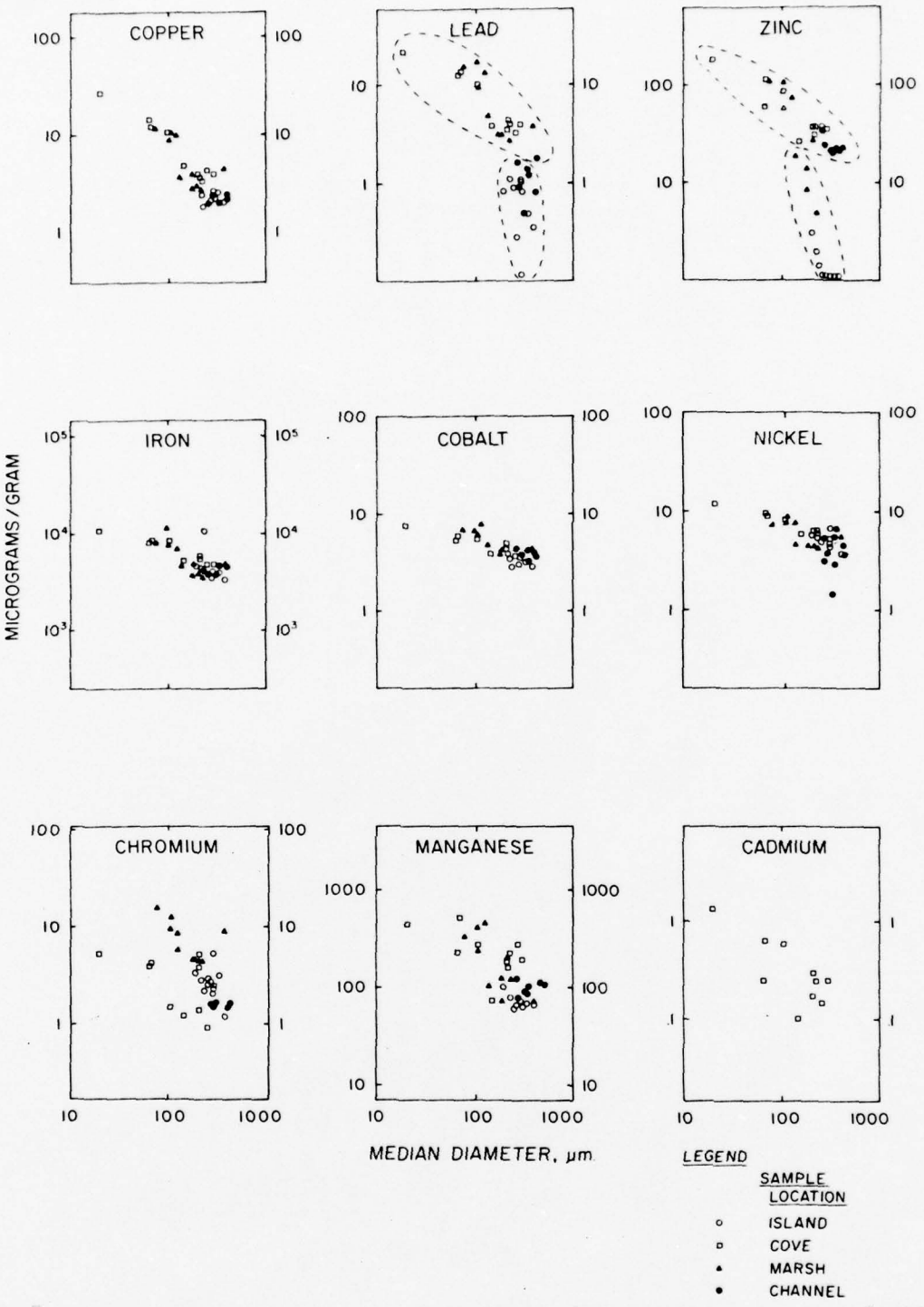


Figure 11. Acid-leached trace metal concentrations versus median particle diameter in Miller Sands soil and sediment samples collected in summer 1975

sediment samples and some of the marsh soil samples seem to follow a more or less linear relationship with median particle diameter. The island soil, however, breaks from this trend and shows much lower concentrations than predicted by particle size. The island soil apparently is 30-40 yr old and has approximately the same median diameter and sorting parameters as those of contemporary channel sediment, and thus is considered to have come from approximately the same source. Island soil and channel sediment presumably have similar mineralogy as well. Although vegetative cover exists over the areas sampled, it is very sparse. Thus neither depletion by plant growth nor differences in mineralogical composition seem to explain the low Zn concentrations of the island soil. It appears more likely that the well drained island soil has experienced a different chemical environment and that this has resulted in preferential leaching of metals such as Zn. Earlier work* on binding mechanisms of Zn-65 in Columbia River sediment indicated that air-dried sediment has a significantly higher exchangeable fraction than undried samples. Perhaps the alternate wetting and drying of the island soil along with exposure to acidic rainwater has leached away some of the formerly bound Zn.

The practical implications of these observations were pursued in terms of possible Zn deficiency with respect to plant growth on the island's sandy substrate. Prior work done at the OSU Agricultural Experiment Station on the relationship between the amount of soil zinc, as measured by chelate extraction, and crop response indicates that

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* Unpublished data from V.G. Johnson and N.H. Cutshall, OSU School of Oceanography, Corvallis, Oregon.

soils with less than 1 µg/g extractable Zn are deficient in this element and can be expected to produce low yields. Selected samples from newly dredged channel sediment as well as marsh and island soils were analyzed by the OSU Soil Testing Lab using an available zinc leaching technique. These results showed that the island soil contained less than 0.19 µg/g available Zn, well below the 1 µg/g considered deficient; whereas dredged sediment, which had been exposed for approximately 4 months, yielded extractable Zn values of nearly 2 µg/g. The marsh soils ranged from 1 to 18 µg/g available Zn.

The relationship of lead to particle size also varies with soil type, but the differences were less strong than in the case of Zn. In contrast, Cu does not exhibit the anomalously low values for the island soils shown by Zn and Pb. Thus there appears to be differential mobilization taking place in the surface soils of the older vegetated part of the island.

Chromium, and Cd show a rather scattered distribution when plotted against particle size. In the case of Mn, this probably is mostly due to redox conditions, while the scatter in the Cr and Cd plots is probably caused by analytical uncertainties. Standard linear regression analysis was performed on the metal-particle size data from the sediment samples (i.e. excluding marsh and island soil samples). These analyses showed that Fe, Co, Cr, Ni, and Mn exhibited very weak particle size dependence as indicated by low regression slopes, whereas Cu, Zn, Pb and Cd exhibited moderately strong particle size dependencies.

Interstitial Water. As previously discussed, the concentrations of Fe and Mn are related to the redox potential of the sediment.

Concentrations of other metals seem less closely related to sediment redox potential, although their concentrations in interstitial waters are distinctly higher than those in ambient water. This enrichment in interstitial waters has been noted by Lee and Plumb (1974), and others.

The significance of enrichment to the Habitat Development Research Project is that it may indicate the character of the chemical environment for future marsh grass root systems. For example, the maximum Fe concentration found in this study was 60 µg/mℓ and that of Mn was 28 µg/mℓ. These are about 10 and 100 times, respectively, the levels considered acceptable for irrigation waters (U.S. NAS/NAE, 1973). Manganese concentrations of a few tenths to a few mg/ℓ have been found to be toxic to several crops (U.S. NAS/NAE, 1973). Interstitial concentrations of metals other than Fe and Mn, however, fell below the maximum concentrations recommended for irrigation waters.

The samples producing high Fe and Mn values were very fine textured. Presumably the fine grained sediment prevents oxygen penetration, thereby allowing reducing conditions to prevail. If phytotoxic levels of Mn and Fe do exist in fine textured marsh substrates, the indigenous plant species must have adapted to these conditions; for example, rather dense stands of *Carex*, *Scirpus* and *Juncus* are found in very muddy substrates as well as in sandy bottom types (Renfro, 1968). Furthermore, some plants such as *Scirpus* have a mat-like network of very shallow roots, whereas *Carex* has a deeply imbedded root system. Renfro (1968) noted that the shallow rooted species apparently derive less Zn from their substrate than do the deeper-rooted type. Whether this is due to a difference in requirements or to root chemical environment is unknown.

It is easy to see, however, how a significantly different root environment could exist for these two different types of common sedges. The role that root chemical environment may have on zonation and distribution warrants further study.

Nutrients

In general, ammonium and total nitrogen, carbon and phosphorus exhibited an approximate correlation with median grain diameter with the highest values being found in the fine textured samples. Ammonium ranged from 0.2 to 119 µg/g; total nitrogen from 59 to 1260 µg/g; total carbon from 240 to 15,000 µg/g and total phosphorus from 752 to 2800 µg/g.

Subsamples of dried sediment collected for nutrient analysis were subjected to some of the standard soil fertility tests in order to gain insight into the fertility status of material intended as substrate in the experimental marsh. Extractable calcium, magnesium, sodium, potassium, nitrate and phosphate were determined for this purpose, as described in the soil testing procedures. The data show that nearly all of the sediment samples were either marginal or submarginal with respect to the fertility guides used for agricultural crops. However, the fine textured sediments were all significantly higher in phosphorus, nitrogen and potassium and would presumably act as a richer substrate for marsh grass propagation than the coarser textured sandy substrates characteristic of the dredged material at the site.

Chlorinated Hydrocarbons

Time did not permit analysis of all the samples for chlorinated hydrocarbons. Four representative sediment samples and two island soil samples were analyzed to give an indication of prevailing levels.

With the exception of one of the finer textured samples, all of the samples analyzed were near the blank level of 1.3 µg/kg for polychlorinated biphenyls (Aroclor® 1254) and 0.012 µg/kg for the degradation products of DDT. The highest levels found, on a dry weight basis, were 14, 2, and 4 µg/kg for Aroclor 1254, DDE, and TDE, respectively. The levels in the channel sediment that will serve as substrate for the experimental marsh were at the blank or detection limit. By contrast, levels in San Francisco Bay ranged from 30 to 830 µg/kg for PCB levels, and from 1-100 µg/kg for selected pesticide residues (Serne and Mercer, 1975).

PART VI: SOILS

Sample Collection

Soil samples were collected at 17 locations covering the full length of the older vegetated island. The samples were taken adjacent to vegetation quadrats established by Woodward-Clyde Consultants.* These samples are biased toward the open areas, since upland propagation efforts were directed at substrates found there. Photographs were taken of each profile and are included in Addendum B. Samples for soil analysis were taken from the 5 to 15 cm stratum in order to study the soil-chemical environment that would be experienced by rooted vegetation. The top 5-cm layer was not sampled because moss and/or litter had accumulated there.

Soil samples were taken from intertidal sites located adjacent to five Woodward-Clyde aquatic quadrats. Three of these quadrats were monitored by Woodward-Clyde for plant production rate. Hopefully, future study will show a relationship between the soil chemical results and plant production estimates for these sites.

Several additional samples were collected for fertility studies. These were taken at the sites receiving test plants during summer 1975 and from material to be used for substrate in the experimental marsh.

With the exception of grain size analysis and heavy metal determinations, all of the soil analyses were performed by the Soil Testing

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* Personal Communication, D. White, 730 SW Third, Suite 112, Portland, Oregon 97204.

Lab at Oregon State University. The analytical procedures used are described in Addendum A.

Island Soil

The island soils can be described as sandy textured, azonal and very low in organic matter. On the basis of the Unified Soil Classification System as set forth in *Guide for Interpreting Engineering Uses of Soils* (USDA, Soil Conservation Service, 1971), all of the island soil sites examined in this study can be placed in the category designated "SW." All of the soil samples can likewise be placed in the textural classification "sand" (*Op. Cit.*, Chart 2).

A summary of all data for the island soil samples is shown in Table 2. These data show that composition is fairly uniform from one end of the island to the other. It should be remembered that these samples are biased because areas with trees were intentionally avoided and because the top 5 cm was excluded from each sample. Within these limitations there is fairly good uniformity among the 17 sample stations.

In terms of fertility, the soil chemical results show that these soils contain less than (what is considered) minimal concentrations for grasses. However, it must be cautioned that these results are based on soil test procedures which determine only the readily available fraction. For example, the average amount of extractable potassium (K), 46 ppm, is below the 100 ppm level considered minimal for grass production, However, root interaction with soil minerals such as potash feldspars or muscovite may provide a larger available reservoir than would be indicated by the extraction procedure. Mineralogical analysis would have been helpful in this regard.

Table 2

Summary of soil analyses for Miller Sands, 1975*

Parameter	Units	Mean $\bar{x}$	Standard Deviation σ	Standard Error of Mean $\sigma_{\bar{x}}$	No. of Samples
Physical Characteristics*					
Median Grain Diameter	Mdϕ	1.84	0.29	0.09	10
Sorting	$\sigma\phi$	0.81	0.28		10
Fertility Factors†					
Cation Exchange Capacity	meq/100g	4.0	0.60	0.15	17
Extractable Calcium	meq/100g	2.6	0.35	0.084	17
Extractable Magnesium	meq/100g	0.84	0.16	0.039	17
Extractable Sodium	meq/100g	0.10	0.027	0.0065	17
Extractable Potassium	µg/g	46.4	18.0	4.4	17
Total Kjeldahl Nitrogen	percent	0.012	0.004	0.0012	17
Available Nitrate	µg/g	0.71	0.42	0.10	17
Ammonium	µg/g	0.55	0.43	0.11	17
Available Phosphorus (PO_4)‡	µg/g	6.1	1.4	0.34	17
Total Organic Carbon	percent	0.1	0.1	0.04	17
pH		6.3	0.17	0.039	17
Available Zinc	µg/g	0.2			6
Acid Leached Metals					
Iron	percent	0.473	0.22	0.070	10
Manganese	µg/g	73.0	11.0	3.5	10
Zinc	µg/g	1.3	0.71	0.22	10
Copper	µg/g	2.4	0.40	0.13	10
Lead	µg/g	0.69	0.38	0.12	10
Nickel	µg/g	5.1	0.80	0.25	10
Cadmium	µg/g	0.05			10
Chromium	µg/g	3.4	0.53	0.13	10
Cobalt	µg/g	2.5	2.0	0.30	10

* Based on 17 samples collected from the vegetated main island on 17 July 1975. Texture class: Sand. Soil Classification: SW.

† All fertility analyses performed by OSU Soil Testing Lab, see Addendum A.

‡ Available phosphorus determined by dilute acid-fluoride extraction procedure.

In addition to the major plant nutrients, the available Zn level is clearly deficient as already discussed. Freshly deposited dredged material, however, does not exhibit a Zn deficiency.

Fertilization. Given the fertility tests discussed above and considering a potential crop of upland grasses, a recommended fertilizer application rate was chosen after discussions with soil fertility specialists at the OSU Soil Testing Lab. This suggested application rate is presented in Addendum B. The fertilizer guide is for commercial preparations. An alternative would be to apply seafood cannery waste, a rich source of all the necessary plant nutrients. The proximity of the test site to several seafood processing plants makes this alternative attractive because it would usefully combine two waste byproducts (dredged material and seafood waste). Also, nitrogen from seafood waste is less leachable than that from many commercial preparations, and, thus, runoff from the test plot would carry less nitrate/ammonia into local waters. This would be less of a problem for the terrestrial plant propogation site, perhaps, than for the experimental marsh site.

Another aspect of fertility status is soil pH. For the island soil the average pH was 6.3. Liming is not required where pH is this high. Also, the high pH reduces chances of toxicity by aluminum and other metals (U.S. NAS/NAE, 1973).

Marsh Soil

In general, marsh soils were higher in major nutrient levels than the island soils, reflecting differences in soil textures. Zinc defi-

ciencies were not found. Test plots having the highest major nutrient and Zn supplies were those for which Woodward-Clyde personnel measured highest plant production. It appeared that the top 5 cm was higher in nutrients and available Zn than the 20-25 cm stratum, despite similar textures. It is possible that vigorous growth of cover grasses has depleted the deeper layers. Whether these relationships change seasonally or are permanent features of developing marsh systems in this area is presently unknown.

Chemical analyses of the channel sediment in the area from which the dredged material was taken indicate no toxicity problems, although the nutrient status is submarginal with respect to agricultural crop production. The zinc deficiency problem found in older island soils was not found in the newly deposited channel sediment. (Samples of this material were collected on 29 November, approximately four months after placement.) Thus, the development of Zn deficiency appears to be a longer term problem.

The median grain size of the channel sediments was 0.33 mm, and that of two composite samples from the new fill material was 0.28 mm. In both cases, the sediment is moderately well sorted with most of the samples falling in the 0.500 to 0.250 mm and 0.250 to 0.125 mm size classes. While the actual experimental marsh substrate was not sampled, its physical and chemical characteristics are believed to be similar to the sediment samples mentioned above. Samples taken from the test plot used to test indigenous plant growth response during the summer of 1975 yielded nearly identical grain size and chemical results.

Work involving transplanting of *Spartina* to sandy substrates has indicated that growth there is nitrogen limited (Woodhouse, Jr., Seneca and Broome, 1972). Although the Miller Sands site is a freshwater rather than salt water system, it is very likely to be nitrogen limited. If additional nitrogen is used, either a commercial slow-release nitrogen source or the fish/shrimp waste mentioned previously might be considered.

PART VII: CONCLUSIONS AND RECOMMENDATIONS

It appears that much of the physical and chemical change expected from creation of the island-marsh complex was already taking place at the time this baseline study began. A major portion of the sand spit already existed by summer 1975, and the portion that remained unfilled prior to 16 July 1975 was not sufficiently open to prevent accumulation of fine sediment inside the cove. Accompanying the fine sediment were changes in sediment chemistry, such as lowered redox potential and the appearance of reduced chemical species in the interstitial waters.

The fact that conditions were so altered before dredged material placement and sampling began, combined with the extreme variability of cove parameters such as sediment texture, argue strongly against development of a follow-up study for purposes of post-operational comparisons. Although such efforts might discover changes from the summer 1975 survey, time constraints of the WES Habitat Development Project suggest that available resources might be better committed elsewhere.

Water Quality Response to Dredging and Placement Activities

The survey conducted during operation of the pipeline dredge showed negligible differences in water-quality parameters in comparison to ambient water. Suspended sediment and heavy metal concentrations exceeded control samples by only a factor of approximately two, and these differences existed only in close proximity to the outfall. Dredge removal and placement of the well-washed coarse sands from the

Columbia River main channel do not appear to require use of dredged material confinement by diking, as has been used elsewhere (Windom, 1972).

Environmental Impact of Dredged Material Deposition

Perhaps the most significant impact that the Habitat Development Project has had on the local environment is the loss of some existing marsh by the filling operation. Some of this area, however, may be returned to productivity as the outer or shoreward side of the fill is eroded away, exposing some of the previously buried marsh (Figure 9).

Impact of Environmental Factors on Miller Sands

Erosion by wind waves and ship wake appear to be the most significant physical factor to contend with at Miller Sands. The impact of ship wakes on the new berm provided a dramatic, albeit unintended, experiment in sediment transport. It is unfortunate that elevation surveys were not performed across the berm just after placement of the fill material, since this would have been the most accurate way in which to monitor changes in beach profile. The erosive force of ship wake and its relationship to potential stream bank stabilization efforts using marsh grasses should be a topic of general concern.

The present study and previous studies of estuarine circulation suggest that salt intrusion does not occur at the project site as long as discharge exceeds 100,000 cfs. Flow regulation by upstream reservoirs makes it unlikely that flows would ever drop below this level.

Substrate Fertility and Water Quality Considerations

Fertility analyses indicate that the island soil is submarginal in major nutrient content and clearly deficient in Zn. An application of approximately 10 lb/acre of zinc is suggested to stimulate good growth response by the island plantings. While vegetation in the experimental marsh substrate and the island soils would undoubtedly benefit from fertilizer application, this should be weighed against the potential impact of leached nutrients on aquatic biota.

An alternate fertilization method involving the use of locally obtained seafood processing waste is recommended. This would provide a less leachable nitrogen supply. If commercial fertilizer preparations are chosen, it is recommended that at least a few test plots receive cannery waste for comparative purposes.

Finally, if fertilizers are used it is advised that close monitoring of the water for nitrogen compounds (especially ammonia) and phosphate be conducted. The extremely low nitrogen levels in the Columbia River during spring and summer would make even a small input recognizable in the cove.

Results from the nutrient analyses made in the present study show that ammonia is a difficult parameter to measure on stored samples. Immediate on-site ammonia analyses would be the most desirable.

Benthic Habitat Improvement

Studies (Higley and Holton, 1975; Higley, Holton and Komar, 1976) of the benthic fauna of the Columbia River estuary (up to river mile 35) indicate that the brackish and freshwater regions are characterized by a tube-dwelling amphipod, *Corophium salmonis*. This deposit feeder and its faunal associates (especially oligochaetes, the polychaete *Neanthes limnicola*, and nematodes) seem to predominate wherever fine sediments accumulate, i.e. in low velocity areas. In Youngs Bay, *Corophium* densities of 20,000/m^2 are common and occasionally exceed 50,000/m^2. Near Miller Sands, densities of 2,000 to 20,000/m^2 have been found in protected areas, as for example in Grays Bay and in small natural channels running between islands.

Near shore, the fauna grades into a somewhat different community, including the amphipods *Corophium spinicorne* and *Anisogammarus* sp., and the isopod *Gnorimosphaerma oregonensis*. These animals are most abundant near emergent vegetation. Areas of medium to coarse sand, as in the ship channel, harbor low animal densities and are characterized by the amphipod *Eohaustorius* sp.

Presumably, the habitat alterations conducted at Miller Sands will encourage development of these fine-sediment and shoreline faunas and thus contribute to feeding by fish and waterfowl. These effects may be diminished, however, by wave action stimulated by southerly gusting winds. In this case, some type of breakwater may be desirable in the upper cove. For example, a log barrier might be placed across the cove, at approximately the downstream reach of the new fill. This barrier

would protect the upstream area at least until emergent vegetation becomes stabilized.

Suggested Further Research

Some scientifically interesting observations were made and questions raised during the course of this investigation. These are listed below, without regard to the relevance they may have to the goals of the specific habitat development program being conducted at the Miller Sands site:

1. Does interstitial water chemistry, specifically redox environment and associated metal concentrations, have an influence on the success of different species of rooted aquatic plants in muddy substrates? Is there a selective advantage for shallow root types over deep rooted varieties? Could it be that die back in *Spartina* marshes (Eltringham, 1971) is related to some change in interstitial water chemistry, such as heavy metal content, redox, etc?
2. There is a suggestion from the heavy metal data in this study that an increase in the soluble manganese level (approximately 10 times ambient) which was coincident with an elevated suspended load level, may represent a mechanism whereby soluble manganese can be recycled from bottom sediment in shallow water areas where wind-wave mixing occurs periodically. This mechanism has been suggested previously, but observations made in this study not only lend support to the concept but

also suggest that experimental or field testing of the concept is possible; experimental verification is lacking. This transfer mechanism probably is a random event type of phenomenon that is closely coupled to bottom disturbance events (strong tides, storm waves, etc.), producing a pulse-type increase.

3. The mechanisms that permit fine sediment to accumulate in what is apparently a high energy environment need investigation. Such work should perhaps include an attempt to estimate sediment turnover in the zones of fine sediment accumulation of the inner cove. Sediment traps such as those used by Oviatt and Nixon (1975) could be used to monitor suspended sediment and would provide a partial sediment budget for the cove. This type of research would require long term funding (a minimum of two years, with at least seasonal measurements of bottom sediment texture, suspended sediment accumulation or activity, wave recorder data, etc.). It does not appear that this type of effort falls within the time scale of the Habitat Development Project.

4. Since the different mobilities of Zn, Cu and Pb in the island soil appear to be different than the generally observed mobility classes (Brooks, 1972), this difference warrants further geochemical investigation.

5. The observation that relative to the top 5 cm the deeper layers of marsh soil are depleted both in trace metals (specifically available Zn) and in major nutrients suggests

several questions. How does this pattern vary with season? Is the feature permanent or are the deeper layers replenished during the winter so that the materials necessary for spring growth are regenerated? Windom (1972) suggested that in *Spartina* marsh systems, reducing conditions develop in the deeper strata that permit regeneration of essential trace elements and allow diffusion upward into the root zone, thus providing a continuing nutrient supply. It would be profitable to examine soil profiles in more detail (e.g. by using more core sections) and on a seasonal basis to see whether depletion is a permanent feature or whether regeneration occurs in the root zone of the Miller Sands marsh areas.

LITERATURE CITED

Barnes, C.A., A.C. Duxbury and B.A. Morse. 1972. Circulation and selected properties of the Columbia River effluent at sea. Pp. 41-80 in A.T. Pruter and D.L. Alverson, eds., *The Columbia River Estuary and Adjacent Ocean Waters.* University of Washington Press, Seattle.

Brooks, R.R. 1972. Distribution and mobilization of minor elements in soils. Pages 80-91 in R.R. Brooks, *Geobotany and Biogeochemistry in Mineral Exploration.* Harper and Row, New York.

Clark, S.M., and G.R. Snyder. 1969. Timing and extent of a flow reversal in the lower Columbia River. *Limnology and Oceanography* 14 (6):960-965.

Conomos, T. John, and M. Grant Gross. 1972. River-ocean suspended particulate matter relations in summer. Pp. 176-202 in A.T. Pruter and D.L. Alverson, eds., *The Columbia River Estuary and Adjacent Ocean Waters.* University of Washington Press, Seattle.

Eltringham, S.K. 1971. *Life in Mud and Sand.* English Universities Press, Ltd., London. 218 pp.

Evans, D.W., and N.H. Cutshall. 1973. Effects of ocean water on the soluble-suspended distribution of Columbia River radionuclides. Pp. 125-140 in International Atomic Energy Agency, *Radioactive Contamination of the Marine Environment* (IAEA-SM-158). IAEA, Vienna.

Forster, W.O. 1972. Radionuclide distribution in the Columbia River and adjacent Pacific shelf sediments. Chap. 27 in A.T. Pruter and D.L. Alverson, eds., *The Columbia River Estuary and Adjacent Ocean Waters: Bioenvironmental Studies.* University of Washington Press, Seattle.

Glenn, J.L. 1973. Relations Among Radionuclide Content and Physical, Chemical, and Mineral Characteristics of Columbia River Sediments, with a section on Sand and Gravel Mineralogy by R.O. Van Atta. U.S. Geological Survey, *Professional Paper 433-M.* U.S. Government Printing Office, Washington, D.C. 52 pp.

Guy, H.P. 1969. *Laboratory Theory and Methods for Sediment Analysis.* Book 5, U.S. Geological Survey. 58 p.

Haertel, L.S. 1970. Plankton and nutrient ecology of the Columbia River estuary. Ph.D. Thesis, Oceanography, Oregon State University, 71 numbered leaves.

Haertel, Lois, Charles Osterberg, Herbert Curl, Jr., and P. Kilho Park. 1969. Nutrient and plankton ecology of the Columbia River estuary. *Ecology* 50(6):962-978.

Higley, Duane L., and Robert L. Holton. 1975. Biological Baseline Data: Youngs Bay, Oregon, 1974. Final Report to ALUMAX Pacific Aluminum Corporation, 1 November 1973 through 30 April 1975. *School of Oceanography Reference 75-6.* Oregon State University, Corvallis, Oregon 91 pp.

Higley, Duane L., Robert L. Holton and Paul D. Komar. 1976. Analysis of Benthic Infauna Communities and Sedimentation Patterns of a Proposed Fill Site and Nearby Regions in the Columbia River Estuary. Final Report to Port of Astoria, Astoria, Oregon, 1 November 1975 through 29 February 1976. *School of Oceanography Reference 76-3.* Oregon State University, Corvallis, Oregon. 788 p.

Hubbell, D.W., and J.L. Glenn. 1973. Distribution of Radionuclides in Bottom Sediments of the Columbia River Estuary. U.S. Geological Survey, *Professional Paper 433-L.* U.S. Government Printing Office, Washington, D.C. 63 pp.

Jennings, C.D. 1966. Radioactivity of Sediments in the Columbia River Estuary. Master's Thesis, Oceanography, Oregon State University. 62 numbered leaves.

Johnson, V.G., and N.H. Cutshall. 1975. Geochemical Baseline Data, Youngs Bay, Oregon, 1974. Final Report to ALUMAX Pacific Aluminum Corporation, 1 November 1973 through 30 April 1975. *School of Oceanography Reference* 75-7. Oregon State University, Corvallis, Oregon.

Knebel, H.J., J.C. Kelley and J.T. Whetten. 1968. Clay minerals of the Columbia River: A qualitative, quantitative, and statistical evaluation. *Journal of Sedimentary Petrology* 38(2):600-611.

Komar, P.D., and M.C. Miller. 1975. On the comparison between the threshold of sediment motion under waves and unidirectional currents with a discussion of the practical evaluation of the threshold. *Journal of Sedimentary Petrology* 45(1):362-367.

Kopp, J.F., and R.C. Kroner. *ca.* 1969. *Trace Metals in Waters of the United States.* A Five-year Summary of Trace Metals in Rivers and Lakes of the United States (October 1, 1962-September 20, 1967). U.S. Federal Water Pollution Control Administration, Cincinnati, Ohio. Various pagings.

Lee, G.F., and R.H. Plumb. 1974. Literature Review on Research Study for the Development of Dredged Material Disposal Criteria. *Contract Report D-74-1.* Dredged Material Research Program, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 145 pp.

Lockett, J.B. 1963. Phenomena affecting improvement of the lower Columbia estuary and entrance. Pp. 695-755 in *Proceedings of the Eighth Conference on Coastal Engineering*. Council on Wave Research, Berkeley, California.

Lutz, G.A., D.W. Hubbell and H.H. Stevens, Jr. 1975. Discharge and Flow Distribution in the Columbia River Estuary. U.S. Geological Survey, *Professional Paper 433-P*. 31 pp.

Naidu, J.R., and N.H. Cutshall. 1974. Radioactive Zinc (^{65}Zn), Zinc, Cadmium and Mercury in the Pacific Hake, *Merluccius productus* (Ayres) off the West Coast of the United States: A Data Report. *Data Report 60, Reference 74-9*. School of Oceanography, Oregon State University, Corvallis, Oregon 53 pp.

Neal, V.T. 1972. Physical aspects of the Columbia River and its estuary. Pp. 19-40 in A.T. Pruter and D.L. Alverson, eds., *The Columbia River Estuary and Adjacent Ocean Waters*. University of Washington Press, Seattle.

Oregon State University. Ocean Engineering Programs. 1975. Physical Characteristics of the Youngs Bay Estuarine Environs. Final Report to ALUMAX Pacific Aluminum Corporation, November 1973 to April 1975. School of Engineering, Oregon State University, Corvallis, Oregon 310 pp.

Oviatt, C.A., and S.W. Nixon. 1975. Sediment and resuspension and deposition in Narragansett Bay. *Estuarine and Coastal Marine Science* 3:201-217.

Park, P. Kilho, Magdalena Catalfomo, George R. Webster and Barry H. Reid. 1970. Nutrients and carbon dioxide in the Columbia River. *Limnology and Oceanography* 15(1):70-79.

Park, P. Kilho, Charles L. Osterberg and William O. Forster. 1972. Chemical budget of the Columbia River. Pp. 123-134 in A.T. Pruter and D.L. Alverson, eds., *The Columbia River Estuary and Adjacent Ocean Waters*. University of Washington Press, Seattle.

Postma, H. 1967. Sediment transport and sedimentation in the estuarine environment. Pp. 158-179 in G.H. Lauff, ed., *Estuaries*. Publication No. 83, American Association for the Advancement of Science, Washington, D.C.

Renfro, W.C. 1968. Radioecology of ^{65}Zn in an arm of the Columbia River estuary. Ph.D. Thesis, Oceanography, Oregon State University. 88 numbered leaves.

Serne, R.J., and B.W. Mercer. 1975. Dredge Disposal Study: San Francisco Bay and Estuary, Appendix F--Crystalline Matrix Study. U.S. Army Engineer District, San Francisco Corps of Engineers, San Francisco, California. 215 + 23 pp.

Simmons, H. 1971. The potential of physical models to investigate estuarine water quality problems. *Proceedings: 1971 Technical Conference on Estuaries of the Pacific Northwest.* Oregon State University Sea Grant Circular 42:4-28.

U.S.D.A. Soil Conservation Service. 1971. *Guide for Interpreting Engineering Uses of Soils.* U.S. Government Printing Office, Washington, D.C. 87 pp.

U.S. Geological Survey. 1965-1976. *Water Resources Data for Oregon. Part 2. Water Quality Records.*

_____. 1972b. *Annual Summary of Water Quality Data for Selected Sites in the Pacific Northwest, October 1971 to September 1972.* U.S.G.S. Northwest Water Resources Data Center, Portland, Oregon.

U.S. National Academy of Sciences--National Academy of Engineering. 1973. *Water Quality Criteria, 1972: A Report of the Committee on Water Quality Criteria.* EPA Publication No. R3-73-033. 594 pp.

Whetten, J.T., J.C. Kelley and L.G. Hanson. 1969. Characteristics of Columbia River sediment and sediment transport. *Journal of Sedimentary Petrology* 30(3):1149-1166.

White, Stan M. 1970. Mineralogy and geochemistry of continental shelf sediments off the Washington-Oregon coast. *Journal of Sedimentary Petrology* 40(1):38-54.

Windom, H.L. 1972. Environmental aspects of dredging in estuaries. *Journal of the Waterways and Harbors Division*, ASCE, 98(WW2, Proc. Paper 9342):475-487.

Woodhouse, W.W., Jr., E.D. Seneca and S.W. Broome. 1972. Marsh Building with Dredge Spoil in North Carolina. Sea Grant Advisory Services *Report NCU-G-72-002.* North Carolina State University, Agricultural Experiment Station, Raleigh, N.C. 28 pp.

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Sampling and Analytical Procedures

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ADDENDUM A

SAMPLING AND ANALYTICAL PROCEDURES

Introduction

This addendum describes sampling methods and analytical procedures used to obtain data for Miller Sands studies during 1975. (The data are tabulated in Addendum B.) Although the procedures are as complete and accurate as possible, since several laboratories participated in the analyses, this compilation may be incomplete in cases where the analyses performed were not under the direct control of the authors.

The procedures are arranged in the same order as the data presented in Addendum B.

Sample Site Locations

Positions of sampling stations were documented (determined) by "shooting" land marks with a sextant. The positions were then plotted on a chart of the area (Titled: Columbia River-Miller Sands Channel, dated 14 April 1975. COE Condition Survey CL-21-137; aerial photos taken 6 September 1974 restitued by orthophotoscope; superimposed coordinates based on the Lambert Projection for Oregon, North Zone. Control by USACE and NOS-C & GS). The plotted points were then assigned latitude and longitude values to the nearest tenth of a second using an overlay grid aligned with the latitude-longitude markings on the chart. Precision of the method was checked by comparing plotted

position location of known landmarks using the common siting reference points used in determining the unknown positions. When plotted on the above chart the plotted points were within approximately 20 feet of known position on the chart. This precision is thought to represent the average case. For water sample stations the method is probably more than adequate. However, a 20 ft. error in sediment sample location precludes return sampling since sediment variations occur on a scale of inches to feet.

Current Measurements

Current measurements were made with an Oceanics current meter, Model C02035 deck readout with a model G02031 sensor which had been calibrated while towing at known speeds in a wave tank.

The measurements were made from an anchored boat using a single anchor. The sensor was attached to a hydrographic wire weighted with a lead depressor. The sensor was tethered to the wire approximately 1 meter above the lead depressor. Readings were taken every 10 minutes near the surface and once each hour every two meters from surface to bottom. The direction of the current was recorded as "upstream", or "downstream" based on the orientation of the boat.

Water

Water sample collection involved two different procedures. For one, small boats, capable of sampling in the very shallow water of the cove, were used. For the other, ocean-going research vessels (R/V Yaquina and the R/V Cayuse) were used. The latter were, of course, confined to the main shipping channel. Samples acquired from the large

vessels were mostly analyzed at the time of collection using the onboard chemical laboratory coupled to a pumping-STD system (described later). Data acquired in this manner are referred to as in situ for purposes of this report. With the small craft operation, discrete samples of water were taken and except for temperature, dissolved oxygen, salinity and conductivity were preserved and stored for return to the laboratory. Samples acquired in this fashion are identified as "grab samples." A table of sampling events and dates is included in the introduction to Addendum B.

Grab Samples

Salinity, Conductivity and Temperature were all determined with a portable salinometer, Industrial Instruments Model RS 5-3. The sensor head was lowered to the same depths at which the grab samples were taken.

Dissolved Oxygen, Suspended Sediment, Nutrients were measured on subsamples of water taken from the same sampling bottle. A plastic National Institute of Oceanography (NIO) bottle fixed to a plastic coated hydrographic cable was used. Sampling was done at near high slack tide on all occasions in order to have as much water in the shallow cove as possible for navigation. (Water depths were generally 5 feet or less, except for the narrow channel zone in the cove.)

a. Dissolved oxygen was measured in the field immediately upon collection of the sample. A small portion was carefully drawn from the water bottle taking care to avoid excessive turbulence. The oxygen content was measured in an open 100 ml plastic beaker with a YSI Model 54 A meter and oxygen probe. The meter was air calibrated according to

manufacturers directions. Agreement between replicate determinations was within a few tenths of a part per million (ppm). Results obtained with this method and results from R/V YAQUINA analyses using the standard Winkler method agreed within 6 percent.

b. Suspended sediment was analyzed in 500 ml samples drawn from the NIO bottle, refrigerated in polyethylene bottles, and returned to the laboratory. These samples were usually processed within one week of collection. Sample bottles were shaken vigorously, and then filtered. A Millipore filter holder and 0.8 µm type AA Millipore filters were used for this purpose (Millipore catalogue No. AAWP040700). Each filter was preweighed after being dried in an oven at 70°C and stored in a vacuum dessicator for a minimum of one day. Blanks were determined periodically by filtering 500 ml portions of distilled water (A small blank correction was made for weight loss). Samples were also dried to constant weight at 70°C and stored in the vacuum dessicator until weighing.

The standard deviation (SD) computed from the differences between duplicate samples (excluding shallow water stations) using the method for paired samples (Youden, 1951) is ± 1 mg/liter. The relative standard deviation of duplicates (RSD) was ± 5% of the mean. These estimates of precision include all sources of variability including sampling uncertainty.

c. pH was measured with an Orion 407A portable meter and a Dow Corning (Catalogue No. 476050) combination pH/reference electrode (Ag/AgCl). Nominal 50 ml portions were drawn immediately after sample collection and placed in a 100 ml plastic beaker. Calibration was

checked before and after each station was occupied using NBS certified pH 7.0 buffer. The SD of duplicate samples for all stations was ± .07 pH units.

d. Nutrients were analyzed using procedures described for the in situ samples. Grab samples were drawn from the same NIO bottle used for all other analyses. A variety of preservation techniques were used. On the 17 June sampling trip, samples were taken for comparison with the EPA-Corvallis method of nutrient analysis used in the Great Lakes nutrient study. These samples were preserved with mercuric chloride according to EPA specifications and were kept cool until analysis (approximately 5 days after collection). The other samples collected on 17 June were unfiltered and untreated but were kept chilled. These were processed on board the R/V YAQUINA within 3 hours of collection. Subsamples were frozen and stored for total available nitrogen (TAN) and phosphorus (TAP). Comparison between the OSU-Oceanography results and the EPA results on this sampling date is made in Addendum Table B3. EPA results are those designated with an "HG" under the treatment/ preservative column heading; all others were run by OSU.

Comparison of the EPA total Kjeldhal nitrogen (TKN) and total phosphorus (TP) and the OSU total available nitrogen (TAN) and phosphorus (TAP) showed that the OSU results averaged 30% lower for both nitrogen and phosphorus. This is attributed to incomplete degradation of the particulate associated nitrogen and phosphorus compounds in the sample.

The agreement among duplicates for the OSU results for 17 June grab data (based on the standard deviation computed from the difference

between duplicates) was as follows:

ammonia ± 9.9 µg/l, RSD: 145%; nitrate, ± 2.2 µg/l, RSD: 48.5%; TAN ± 22 µg/l, RSD: 11%; TAP, ± 2.9 µg/l, RSD 8.0%; ortho-phosphate ± 1.5 µg/l, RSD: 6.0%; silicate, ± 0.2 µg/l, RSD: 4.4%.

High variation of the ammonia and nitrate analyses occurred because the levels are very near the limit of detection. For ammonia, however, even higher levels would likely be variable because of its volatility. (Reproducibility for ammonia analyzed immediately from the sampling stream using the STD system is considerably better than for stored samples. It seems clear that reliable ammonia results can only be obtained by immediate analysis.)

On the 30 June and 16 July grab sampling dates different preservation methods for nutrient samples were used for a comparison study. Subsamples from the same bottle were preserved using mercuric chloride, using no filtration and stored unfrozen (EPA method). One set was filtered through 0.4 micron Nucleopore filters in the field and stored in dry ice and kept frozen until analysis, while another set was drawn through a 10 micron Nitex screen prior to storage in dry ice. The extreme variability among replicates and duplicates for these sampling dates precludes any comparison among treatments. Apparently some problem during storage and or handling of the samples resulted in highly irreproducible results. The problem apparently stems from the process of freezing nutrient samples for later analysis. Certainly, such parameters as ammonia and silicate cannot be determined reliably from frozen samples. The grab sample nutrient data for 30 June and 16 July are *not* reliable.

Trace Metal samples were collected on the 30 June and 16 July sampling dates. The samples were taken with a teflon (FEP) bottle attached to a polyvinylchloried rod approximately 3 meters in length. Only surface water (approximately 0.5 meter deep) was taken for these samples. The sampling rod and bottle were held as far as possible from the boat (fiberglass coated wooden hull), near the bow and with the boat oriented in the upstream direction in order to aviod contamination from the boat.

A precleaned filter assembly was attached to the sampling bottle and the bottle was pressurized with filtered nitrogen to force the water sample through the filter and into a 30 ml teflon (FEP) storage bottle. The filtered water was immediately frozen. Additional water was passed through the filter until 100 ml had been filtered and the filter was carefully removed from the filter holder, placed in a plastic vial, and immediately frozen with dry ice. All samples were frozen in the field and kept frozen until they were analyzed. Laboratory preparation of the filtered water samples involved only thawing and addition of 0.15 ml of 6N HCl and 0.30 ml 16 HNO_3.

Filters were thawed, placed in scrupulously cleaned 50 ml glass beakers with watch glass covers. Five ml of high purity concentrated nitric acid and 1 ml of 30% H_2O_2 were then added and the beakers heated on a hot plate. The watch glass cover acted as a reflux condenser for the nitric acid while the opening around the top of the beaker allowed some of the nitric acid fumes to escape so that after approximately 24 hours the acid was driven off and only a dry residue remained in the bottom of the beaker. The residue was taken up in dilute HCl/HNO_3

and again heated for another 2 hours. The resultant solution was carefully transferred to 10 ml volumetric flasks with successive washings of deionized distilled water and brought to volume. The same quantities of reagents used to digest samples were carried through the same process and used as blanks. Clean filters were also digested in the same manner as samples. These analyses were used to determine the background levels in the filter. Only small blank corrections were necessary.

Since prior inspection of some of the filters showed that the largest proportion of particles were freshwater diatoms, 50 mg quantities of NBS orchard leaves were processed with each of the four groups of filters analyzed. Orchard leaf results were used to assure consistency of procedure among batches and to estimate recovery.

The dilute acid solutions were analyzed by atomic absorption spectrometry (AAS) using the flameless techniques. The instrument system used consisted of: 1) Varian Techtron Model AA-5R spectrometer with the Varian Model BC-6 Background Corrector and 2) Varian Model 63 carbon rod atomizer. Samples were run in triplicate and standards were prepared in a matrix simulating the samples. All instrument settings were as recommended in the manufacturers manuals. Blank contributions were subtracted where necessary before calculating the final concentrations.

Results for NBS orchard leaves processed with the filters analyzed for this study were as follows:

metal	N	Concentration Found, µg/g mean	standard deviation	standard error of mean	NBS value
Iron	4	270	35	17	270
Zinc	4	26	3.7	1.8	25
Manganese	4	93	3.2	1.6	91
Copper	4	9.3	1.4	0.7	12
Cadmium	4	<0.1	-	-	0.11
Lead	4	21	2.2	1.1	44
Cobalt	4	<0.5	-	-	0.2
Nickel	4	<3	-	-	1.3
Chromium	4	7.6	5.1	2.6	2.3

Excellent to fair agreement was obtained for Fe, Zn, Mn, and Cu. With the exception of lead all the other metals analyzed were at concentrations below the detection limit of the system. Lead values found were approximately half of the expected value. No explanation can be given for this discrepancy. The reported lead data should be viewed with this in mind. Agreement among duplicates for the particulate metal concentrations shown in table B5 (excluding the first pair) was approximately ± 5% (RSD) for Mn, Zn, and Fe; ± 25% for Cu. (These estimates of RSD include sampling variability.) The other metals were either below the limit or detection or too near it for meaningful comparison of duplicates. The less than values entered in the tables, however, are reliable upper limits for the expected concentrations for these metals. Only Fe, Mn and Zn, and possibly Cu have sufficiently low RSD values for comparison with other data.

In Situ Samples

As mentioned previously, a pumping-STD system operated from oceanographic research vessels was used to obtain samples for data referred to as"in situ", Addendum Table B7. (Cruises to Miller Sands were

coordinated with work being conducted near the mouth of the Columbia River for a WES open ocean disposal study.)

The instrument package consisted of salinity, temperature and depth sensors and a submersible pump. The nutrients, NO_3^-, NO_2^-, SiO_3, NH_3, $O\text{-}PO_4$, were determined by on-line analysis of the sampling stream. This was accomplished in a laboratory set up on board which was equipped with a Technicon Autoanalyzer system (described later). A small intake line covered with a Nytex screen (10 micrometer) was immersed in the pump stream. The sample stream was routed directly to the Autoanalyzer. On some occasions, discrete samples were drawn from the main pump stream and filtered through glass fiber filters (GFC) using a vacuum filter assembly. For these samples, the filtered water was stored in plastic bottles for a short time before analysis. Discrete samples were drawn from the sampling stream for particulate carbon and nitrogen, pH, TAN, TAP, dissolved oxygen, and chlorophyll. The pH samples were analyzed immediately on board using an Orion pH meter and dissolved oxygen was determined on-board by Winkler titration. Samples for particulate carbon and nitrogen were drawn from the main sampling stream and filtered through GFC filters. These filters were stored frozen until they were analyzed by a CHN analyzer. The same collection and storage procedure was used for the chlorophyll samples, except that 0.45 µm Millipore filters were used for this purpose. The filters were extracted in the laboratory with 90% glass distilled acetone. After centrifugation the extracts were placed in 10 cm cells in a Hitachi Perkin-Elmer 111 spectrophotometer and were analyzed for chlorophyll, A, B, and C and phaeophytin A (Strickland and Parsons, 1972). The discrete samples

drawn for TAN and TAP were stored frozen until analysis at a later date. These samples were subjected to an ultraviolet irradiation procedure prior to analysis of NO_3 and PO_4.

Pumping STD System. The STD sensor package consisted of a Plessey Model 9040 STD which transmits FM multiplexed data to the deck unit via a 200 m hosecable, consisting of a signal coaxial cable, a 3/4 inch hose, a braided strength member, and power leads for the submerged pump. The STD deck unit converts the FM data to analog signals which are amplified and interfaced to a Digital Electronics Corporation PDP-8/L computer. Salinity values recorded in data table B7 for the Miller Sands Study were determined by analyzing discrete samples drawn from the sample stream on an inductive salinometer since calibration of the STD is uncertain below salinities of a few parts per thousand.

Autoanalyzer System Description. A Technicon Instruments Corporation Autoanalyzer® was used to determine inorganic nutrients. Basically, nutrients are determined with this system in the same manner as with batch chemical and spectrophotometric methods, except that with the Autoanalyzer the filtered sample and reagents flow continuously through the system.

The total system is composed of 1) input tubes from reagent bottles and the sample bottle for each nutrient being analyzed (a specialized dialysis filter is employed with the sample tubing); 2) a specialized peristaltic pump to move the reagents and sample through the input tubes and into the mixing coils, with one pump required for each nutrient analyzed; 3) mixing coils in which chemical reactions take place and 4) colorimeters to analyze the color of the reaction mixtures, with

one colorimeter required for each nutrient analyzed. For analysis of $NO_3 + NO_2$, NH_3, PO_4, and SiO_4, four pumps and four colorimeters, with attendant mixing coils and reagent tubes, were used in the Autoanalysis system. Readings from each colorimeter were output to a chart recorder, with a different colored pen used for each nutrient. Suitable standards and blanks were analyzed with each nutrient run.

The $NO_3 + NO_2$ chemical analyses were done as suggested in the RFP, except we used the Autoanalyzer as discussed above. The method begins with reduction of nitrate to nitrite by cadmium filings lightly coated with copper. The NO_2 is then made into a highly colored azo dye by adding sulfanilamide and N-naphthylethylene-diamine dihydrochloride, and the solution is "read" in the colorimeter at about 542 nm. Analysis for NO_2 alone can be done by bypassing the Cd-Cu column in the Autoanalyzer setup. Nitrate alone is determined by subtraction of NO_2 from $(NO_3 + NO_2)$. The procedure for doing NH_3 was basically the same as given in the RFP, except that sodium phenate solution, sodium nitroprusside, and sodium hypochlorite solution are mixed in the Autoanalyzer coils to form the strong oxidizing agent, phenylhypochlorite, which oxidizes ammonia to nitrite in the alkaline medium and NO_2 is then measured. Total available nitrogen is measured after UV irradiation. Nitrogen from all dissolved organic compounds except probably some tertiary amines is oxidized and released in the presence of O_2 and UV radiation (250 nm wavelength) to give a $NO_3 + NO_2$ mixture which is analyzed by the $(NO_3 + NO_2)$ method. Total available nitrogen is thus inorganic plus dissolved organic N. Total nitrogen is total available N plus particulate N (determined chromatographically by CHN analyzer).

Silicate was determined via the Autoanalyzer by the reduction of a silico-molybdate complex to a blue color that is colorimetrically determined at 810 nm. The procedure is a standard one. Stannous chloride is used as the primary reductant, and tartaric acid acts to reduce, or decompose, any phospho- or arseno-molybdate formed along with the silicomolybdate complex.

We determined phosphate via Autoanalysis by the method in the RFP, except that hydrazine rather than ascorbic acid is used as the reductant. The method involves reacting each sample in the mixing coils with molybdic acid (plus H_2SO_4) and hydrazine sulfate. The resulting blue-colored complex is read in the colorimeter at 830-840 nm. Total available phosphorus was a UV-treated sample in which the phosphate was determined after the UV treatment.

Precision is dramatically better for the in situ nutrient measurements than for stored grab samples. Since the same equipment, analysts, and procedures were used for the final finish step for both the grab and in situ analyses, these results illustrate the problems of sample preservation and/or storage. This is especially evident for the ammonia and silicate analyses. Thus for nutrient measurements, the most reliable data are the in situ results and the grab data for 17 June which were run within 3 hours of collection (Addendum Table B7).

Sediment

Sediment grab samples and core samples were collected. The grab samples were used to determine texture variations in the study area and only textural analyses were performed on them. Results of the texture

survey were then used to select coring sites. The core samples were subjected to chemical analyses in addition to textural analysis. Procedures are arranged here according to the type of analyses made; 1) physical, 2) chemical or 3) radiochemical.

Sample Collection

At exposed sites grab samples were taken by scooping the top 2 to 3 cm of sediment into a 250 ml plastic beaker. Submerged sites were sampled with a small hand operated dredge that skims off approximately the top 3 to 5 cm (Farrow and Larsen, 1974). Samples were placed in plastic bags in an ice chest and kept in a cool room until they were processed.

Cores were taken by two different techniques as appropriate to water depth and sediment texture. In the ship channel near the source site for dredged material, the water depth was 40 feet and sediment consisted of coarse, well washed sand. To obtain cores under these conditions, a large, heavy corer was needed. Coordination with the WES open ocean disposal study near the mouth of the estuary, permitted the use of a Bouma Box Corer (Bouma and Marshall, 1964) on board the R/V CAYUSE. The Bouma Box Corer in use at the OSU School of Oceanography consists of a rectangular stainless steel core barrel ("box") 8" x 12" in cross section and 18 inches long. The core barrel is pushed into the sediment through the center of a pyramidal framework by approximately 1000 lbs. of lead. The upward pull of the ships cable on a lever arm forces a steel plate down through the sediment and underneath the sampling box to seal the sediment inside. On deck, the box is removed and placed on an extruder stand. As the sediment is extruded,

the desired sections are sliced off using a stainless steel cutter.

The desired section thickness (5 cm) was extruded into a sample frame positioned at the top of the box. One side of the sampling frame was covered with plexiglass sheet in which ports of various sizes were cut and filled with plugs. The bottom of the sample frame consisted of the steel cutter. Air was excluded from the sample while the section was removed from the core and when the various subsamples were drawn for analyses.

Subsamples were taken by removing the plugs and inserting "mini-corers" fitted with small valves to allow escape of air while the mini-corer was filling. After insertion, the valve was closed, the mini-corer withdrawn from the sample frame, and either transferred to appropriate containers for subsequent analysis or covered with a plastic lid to exclude air. The latter type of samples were stored at room temperature for short intervals between the time of collection and when they were placed in the squeezing chambers for extraction of interstitial water.

For collection of the shallow water cores inside the cove and at the control site (Snag Island), a different coring device was necessary. A hand operated 6-inch diameter, corer with a removable top head was used for this purpose. The corer was operated from a shallow draft boat equipped with a hydraulic winch. The boat was anchored in position with three point anchoring. The shallow water, 4-8 feet, permitted the use of a push rod fastened to the top head of the corer for inserting the corer into the sediment. After insertion, the core was retrieved with

the winch. No valve closure device was used on the cutting head end of the corer. As the corer was removed from the water, a plug was inserted into the bottom of the barrel to prevent loss of sample as the barrel was moved into position on the extrusion device. The cores were extruded by placing the cutting end of the corer on a vertical stand or pedestal and then pushing the core barrel down. Sections of the desired width were extruded into a circular sampling frame similar to the one described for the box corer. Two cores were taken at each site in order to obtain enough material for all the samples required. A fiberglass barrel was used for collection of all but the chlorinated hydrocarbons and nutrient samples. The latter samples were taken with an aluminum barrel corer. Care was taken in the latter case to avoid all possible sources of contamination of the sample with residues that may have been associated with plastics, glues, hydraulic fluid, etc.

Physical Analyses

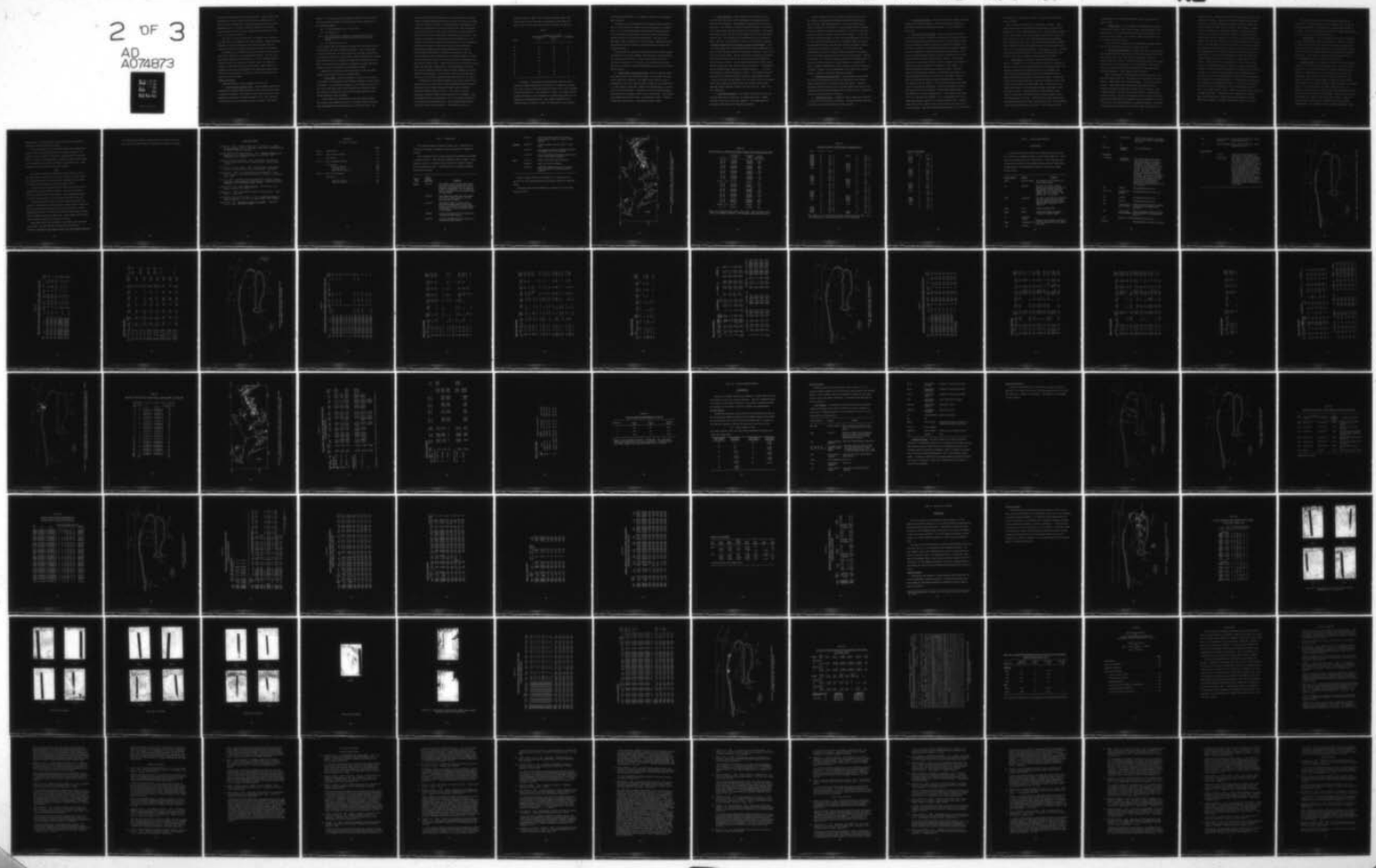
Grab samples were all air dried prior to analysis. Nominal 10 gram portions were disaggregated in a mortar using a rubber tipped pestle and taking care not to grind the particles. The disaggregated sample was sieved for 10 minutes on a mechanical shaker. Three inch (diameter) U.S. Standard Testing Sieves, (ASTM E-11 specification, W.S. Tyler, Incorp.) were used for all sieve analyses. The shaking time was determined for the above system with a loading of 10 grams by sieving until no further change occurred for a typical sample. Sieve fractions were weighed directly in the sieves on a top loading Mettler balance. The dry sieve data for the grab survey were to allow a rough approximation of sediment texture in the study area and it was originally

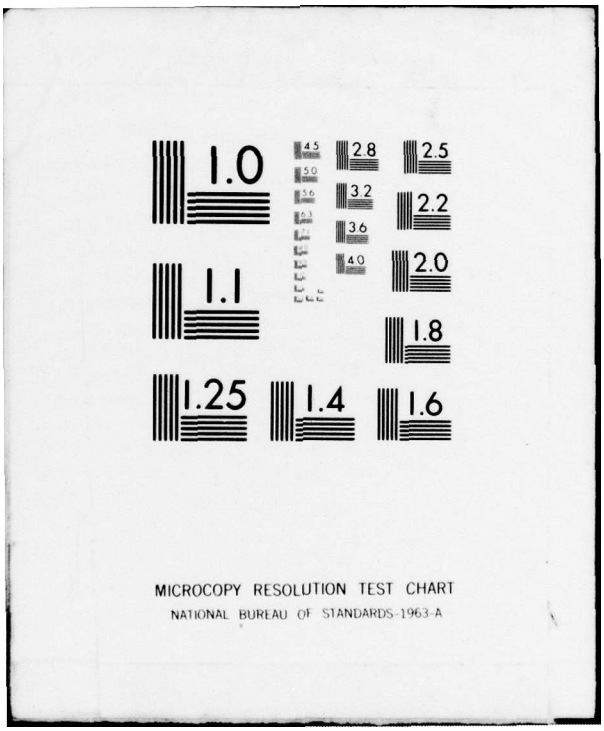
expected that only sand would be encountered. Thus, size distribution data for samples which contain a significant amount of fine material may not be accurate. The grab survey data are reliable for all samples where the amount of <63 μm fraction is less than 10%.

Core sections, on the other hand, subjected to a sieve-pipet analysis for complete particle size determination. Samples were kept refrigerated until analysis. Approximately 30 grams of wet sediment were first digested on a hot plate with 30% H_2O_2 (Guy, 1969). The digested sample was then centrifuged and the supernate decanted. The treated sediment was then placed in 500 ml of dispersing solution, and mechanically stirred for 5 minutes in a malt type mixer. This slurry was then poured onto an 8 inch diameter 63 μm Tyler screen. The sand remaining on the screen was washed with a jet from a squeeze bottle filled with the same dispersing solution. The washings were all collected in a beaker. The sand fraction was dried in an oven at 70°C, weighed, and then subjected to the mechanical sieve procedure described above. The sediment-dispersant mixture passing through the screen was transferred to a 1 liter graduate cylinder and brought to volume with additional dispersant solution. The suspensions were thoroughly mixed with a plunger prior to beginning the pipet analysis. Times and depths of withdrawl were as specified in Guy (1969). Aliquots (20 ml) were transferred to preweighed 25 ml glass beakers. These were dried to constant weight at 70°C. The beakers were then placed in a vacuum dessicator and stored until final weighings were made. All weighings were made on a Mettler analytical balance and weights recorded to the nearest 0.1 mg. The weight of a dried 20 ml aliquot of the dispersing

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solution was subtracted from each beaker weight. Results from the dry sieving for the greater than 63 μm fraction were combined with the pipet results to compute the % weight distribution in each size class. Reproducibility was checked by triplicate analysis of one sample representative of average textural composition (See table B11, SC05, A, B, C for replicate results).

Only those core sections that had a substantial <63 μm fraction were subjected to the complete sieve-pipet analysis. Samples consisting primarily of sand were processed in the same way except that the washings were dried and weighed to obtain a less than 63 μm fraction.

In addition to the standard sieve-pipet procedure, a few selected samples were subjected to a non-dispersed treatment. For these, the wet sediment sample was added directly to a 1 liter graduate cylinder containing river water collected at Miller Sands. The slurry was brought to volume and stirred with the plunger. These samples were subsequently processed as described for the dispersed analysis above. Results for these analyses are entered as "Native" for native water analysis in the data tables.

Chemical Procedures

Measurements made on total sediment were as follows:

a. Cation Exchange Capacity (CEC). Cation exchange capacity was determined for sediment samples recovered after interstitial water was separated by squeezing. The sediments, which had been stored at room temperature, were dried to constant weight at 70°C. The procedure for measuring the cation excuange capacity was adapted from Jackson

(1958). 5.1 g dried sediment (unground) was placed in a 90 ml centrifuge tube and then treated successively with 30-40 ml quantities of the following reagents:

2x: 1 N sodium acetate, pH 5, 30 min, 90°C.

4x: 1 N $MgCl_2$, pH 7.

5x-7x: 80% acetone-water. Washing was continued until no turbidity resulted when $AgNO_3$ was added to the clear wash mixture.

4x: 1 N sodium acetate, pH 7.

In each washing step, the sediment and reagent were thoroughly mixed in the centrifuge tube with a mechanical agitator. After centrifuging 5 minutes at 2000 rpm, the clear liquids were decanted or sucked from the centrifuge tube with a large pipette, without disturbing the sediment. The sodium acetate pH 7 washings were combined and diluted to 250 ml. These solutions were then analyzed for magnesium by atomic absorption. Results of analysis as mg/liter were converted to meq/g.

Samples of a "known" clay standard processed in the same manner yielded values within ±10% of the accepted value.

b. Heavy Metals. With the exception of mercury, all the heavy metal analyses were made by an acid leaching technique on dried portions of sediment. For the mercury procedure, a 10 cc sample was taken from the core section with a mini corer fashioned from a plastic syringe. The sample was transferred to nitric acid cleaned glass bottle and frozen immediately until analyzed.

A 100 cc sample was refrigerated for all other metal analyses. For analysis metal samples were dried to constant weight at 70°C and then disaggregated by gentle grinding in a mortar and pestle. Ten

Ten gram (g) portions were digested in 50 milliliters (ml) of a hydrochloric acid/hydroxylamine hydrochloride solution (1 N HCl/0.25 N NH_2OH ·-HCl) for two hours at 50°C. The suspension was centrifuged and the supernate transferred to a 100 ml volumetric flask. The centrifugate was rinsed twice with a total volume of 25 ml of one Normal ammonium chloride, and the rinse solution was combined with the extracts. This solution was brought to volume with deionized distilled water. The samples processed in this manner were all stored in linear polyethylene bottles until analysis. Trace metal levels in the extracts were determined by atomic absorption spectrophotometry (AAS) using a Varian Techtron model AA-5R. Standards were prepared in the same solution mixture used for extraction of the sediment samples. The AAS operating parameters used for each metal were those recommended by the manufacturer (Varian, 1971). Output from the AAS was recorded on punched paper tape and typed simultaneously. The punched paper tape record was used for computer processing using a Digital Equipment Corporation model PDP 11/05 computer. The instrument precision was better than 1% for Zn, Cu, Fe, Mn, and Co and better than 10% for Cd, Ni, Pb, and Cr.

A comparison of the relative amounts of each metal removed by the method used in this study with a nitric acid/hydrogen peroxide method (EPA Great Lakes sediment analysis procedure) and pH 7 buffered dithionite method is shown in Table 1. All values are given as percentage of amounts found by total digestion in an acid/bomb. With the exception of Fe, and possibly Ni, most of the metals determined by our method and the EPA method agree. The dithionite method removes less of all metals except manganese. (The sediment used in the

comparisons shown in Table 1 was a composite sediment sample from nearby Youngs Bay and consisted of approximately equal amounts of sand (1 mm to .063 mm) and silt plus clay (less than .063 mm size).

Table 1

Metal	Treatment, % of total		
	Hydroxylamine/ HCl	EPA Nitric/ H_2O_2	Dithionite
Fe	19	32	10
Mn	37	40	33
Zn	56	60	--
Cu	25	17	9
Co	44	47	8
Cd	--	--	--
Pb	--	--	--
Ni	18	36	--
Cr	8	--	--

c. Mercury. Total mercury was determined by flameless atomic absorption following digestion with nitric acid. Samples are weighed (wet) into a 250 ml flask, mixed with 15 ml Baker nitric acid ("Suitable for Hg Determination"), and refluxed for 2 hours. The liquid and suspended particulate are then decanted to a cleaned (HNO_3 washed) 100 ml polyethene or polypropene bottle. The sediment remaining in the digestion flask is washed 3-4 times with water which is also decanted

into the polyolefin bottle. The combined solutions are refrigerated until analyzed.

The solutions are analyzed for Hg by flameless atomic absorption. Five to 10 ml solution is weighed into an aeration tube, and treated with 1 to 3 ml of hydroxylamine-stannous chloride reducing mixture. Air flow through a fritted bubbles tube then carries the liberated Hg into the beam of the atomic absorption unit. The short-lived absorption signal is plotted on a chart recorder. Standard solutions prepared from certified reference solutions provide the points for a calibration curve.

The procedure was checked by processing known Hg solution through the digestion and analysis sequence (112% recovery), and by analyzing NBS certified orchard leaves. For the orchard leaves, which are certified to contain 155 ± 15 ng/g Hg, our procedure gave 135 ng/g. Our value is subject to slight change because the leaves were not dried before analysis.

d. Total Organic Carbon and Nitrogen. Three cc sediment samples were taken from the core section and placed in 10 cc vials which were stored frozen until analyzed. The samples were dried in an oven at approximately 100°C and a small subsample weighed out and loaded in the F & M CHN analyzer and burned. Samples were reburned until no further peaks for C and N occurred. Calibration curves were made by burning known amounts of a standard C and N source (acetanilide). Peak heights were plotted against concentration for calibration curves. Inorganic carbon correction was made as described by Allison (1965).

e. Total Phosphorus. Total phosphorus was determined at the Corvallis-EPA laboratory on dried subsamples of the samples used for the heavy metal analyses. Approximately 5 gram quantities were first ground to a fine powder in a mechanical mortar and pestle. A subsample of the sample powder was then analyzed as described below. "Accurately weigh approx 0.1000 g of finely ground sample into a 25 x 200 mm screw-cap test tube. Wet the sample with approximately 10 ml of distilled water. Add 6 ml of total Kjeldahl nitrogen acid digestant as prepared in Standard Methods for the Examination of Water and Wastewater. Heat in a block digester until fumes appear and then heat an additional two hours or until the major portion of the sample is digested. Cool and add 10.00 ml distilled water. Let the solids which are caked in the bottom of the tube soak until they soften then disperse them by shaking the tube on a vortex stirrer. Let the tubes stand until the solids settle, and then analyze the clear solution above the solids for orthophosphate, and run standards which contain the Kjeldahl digestant and which have been digested in the block digester as above." A geochemical reference standard (G-2) submitted along with the Miller Sands samples yielded a value of 810 µg/g, somewhat higher than the values reported in Flanagan (1968) (The highest value reported for this material was 650 µg/g). Agreement between duplicate analyses was better than 5%. (RSD ± 2%), for 4 duplicates.

f. Extractable Ammonium. 100 cc samples were taken from the core sections and placed in glass jars and immediately frozen. Samples were kept frozen until just before analysis. The thawed sample was processed as described in the following paragraph.

"Using a reagent of 10% (1.7 N) NaCl, acidified to pH 2.5 with HCl, ammonia is extracted from sediment by the following procedure (after Jackson, 1958, through item 5): 1) A 100 g, freshly taken sample is weighed out and placed in a 500 ml conical flask (a separate sample is needed for a moisture determination). 2) 200 ml of the acidified NaCl solution is added to the flask with sediment. 3) The suspension is shaken thoroughly at first, then intermittently for 1/2 hour. 4) The suspension is poured onto an 11 cm Buchner funnel on which an 11 cm Whatman #42 filter paper has been moistened and seated firmly by suction, and the leachate is collected. 5) 250 ml more of the acidified NaCl solution is passed through the sediment in increments, the first increment being used to rinse out the conical flask. Leachate is collected. 6) The total leachate from the 100 g sediment sample (in 450 ml of acidified solution) is sealed tightly in the collecting bottle. Ammonia determinations are run as soon as possible in the Auto-Analyzer®. Analysis in the AutoAnalyzer® is the same as for seawater samples. Ammonia is reported as mg/kg dry sediment."

g. Extractable Ca, Mg, Na and K. These analyses were performed by the OSU Soil Testing Lab on air dried subsamples of the sediment samples remaining after interstitial water was removed. The basic procedure involved extraction of the sediment sample with neutral normal ammonium acetate followed by analysis of the extract for the appropriate metal (see soil procedures for details).

h. Extractable Nitrate. Subsamples taken as above were submitted to the Soil Testing Lab for this analysis. The basic procedure involved extraction with 2 M KCl followed by nitrate analysis.

i. Extractable Phosphate. This was determined on samples collected as above at the Soil Testing Lab. The basic procedure involved an extraction with dilute acid-fluoride solution. See Soil procedures for details.

j. Eh, pH, and "Free" Sulfide. These measurements were made in the field at the time of collection and extrusion of the core sections. Eh and pH measurements were made by inserting a narrow diameter combination pH-reference electrode, to which was taped a bare platinum wire, into the wet sediment. The combination electrode was gently "agitated" in the wet sediment to facilitate the approach to equilibrium. Both the pH scale and absolute millivolt scales of the portable Orion 407A meter were used to record response from the probes. The same meter coupled to an Orion double junction reference electrode and sulfide ion electrode were used to attempt an estimate of "free" sulfur. The absolute millivolt scale was used in the latter case. Millivolt response was recorded and compared to calibration curves made in the laboratory before and after the field trip. Calibration curves were made by recording the millivolt readings obtained from a solution into which H_2S gas was bubbled. HCl in incremental amounts was added to vary the pH and the pH measured. From the dissociation constant for H_2S, the $S^=$ can be calculated. All millivolt readings made in the field (0 to + 100 mV) suggested the $S^=$ level would be well below 10^{-14} M; at the pH of the sediment, 7-7.5, approximately 10^{-6} of the total sulfur species (H_2S, HS^-, $S^=$) would be present as $S^=$. Thus the upper limit of total "free" sulfur species would be less than 10^{-8} M in these samples. The direct insertion determination of free sulfur must

be recognized as a rough guess at best. Titration of extracts would be more reliable.

The pH and Eh were read after no longer than 5 minutes. While longer equilibration times would have been desirable, the processing schedule and logistics precluded longer times. For the samples analyzed in this study, however, most of the change seemed to occur within the first few minutes. This is one constraint that must be recognized when considering the Eh values. The Eh value was calculated by adding 200 mV (Ag/AgCl reference electrode potential versus the hydrogen electrode) to the field recorded potential. ($Eh=E_{observed} + E_{ref}$). Response of the Eh/pH combination probe was continually checked against known solutions while in use (Zobells solution and NBS pH 7 buffer).

k. Total Sulfide. Collection, storage and analysis were as follows: Disposable 10 or 12 ml polypropene syringes were modified by cutting off the end of the syringe barrel with the needle fitting. The resulting cylinder and its plunger was used as a "minicorer" for collecting and storing sediment samples for sulfide determination. Samples were obtained from freshly sectioned box cores. The open end of the minicorer was covered with 2 layers of Saran Wrap that was held in place with a tightly stretched rubber band. (Saran Wrap has low oxygen permeability). After wrapping the sample was promptly frozen and stored at -20°C. Separate studies of sulfide sample storage stability showed that the sulfide content of frozen samples changed <10% during a year of storage. Sulfide content of the sediments was determined titrimetrically (APHA Standard Method 228A). The fluctuation of the blank analyseswas about 0.05 mgS. Since the typical sample

weighed about 15g, the minimum detectable sulfide concentration was about 3 mg/kg.

l. Percent Water. A 10 cc sample of wet sediment was collected from each core section with a plastic syringe, and transferred to pre-weighed bottle. The samples were immediately frozen and kept frozen until they were analyzed. In the lab the samples were dried at 70°C to constant weight and weighed.

Percent Water was calculated as the difference in weights between the wet and dry weight divided by wet weight times 100.

m. Chlorinated Hydrocarbons. Approximately 100 cc of wet sediment were carefully scooped from the core section with stainless steel scoop and placed in glass jars, which had been previously cleaned with reagent grade ethyl alcohol. Alcohol rinsed aluminum foil was stretched across the top of the jar before the lid was attached. These samples were stored frozen until they were analyzed by the OSU Agricultural Chemistry Department. Their procedure was as follows:

Samples were sieved to remove large biotic material, sticks, etc., and excess water poured off. The samples were then weighed into tared beakers. Muddy samples were mixed with Na_2SO_4 until they were free flowing. Samples were then transferred to pre-extracted Soxhlet extraction thimbles and extracted overnight with 9:1 acetone: water. A solvent blank was run with the solvents as well as a spiked sample to check recovery. The spike consisted of 500 µg A-1254 and 100 µg DDE. Extracts were transferred to erlenmeyer flasks, evaporated to a volume of 100 mls or less and transferred to a graduated cylinder: The volume of extract was noted and twice as much water added to the sample in a

separatory funnel. Three portions of hexane were added and the sample extracted three times. Hexane fractions were combined and backwashed with water, and then passed through a funnel containing a glass wool plug and Na_2SO_4 to remove any water from the hexane extract. Samples were then evaporated to a few mls for loading on a Florisil cleanup column. After loading on the Florisil column, the samples were eluted sequentially with two solutions; 1) a 5% benzene in hexane elution to separate DDT, BHC, PCB, chlordane and toxaphene compounds into one group and 2) a 10% ethyl ether, 0.25% acetone solution (in hexane) to remove the remaining heptachlor epoxide, endrin and dieldrin from the column. After evaporation of the 5% benzene-hexane fraction from the Florisil column down to 5 ml, 5 ml of trimethylpentane (TMP) were added and the solution evaporated again to a 5 ml volume to assure removal of the benzene. This fraction was then loaded on a 15 cm, 4.75 g activated silicic acid column and eluted with hexane to separate PCBs from DDT residues. The DDT residues were eluted from the column with 10% benzene in hexane. All fractions were subjected to gas chromatograph scans. Only the two fractions (PCB and DDT cuts) from the silicic acid column were subjected to quantitative analysis. The PCB fraction was analyzed on a HP #5700 A gas chromatograph with a 4' x 1/8" ID pyrex column and the DDT fraction was analyzed on a Varian Aerograph HyFi series 600 with a 5.6' x 1/8" ID pyrex column. Samples were quantified by comparison of sample peak areas determined by a HP computerized integrator. Both solvent blanks and a spiked sample were processed in the same manner as the samples to determine contaminant levels and recovery.

The indicated recovery for A-1254 and ppDDE was 84% and 90% respectively. Blank levels for these two compounds were 1.3 ppb and 0.012 ppb respectively as calculated for a typical sample weight of 35 grams. The final concentration reported in the tables were adjusted to reflect these recoveries and blank levels.

n. Radioanalysis. Air-dried sediment was packed in "Marinelli" beakers and analyzed by gamma ray spectrometry. Samples were counted for 1000 minutes using a High resolution, low-level counting system consisting of an 85 cc GE(Li) detector and 4096 multi-channel analyzer (Canberra 8100 and associated electronic and computer data processing interfaces). Lower levels of detection for Co-60, Eu-152, Cs-137 were approximately 0.01 pCi/g, and 0.2 pCi/g for K-40.

Interstitial Water. One hundred cc samples of the wet sediment collected in the mini-corers as described earlier, were stored at room temperature for the short time between collection and when they were extracted. Lids were kept over the exposed end of the sample plug during this time to prevent as much air contact as possible. The samples were placed in teflon chambers designed after the Reeburgh (1967) apparatus. Pressure was applied by bottled nitrogen. Nucleopore filters, 0.4 μm, were used in the filter holder section of the apparatus. The extracts were stored in two types of containers depending on the type of analysis to be performed. Samples for interstitial trace metals were stored in precleaned teflon bottles. Samples for nutrient analysis were stored in standard 30 ml nutrient bottles (polyethylene). All samples were frozen immediately and kept frozen

until analysis. Nutrient samples were analyzed using the Technicon autoanalyzer system previously described.

Trace metal levels in the interstitial waters were determined by carbon rod AA as previously described for the water analyses. The samples were first thawed, and weighed. Varying amounts of HNO_3 and HCl were added to the thawed samples to produce a sample matrix similar to the standards and to prevent adsorption on container walls. These samples were all run along with the water samples.

Soil

Soil samples include the intertidal or marsh samples as well as the samples on the dry portion of the older island. All soil samples were collected adjacent to the previously established sites selected by Woodward-Clyde consultants for the vegetation survey.

The marsh soils were sampled with the hand held corer previously described and used for sediment analysis. The core was sectioned into a 0-5 cm layer and a 20-25 cm layer. These samples were placed in plastic bags and stored in a cooler until returning to the lab.

Coring methods did not work on the dry, coarse sand of the main island. For these sites it was necessary to excavate with a shovel and then scoop representative material from a vertical profile covering approximately 5-15 cm. The top litter layer was intentionally avoided. Only one sample was taken per sample site. These samples were likewise stored in plastic bags until returning to the lab.

Heavy metal levels were determined in the OCERP lab as described for sediment. All other chemical analyses were determined as described in Methods of Soil Analysis Used in the Soil Testing Laboratory

at Oregon State University, Special Report 321, Revised June 1976, Agricultural Experiment Station, Oregon State University, Corvallis.

References Cited

Allison, L.E. 1965. Organic Carbon. In: C.A. Black, ed., Methods of Soil Analysis, Part II. Agronomy 9:1367-1378. American Society of Agronomy, Madison, Wisconsin.

American Public Health Administration. 1971. Standard Methods for the Examination of Water and Waste Water, 13th edition. APHA, Washington, D.C. 874 pp.

Bouma, A.H., and N.F. Marshall. 1964. A method for obtaining and analyzing undisturbed oceanic sediment samples. Marine Geology 2:81-99.

Farrow, N.D., and I.L. Larsen. 1974. A shallow water "mini-dredge". Exposure: A Newsletter for Ocean Technologists. 2(5):10-11.

Flanagan, F.J. 1969. U.S. Geological Survey Standards-II. First Compilation of Data for the New USGS Rocks. Geochim. et Cosmochim. Acta. 33:95.

Guy, H.P. 1969. Laboratory theory and methods for sediment analysis. Techniques of Water-Resources Investigations: Laboratory Analysis, Chapter C1. U.S. Geological Survey. 58 pp.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J. 498 pp.

Reeburgh, W.S. 1967. An improved interstitial water sampler. Limnol. Oceanog. 12:163-165.

Strickland, J.D.H., and T.R. Parsons. 1972. A Practical Handbook of Seawater Analyses. Fish. Res. Bd. Canada, Bull. 167. 310 pp.

Youden, W.J. 1951. Statistical Methods for Chemists. John Wiley and Sons, Inc. New York. 126 pp.

ADDENDUM B

1975 Miller Sands Data

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PART I: INTRODUCTION

This addendum contains analytical results only. Analytical procedures are contained in Addendum A along with methods of sample collection.

Water discharge data and current velocity measurements are provided in Tables B1 and B2. Other data are arranged by type of sample: water, sediment, and soil. Site maps showing location of sampling stations precede tabulation of data. Sampling dates and a summary of sampling events are as follows:

Sample Type	Dates Sampled (da/mo/yr)	Comments
Water	17/06/75	Grab samples collected from ship channel and cove for water quality and nutrient analyses; sub-samples taken for analysis by EPA for comparison. *In situ* measurements of nutrients and water quality made in ship channel.
	30/06/75	Grab samples collected from ship channel and cove for water quality, nutrients *and* heavy metal analyses.
	16/07/75	Grab samples taken for water quality, nutrients and heavy metals *during* construction of new fill; suspended sediment survey made in vicinity of outwash zone of pipe dredge.
	27/08/75	*In situ* measurement of water quality and nutrients in ship channel.
	20/10/75	*In situ* measurement of water quality and nutrients in ship channel.

	29/01/76	Special follow-up samples collected in ship channel to check for winter nitrate maximum.
Sediment	18/06/75	Initial sediment texture survey in upper cove.
	21/06/75	Box cores for sediment chemistry collected in dredging zone of ship channel.
	01/07/75	Cores for sediment chemistry collected from cove; texture survey extended.
Soil	17/07/75	Samples from main island collected.
	08/08/75	Marsh soil cores collected.
	29/11/75	Substrate samples from new fill and test plot collected for follow-up fertility analyses.

Notes of general nature are included at the beginning of each section; notes of limited application are made as footnotes to specific tables.

References cited in this addendum are included in the list which follows the text.

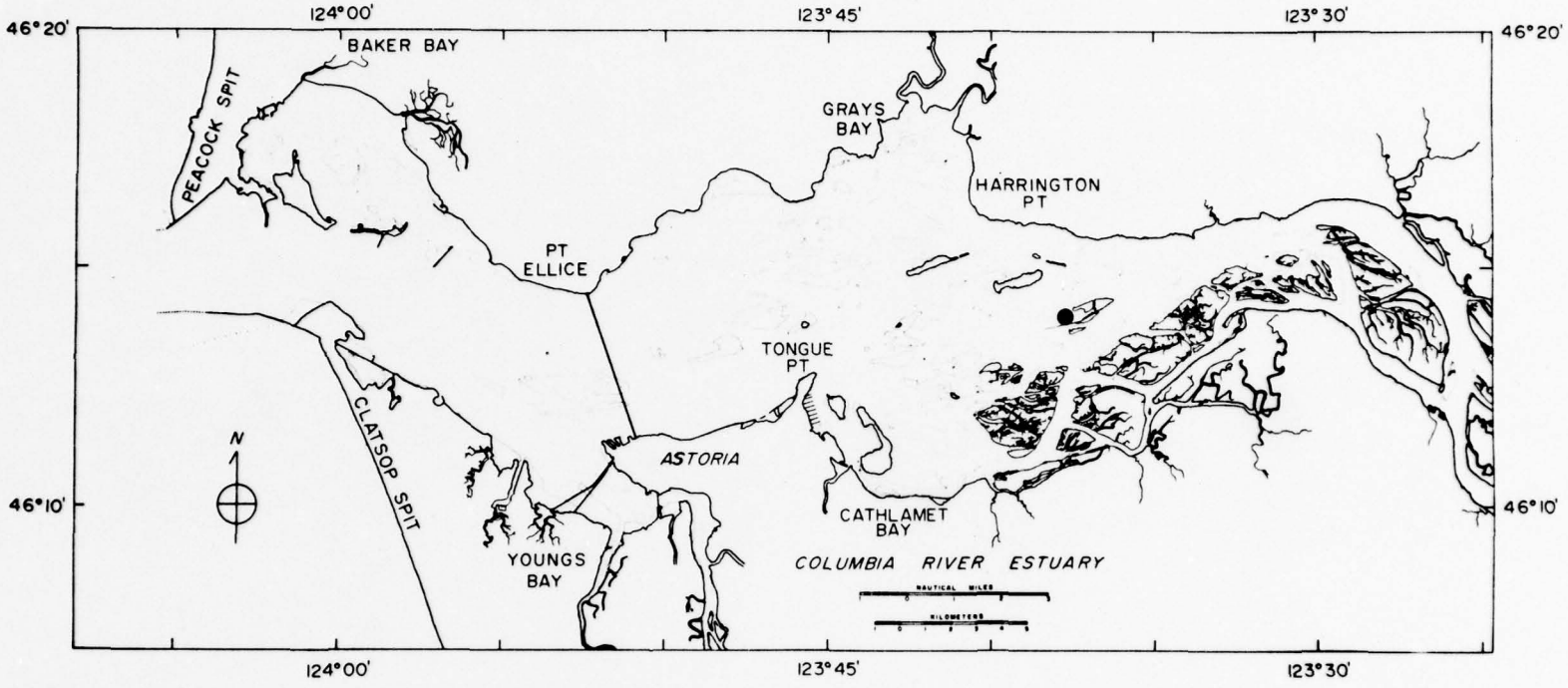


Figure B1. Columbia River estuary. Dot at Snag Island shows location of control station for sediment and water quality samples.

Table B1

Water Discharge, Columbia River Mouth, January 1974 through January 1976[1]

MO YR	ESTIMATED MEAN, CFS	ADJUSTED MEAN, CFS	PER-CENT OF 15 YR AVE
01 74	497000	461400	197
02 74	413600	330500	129
03 74	374500	336800	144
04 74	427800	459200	152
05 74	448400	582600	120
06 74	561600	915300	153
07 74	374300	472100	152
08 74	200000	200800	119
09 74	155200	101700	83
10 74	159600	87090	67
11 74	193300	126000	70
12 74	269600	207100	92
ANNUAL MEAN	354600	383500	141
01 75	347300	27700	110
02 75	307670	226100	87
03 75	333700	237500	99
04 75	283100	242900	90
05 75	373700	508600	97
06 75	389500	681300	114
07 75	248000	390100	123
08 75	149800	157700	93
09 75	139000	117300	96
10 75	163100	137800	107
11 75	250100	214000	120
12 75	412400	394000	176
ANNUAL MEAN	266500	272300	100
01 76	406400	337500	134

[1]From U.S. Geological Survey (1974, 1975, 1976). See "Literature Cited" section for complete reference. CFS indicates cubic feet per second.

Table B2

Current Velocities, Miller Sands, 8 September 1975

TIME	DEPTH, M	CM/S	
1220	0	0	S
1230	0	32	U
1240	0	35	U
1250	0	50	U
1300	0	55	U
1310	0	65	U
1320	0	70	U
1330	0	70	U
1340	0	75	U
1350	0	60	U
	2	60	U
	4	50	U
	6	35	U
	8	10	U
1400	0	60	U
1410	0	70	U
1420	0	80	U
1430	0	95	U
1440	0	90	U
1450	0	95	U
	2	90	U
	4	85	U
	6	80	U
	8	20	U
1500	0	85	U
1510	0	85	U
1520	0	80	U
1530	0	80	U
1540	0	80	U
1550	0	70	U
	2	85	U
	4	80	U
	6	70	U
	8	30	U
1600	0	70	U
1610	0	70	U
1620	0	60	U
1630	0	50	U
1640	0	45	U
1650	0	45	U
	2	45	U
	4	40	U
	6	35	U
	8	10	U
1700	0	20	U
1710	0	15	U
1720	0	15	U
1730	0	5	D
1740	0	10	D
1750	0	35	D
	2	35	D
	4	30	D
	6	30	D
	8	0	
1800	0	35	
1810	0	50	
1820	0	60	
1830	0	65	
1840	0	70	D
1850	0	80	D
	2	75	D
	4	70	D
	6	65	D
	7.5	50	D
	8	0	D
1900	0	80	D
1910	0	80	D
1920	0	90	D
1930	0	85	D
1940	0	80	D
1950	0	90	D
	2	90	D
	4	90	D
	6	75	D
	7.5	40	D
2000	0	90	D
2010	0	85	D

[1]The letters S, U, D are used to indicate direction of water flow. S is for slack water, U is for upstream and D is for downstream.

Table B2 (concluded)

TIME	DEPTH, M	CM/S	
2020	0	100	0
2030	0	110	0
2040	0	95	0
2050	0	95	0
	2	100	0
	4	90	0
	6	70	00
2100	0	105	0
2110	0	105	0
2120	0	100	0
2130	0	100	0
2140	0	105	0
2150	0	105	0
	2	100	0
	4	95	0
	6	70	0
2200	0	100	0
2210	0	100	0
2220	0	105	0
2230	0	100	0
2240	0	95	0
2250	0	90	0
	2	110	0
	4	95	0
	5	50	0
2300	0	90	0
2310	0	85	0
2330	0	80	0
2340	0	75	0
2350	0	75	0
	2	70	0
	4	70	0
	5	45	0

PART II: DATA ON WATER ANALYSES

INTRODUCTION

The grab sample data are given first (Tables B3-B6 and Figure B2-B5), followed by a tabulation of the *in situ* results (Table B7). Blank spaces in the tables mean that no data exists. A zero indicates that a measurement was made, but the amount was either zero or undetectable. An explanation of column headings covering all of the water sample results follows:

Column Heading	Meaning	Comment
STA NO	station number	The letters A and B indicate duplicate bottle casts.
LAT	latitude	The first two digits indicate degrees, the second two digits are for minutes, and the remaining numbers are for seconds to the nearest tenth of a second. Thus 461516.2 is: 46°15'16.2".
LONG	longitude	The first *three* digits are degrees; the next two digits are minutes and the remaining numbers seconds. Thus 1233945.7 would be: 123° 39'45.7".
TIME	time	Pacific Daylight Time
DEPTH	depth	Depth from surface in meters; 0 is used for surface sample.
DO	dissolved oxygen	Measured with portable salinometer (CTI) at same depth as grab sample was taken.
TEMP	temperature, °C	
SAL	salinity	

COND	conductivity	Measured with portable salinometer (CTI) at same depth as grab sample was taken.
pH	pH	
SUSP SED	Suspended sediment	In milligrams/liter
[Nutrients]		
TMT/PRSRV	treatment/ preservative	The *first* single letter code in this column refers to how the sample was treated; U designates unfiltered; F means filtered through 0.4 µm Nucleopore filter; S is for strained through 10 µm Nitex®. The *second* two letters are for the manner in which the sample was preserved following treatment. HG is used for samples preserved with mercuric chloride; FR is used for samples that were frozen, and NN designates no preservative (and analyzed on board the R/V YAQUINA within 3 hours of collection).
NH_3	ammonia	Micrograms/liter NH_3 as N.
$NO_3 + NO_2$	nitrate plus nitrite	Micrograms/liter $NO_3 + NO_2$ as N.
NO_3	nitrate	Micrograms/liter NO_3 as N.
NO_2	nitrite	Micrograms/liter NO_2 as N.
TAN	"total available nitrogen"	Based on nitrate analysis following UV oxidation, micrograms/liter TAN as N.
TAP	"total available phosphorus"	Based on phosphate analysis following UV oxidation, micrograms/liter TAP as P.
PO_4	phosphate (ortho)	Micrograms/liter PO_4 as P.
Silicate		Micrograms/liter silicate as silicon.

TKN	total Kjehldahl nitrogen	Run at Corvallis-EPA lab. Micrograms/liter TKN as N.
TP	total phosphorus	Run at Corvallis-EPA lab. Micrograms/liter TP as P.

[Trace Metals]

S	soluble	Trace metal concentrations are tabulated in three columns for each metal; S is used to designate the "soluble" results (concentrations for water passing the 0.4 µm filter). Following the S column are two columns designated with a P for particulate. The first P column represents the particulate metal concentration on a µg/liter basis while the other P column is used to tabulate particulate metal concentration as µg/gram of suspended sediment in the sample (obtained by dividing the µg/liter particulate metal values by the suspended sediment concentration for the sample).
P	particulate	

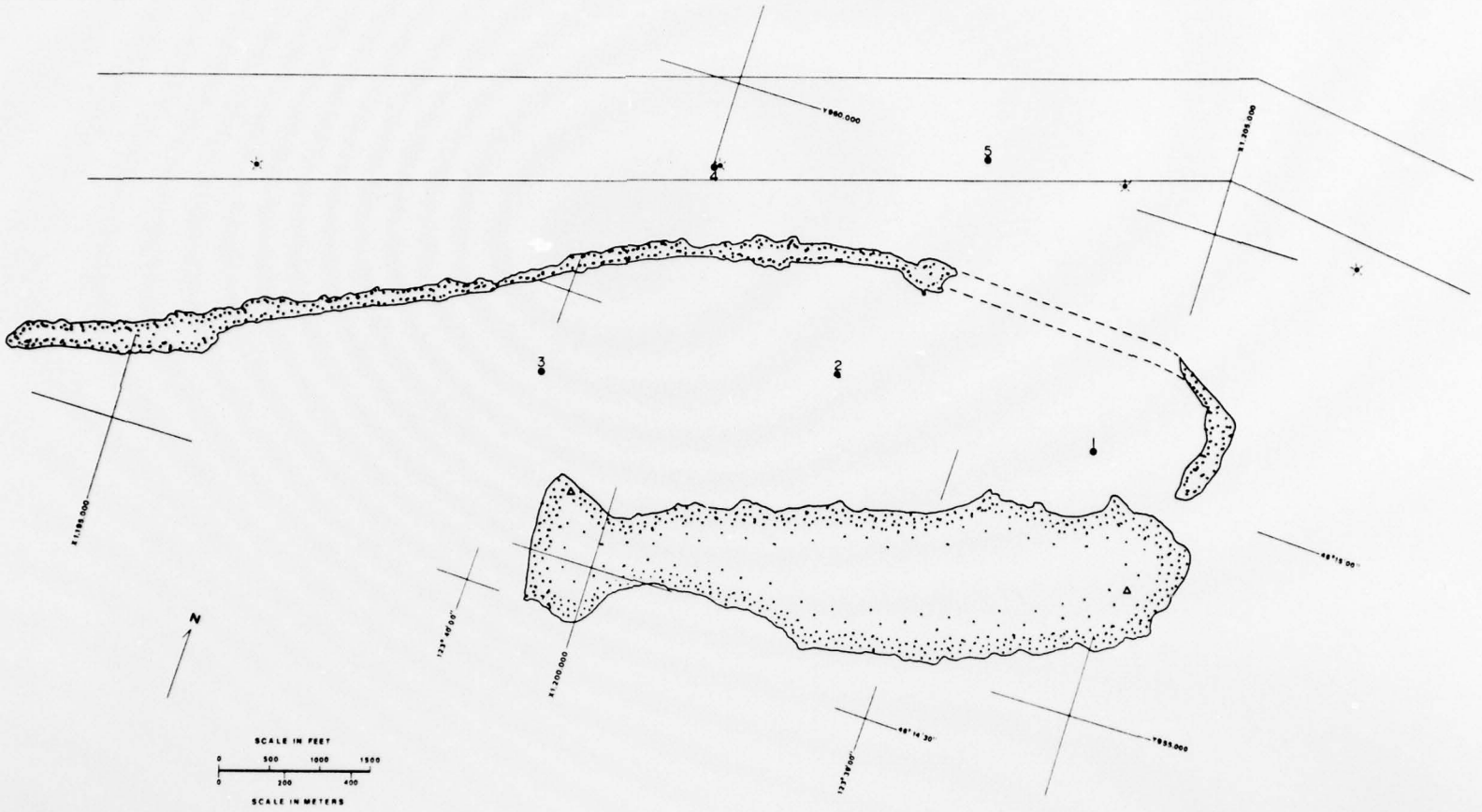


Figure B2. Station locations for water quality survey, Miller Sands, 17 June 1975

Table B3

Water Quality Survey (Grab Samples), Miller Sands, 17 June 1975

STA NO	LAT	LONG	TIME	DEPTH,M	TEMP C	DO MG/L	SAL PPT	COND	PH	SUSP SED MG/L
1A	461502.2	1233812.3		0	14.6	10.2	0	0.1	7.8	30
1B	461502.2	1233812.3	0945	0	14.6	10.0	0	0.1	7.9	21
2A	461501.2	1233919.7		0	14.8	10.4	0	0.1	8.0	
2B	461501.2	1233919.7	1015	0	14.8	10.3	0	0.1	7.9	21
3A	461451.7	1233959.6		0	15.4	10.8	0	0.1	8.2	19
3B	461451.7	1233959.6	1035	0	15.4	10.2	0	0.1	8.2	21
4A	461516.2	1233945.7		0						21
4B	461516.2	1233945.7		0	15.7	10.2	0	0.1	7.9	19
4A	461516.2	1233945.7		10						21
4B	461516.2	1233945.7	1135	10	15.8	10.3	0	0.1	7.7	21
5A	461525.6	1233909.1		0	15.7	10.4	0	0.1	8.0	24
5B	461525.6	1233909.1		0						22
5A	461525.6	1233909.1		10	15.7	10.4	0	0.1	8.1	23
5B	461525.6	1233909.1	1205	10						24

Table B3 (concluded)

STA NO	DEPTH M	TMT/ PRSRV	NH3, UG/L	NO3+NO2, UG/L	NO3, UG/L	NO2, UG/L	TAN, UG/L	TAP, UG/L	PO4, UG/L	SILICATE MG/L	TKN, UG/L	TP UG/L
1A	0	U HG	1	5					30		260	70
1B	0	U HG	4	5					30		350	80
1A	0	U NN	28.4	5.2	4.9	0.3	243	46	38	4.16		
1B	0	U NN	6.7	3.2	3.2	0			42	4.27		
2A	0	U HG	2	5					20		460	60
2B	0	U HG	6	5					20		270	110
2A	0	U NN	1.7	7.2	6.3	0.9			34	4.30		
2B	0	U NN	5.0	11.6	10.6	1.0	126	23	33	4.97		
3A	0	U HG	2	5					10		300	40
3B	0	U HG	2	5					10		270	50
3A	0	U NN	1.3	4.1	4.1	0	178	35	21	4.27		
3B	0	U NN	9.0	1.7	1.4	0.3	223	36	23	4.41		
4A	0	U HG	7	5					10		220	40
4B	0	U HG	5	5					10		160	20
4A	0	U NN	3.5	9.8	8.7	1.1	208	39	18	4.44		
4B	0	U NN	6.3	2.7	2.7	0			19	4.51		
4A	10	U HG	3	5					10		250	50
4B	10	U HG										
4A	10	U NN	1.3	4.2	2.9	1.3	211	35	18	4.58		
4B	10	U NN	5.2	4.6	3.6	1.0	232	35	21	4.58		
5A	0	U HG										
5B	0	U HG										
5A	0	U NN	2.5	3.6	3.6	0	170	34	21	4.41		
5B	0	U NN		4.8	3.7	1.1	205	35	20	4.58		
5A	10	U HG										
5B	10	U HG	2	5					10		260	50
5A	10	U NN	4.1	5.0	4.3	0.7	198	36	20	4.61		
5B	10	U NN	7.7	4.2	3.4	0.8	189	44	20	4.58		

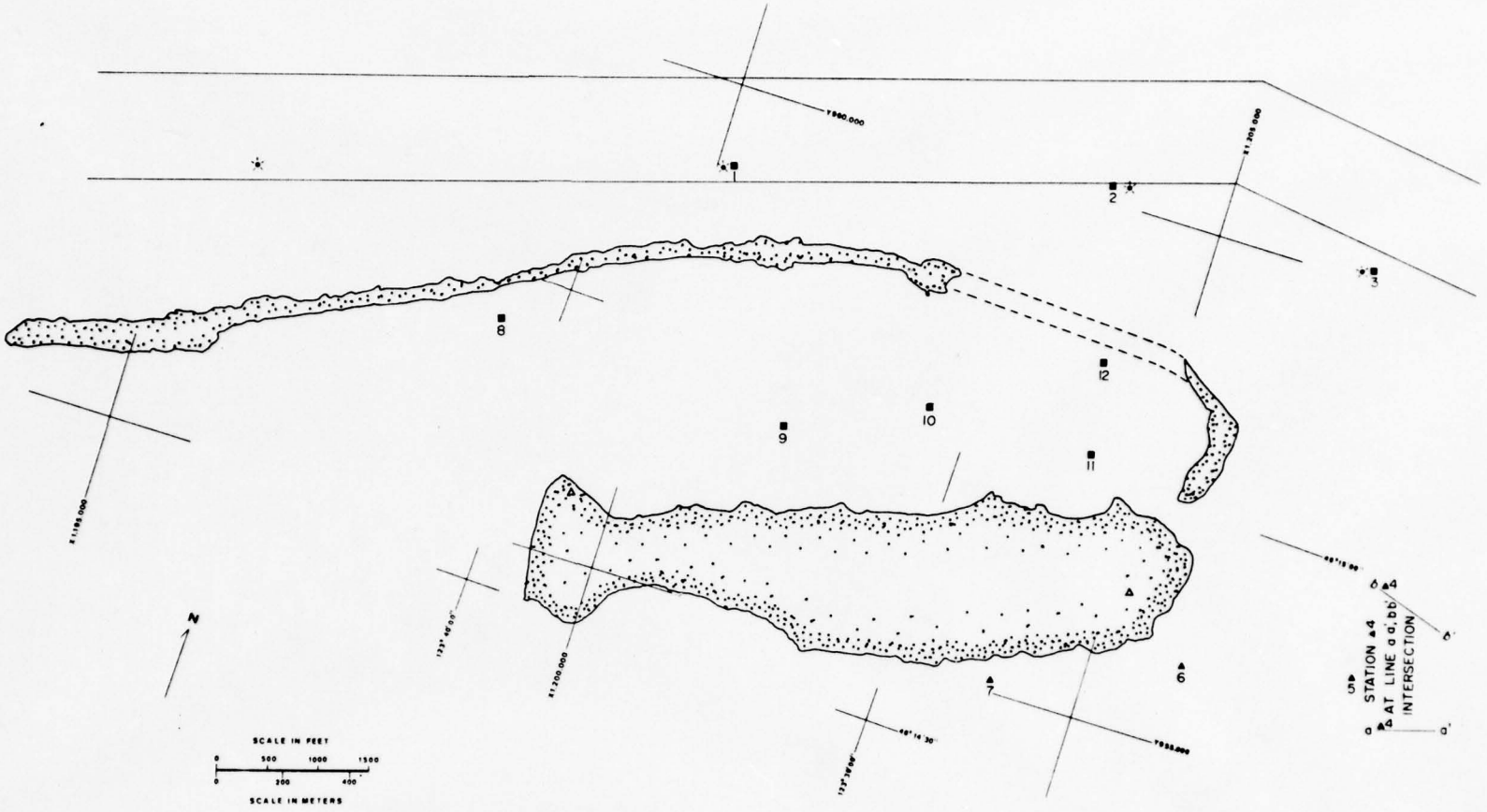


Figure B3. Station locations for water quality survey (grab samples), Miller Sands, 30 June 1975

Table B4

Water Quality Survey (Grab Samples), Miller Sands, 30 June 1975

STA NO	LAT.	LONG.	TIME	DEPTH,M	TEMP C	DO MG/L	SAL PPT	COND	PH	SUSP SED MG/L
1A	461516.7	1233943.7	1545	0	15.8	10.0			8.0	23
1B	461516.7	1233943.7		0						21
2A	461527.5	1233952.0		0	15.8	9.0			7.9	19
2B	461527.5	1233952.0		0						21
3A	461528.2	1233813.0		0	15.8	9.0			7.8	21
3B	461528.2	1233813.0		0						19
4	461452.3	1233727.2		0						18
5	461450.0	1233756.7		0						28
6	461445.2	1233820.2		0						22
7	461437.6	1233845.2		0						19
8A	461455.0	1234003.0	1810	0	15.8	9.9			7.9	24
8B	461455.0	1234008.0		0						24
9A	461454.5	1233925.0	1830	0	16.0	10.4			8.5	38
9B	461454.5	1233925.0		0						
10A	461501.2	1233906.3	1850	0	16.0	10.0				40
10B	461501.2	1233906.3		0						
11A	461501.7	1233842.5		0	17.2	10.0				40
11B	461501.7	1233842.5		0						
12A	461510.7	1233845.2		0	17.0	10.5				58
12B	461510.7	1233845.2	1910	0						

Table B4 (continued)

STA NO	DEPTH M	TMT/ PRSRV	NH3, UG/L	NO3+ NO2, UG/L	NO3, UG/L	NO2, UG/L	TAN, UG/L	TAP, UG/L	PO4, UG/L	SILICATE MG/L
1A	0	U HG	0	0		2.0	11	61	16	0.46
1B	0	U HG	0	0		0.8	54	30	17	0.42
1A	0	U FR	6.2	0.3		0.3	51	34	18	2.56
1B	0	U FR	8.3	1.2	0.8	0.4	54	28	19	1.28
1A	0	S FR								
1B	0	S FR								
1A	0	F FR		15.8	14.7	1.1	61	10		
2A	0	U HG	0	0		0.7	110	189	139	2.58
2A	0	U FR	4.5	0		0.3	60	26	21	1.97
2A	0	S FR	0							
2B	0	S FR	0							
2A	0	F FR	3.4	6.5	5.4	1.1			11	
3A	0	U HG	0	0.7	0.1	0.6	131.	30	17	4.74
3B	0	U HG	0	0		0.6	111.	25	14	4.41
3A	0	U FR	5.2	0	0	0	58.	30	24	4.01
3B	0	U FR	6.0	0	0	0	60.	36	17	1.80
3A	0	S FR		2.1			7.	33		5.83
3B	0	S FR		2.4			4.	15		
3A	0	F FR	3.8	3.2	2.2	1	39.	7	6	0.34

Table B4 (continued)

STA NO	DEPTH M	TMT/PRSRV	NH3, UG/L	NO3+NO2, UG/L	NO3, UG/L	NO2, UG/L	TAN, UG/L	TAP, UG/L	PO4, UG/L	SILICATE MG/L
9A	0	U HG						37	16	1.45
9B	0	U HG	4.5	19.2	18.4	0.8	119.	33	16	5.13
9A	0	U FR	5.9	0	0	0.3	60.	40	20	3.07
9B	0	U FR	7.0	0	0	0.7	64.	28	23	5.87
9A	0	S FR		1.5			3.4	54		4.73
9B	0	S FR	7.7	7.2	6.9	0.3	3.4	46		4.23
9A	0	F FR	3.1	2.9	2.0	0.9			6	
9A	0	U HG	0.3	3.4	3.1	0.3	111	36	18	4.69
9A	0	U FR	4.5	0	0	0.7				
9B	0	U FR	4.5	0	0	0.7	68	29	19	1.21
9A	0	S FR		9.5	9.1	0.4	63	18		0.99
9A	0	F FR	1.3	3.8	3.2	0.6	50	11	6	0.84
10A	0	U HG	0	3.4	3.2	0.2	132	34	20	5.18
10A	0	U FR	4.8	0	0	0.8	68	31	18	0.23
10B	0	U FR	5.5	0	0	0.7	69	30	22	1.06
10A	0	S FR	0	14.2	13.9	0.3	3	38		0.44
10A	0	F FR	1.7	30.4	30.4	0	75	5	6	0.65
11A	0	U HG	0.4	3.2	3.2	0	143	40	24	5.03
11A	0	U FR	5.3	0	0	0.7	54	39	28	1.99
11B	0	U FR	1.1	0	0	0	64	44	17	1.53
11A	0	S FR		16.4	16.1	0.3	63	15		

Table B4 (continued)

STA NO	DEPTH M	TMT/ PRSRV	NH3, UG/L	NO3+NO2, UG/L	NO3, UG/L	NO2, UG/L	TAN, UG/L	TAP, UG/L	PO4, UG/L	SILICATE MG/L
11A	0	F FR	3.9	2.1	1.7	0.4	1	27	1.9	
12A	0	U HG	0.6	0	0	0.1	90	67	25	7.92
12A	0	U FR	4.3	0	0	0	68	31	19	1.56
12B	0	U FR	1.0	0	0	0	3	31	19	2.38
12A	0	S FR	0	17.0	15.6	1.4				
12A	0	F FR	2.7	3.4	2.9	0.5	1	28	8	3.08

Table B4 (concluded)

STA NO	SUSP SED MG/L	IRON SOL UG/L	IRON PART UG/L	IRON PART UG/G X10³	MANGANESE S	MANGANESE P	MANGANESE B X10³	ZINC S	ZINC P	ZINC B	COPPER S	COPPER P	COPPER B
1	22	130	790	36	3	27	1.2	<0.5	6.5	300	<2	1.1	51
2	20	130	570	28	4	16	0.8	1	4.7	240	<2	1.1	54
3	20	14	880	44	3	29	1.4	2	8.1	400	<2	1.3	65
4	18	160	850	47	3	27	1.5	1	7.9	440	<2	1.2	67
5	28	68			2			<0.5	12.4	440	<2		
6	22	25	890	40	4	27	1.2	1	6.9	310	<2	0.9	43
7	19	93	640	34	4	20	1.0	<0.5	4.7	250	<2	0.7	37
8	24	48	1050	44	4	33	1.5	2	9.2	380	<2	1.5	61
9	38	150	1430	38	14	56	1.5	1	11.0	290	<2	1.5	40
10	40	19	2290	57	6	69	1.7	<0.5	17.5	440	<2	2.1	53
11	40	94	1300	32	28	40	1.0	2	8.6	220	<2	1.8	45
12	58	64	3580	62	16	120	2.1	1	24.5	420	<2	2.2	38

STA NO	PB S	PB P	PB B	NI S	NI P	NI B	CD S	CD P	CD B	CR S	CR P	CR B	CO S	CO P	HG S	HG P
1	<2	0.8	40	<5	<0.5		<0.2	<0.1		<3	1.4	64	<3	<0.3	<25	<0.25
2	<2	0.9	40	<5	<0.5		<0.2	<0.1		<3	1.1	55	<3	<0.3	<25	<0.25
3	<2	0.7	40	<5	<0.5		<0.2	<0.1		<3	1.3	65	<3	<0.3	<25	<0.25
4	<2	0.7	40	<5	<0.5		<0.2	<0.1		<3	1.2	67	<3	<0.3	<25	<0.25
5	<2	0.9	30	<5	<0.5		<0.2	<0.1		<3			<3	<0.3	<25	<0.25
6	<2	0.7	30	<5	<0.5		<0.2	<0.1		<3	1.4	64	<3	<0.3	<25	<0.25
7	<2	0.8	40	<5	<0.5		<0.2	<0.1		<3	1.2	63	<3	<0.3	<25	<0.25
8	<2	0.7	30	<5	<0.5		<0.2	<0.1		<3	1.7	71	<3	<0.3	<25	<0.25
9	<2	1.0	30	<5	<0.5		<0.2	<0.1		<3	2.0	53	<3	<0.3	<25	<0.25
10	<2	1.0	20	<5	<0.5		<0.2	<0.1		<3	3.0	75	<3	<0.3	<25	<0.25
11	<2	0.7	20	<5	<0.5		<0.2	<0.1		<3	1.9	48	<3	<0.3	<25	<0.25
12	<2	0.5	10	<5	<0.5		<0.2	<0.1		<3	5.8	100	<3	<0.3	<25	<0.25

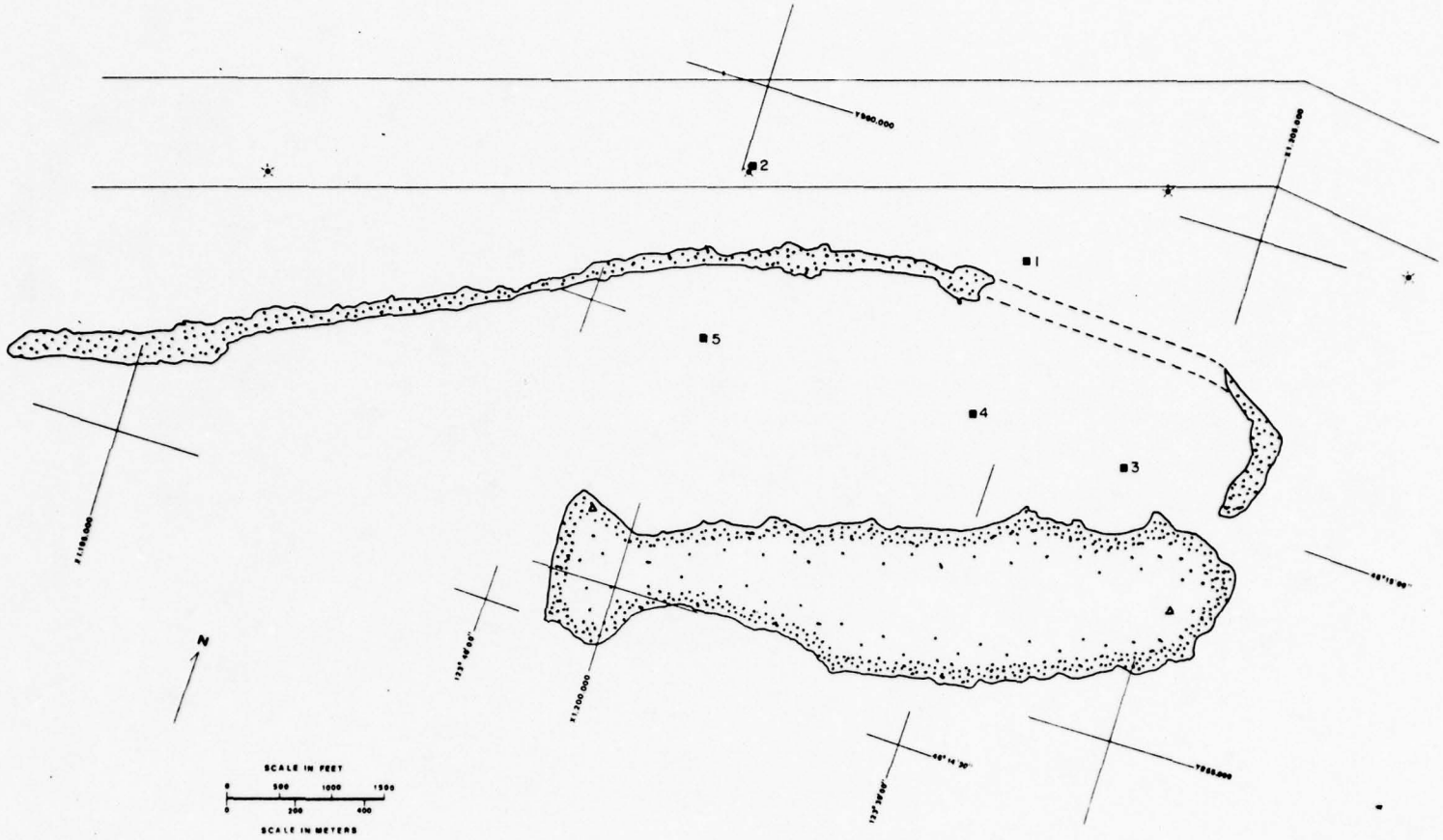


Figure B4. Station locations for water quality survey (grab samples), Miller Sands, 16 July 1975

Table B5

Water Quality Survey (Grab Samples), Miller Sands, 16 July 1975

STA NO	LAT	LONG	TIME	DEPTH,M	TEMP C	DO MG/L	SAL PPT	COND	PH	SUSP SED MG/L
1A	461517.3	1233905.2	1510	0	18.9	9.2	0	0.1	8.0	43
1B	461517.3	1233905.2		0	18.9	9.0	0	0.1	8.0	43
2A	461517.0	1233945.0	1555	0	18.4	8.7	0	0.1	7.9	19
2B	461517.0	1233945.0		0	18.4	8.7	0	0.1	7.8	19
2A	461517.0	1233945.0	1620	10	18.3	8.9	0	0.1	7.8	24
2B	461517.0	1233945.0		10	18.3	9.0	0	0.1	7.9	25
3A	461502.0	1233843.2	1720	0	18.4	8.2	0	0.1	8.0	24
3B	461502.0	1233843.2		0	18.4	8.2	0	0.1	8.0	25
4A	461501.9	1233905.2	1746	0	18.7	8.5	0	0.1	8.0	30
4B	461501.9	1233905.2		0	18.7	9.0	0	0.1	8.0	31
5A	461500.0	1233943.7	1830	0	18.6	8.4	0	0.1	8.0	12
5B	461500.0	1233943.7		0	18.6	8.8	0	0.1	8.0	12
6A	SNAG ISLAND		1910	0	18.4	8.3	0	0.1	8.0	16
6B	SNAG ISLAND			0	18.4	9.0	0	0.1	8.1	15

Table B5 (continued)

STA NO	DEPTH M	TMT/ PRSRV	NH3, UG/L	NO3+ NO2, UG/L	NO3, UG/L	NO2, UG/L	TAN, UG/L	TAP, UG/L	PO4, UG/L	SILICATE MG/L
1A	0	U HG	4.9	6.0	4.9	1.1	112.	26	24	1.64
1B	0	U HG	14.7	6.0	4.9	1.1	121.	31	23	1.74
1A	0	S FR		2.2			69.5	18	29	2.48
1A	0	S FR		2.4			67.3	17	31	
1B	0	S FR		2.7			64.3	18	37	1.15
1B	0	S FR		2.8			66.7	19	30	
1A	0	F FR	29.1	7.0	7.0	0	68.7	13	9	1.88
1B	0	F FR	5.5	3.1	3.1	0	53.5	5	8	
2A	0	U HG	8.9	5.0	3.8	1	106.	31	19	3.17
2B	0	U HG	4.1	2.5	1.8	0.7	95.8	20	14	1.50
2A	0	S FR	0	7.3	7.3	0	80.0	16	13	1.38
2A	0	S FR	0	8.3	8.3	0	70.8	11	13	0.78
2B	0	S FR	0	6.9	6.9	0	71.3	7	14	0.71
2B	0	S FR	0	2.5	2.2	0.3	71.6	12	14	
2A	0	F FR	0	2.7	2.7	0	60.7	9	6	1.78
2B	0	F FR	0	2.1	2.11	0	56.7	13	6	1.76
2A	10	U HG	21.7	5.5	5.3	0.2	118.	3.1	13	1.67
2B	10	U HG	10.5	2.0	2.0	0	125.	2.9	11	1.51
2A	10	S FR	6.9	32.1		0	127	14.	10	
2A	10	S FR		52.5			132	21.	12	0.37
2B	10	S FR		5.2			53.1	9.6	19	0.60
2B	10	S FR		2.4			49.6	2.5	18	1.05
3A	0	U HG	6.2	0.1	0.1	0	138.	34.	21	1.40
3B	0	U HG	7.7	0.1	0.1	0	90.5	35.	25	3.10

Table B5 (continued)

STA NO	DEPTH M	TMT/ PRSRV	NH3, UG/L	NO3+NO2, UG/L	NO3, UG/L	NO2, UG/L	TAN, UG/L	TAP, UG/L	PO4, UG/L	SILICATE MG/L
3A	0	S FR		8.6			91.6	21.	44	2.64
3A	0	S FR		2.7			55.1	11.	41	0.57
3B	0	S FR		1.8			66.5	24	49	1.03
3B	0	S FR		1.5			70.0	27	48	1.62
3A	0	F FR	0	2.1	1.7	0.4	59.4	14	12	2.05
3B	0	F FR	3.1					16	10	0.63
4A	0	U HG	7.6	2.4	2.3	0.1	111.	29	18	1.50
4B	0	U HG	9.5	2.4	2.4	0	115.	33	17	1.79
4A	0	S FR		3.2			56.6	1	47	0.903
4A	0	S FR		3.9			74.7	18	34	1.99
4B	0	S FR		6.0	3.2	2.8	61.4	24	13	1.62
4B	0	S FR		7.1	3.6	3.5	45.3	39	14	0.61
4A	0	F FR	0	4.9	4.9	0	55.2	12	5	0.53
4B	0	F FR	1.3	4.9	4.9	0	76.6	13	7	2.03
5A	0	U HG	0	2.8	2.8	0	102.	24	15	2.06
5B	0	U HG	0	2.7	2.7	0	118.	25	12	2.11
5A	0	S FR		6.2	2.4	3.8	56.5	21	2	0.94
5A	0	S FR		3.8	3.6	0.1			7	
5B	0	S FR		5.0	2.9	2.1	63.5	13	7	1.64
5B	0	S FR		4.1	2.7	1.4	64.2	13	8	2.30
5A	0	F FR	0	3.5	3.5	0	64.7	9	13	
5B	0	F FR	0	2.5	2.5	0	77.3	14	3	2.37
6A	0	U HG	1.8	2.8	2.7	0.1	93.4	26	12	3.70
6B	0	U HG	1.3	2.2	2.2	0	103.	24	11	

Table B5 (continued)

STA NO	DEPTH M	TMT/ PRSRV	NH3, UG/L	NO3+NO2, UG/L	NO3, UG/L	NO2, UG/L	TAN, UG/L	TAP, UG/L	PO4, UG/L	SILICATE MG/L
6A	0	S FR		1.5			66	16	11	1.76
6A	0	S FR		0.7			91	19	16	0.96
6B	0	S FR		5.0			66	15	21	1.76
6B	0	S FR		0			52	14	9	0.98
6A	0	F FR	0	3.9	3.9	0	53	96	10	0.96

Table B5 (concluded)

STA NO	SUSP SED MG/L	IRON SOL UG/L	IRON PART UG/L	IRON PART UG/G X10³	MANGANESE S	MANGANESE P	MANGANESE P X10³	ZINC S	ZINC P	ZINC P	COPPER S	COPPER P	COPPER P
1A	43	77	2240	52	30	77	1.8	1	12.9	300	<2	0.8	19
1B	43	66	3090	72	41	110	2.6	3	15.7	370	<2	1.8	41
2A	19	39	710	37	2	26	1.4	<0.5	7.5	400	<2	0.7	37
2B	19	32	790	42	2	28	1.5	<0.5	6.4	340	<2	1.0	52
3A	24	30	1290	54	35	50	2.1	1	9.5	400	<2	1.3	55
3B	25	45	1210	49	34	48	1.9	1	10.0	400	<2	1.0	41
4A	30	31	1450	48	33	62	2.1	1	10.7	360	<2	1.9	63
4B	31	26	1450	47	34	65	2.1	<0.5	11.3	370	<2	1.1	36
5A	19	32	690	36	4	24	1.3	1	5.5	290	<2	0.6	32
5B	18	94	660	37	4	27	1.5	<0.5	6.4	360	<2	1.0	57
6	16	25	630	39	2	25	1.6	1	5.7	360	<2	0.8	48

STA NO	PB S	PB P	PB P	NI S	NI P	NI P	CD S	CD P	CD P	CR S	CR P	CR P	CO S	CO P	HG S	HG P
1A	<2	0.3	7	<5	<0.5		<0.2	<0.1		<3	3.2	74	<3	<0.3	<2.5	<.25
1B	<2	0.3	7	<5	<0.5		<0.2	<0.1		<3	4.3	100	<3	<0.3	<2.5	<.25
2A	<2	0.2	10	<5	<0.5		<0.2	<0.1		<3	1.3	68	<3	<0.3	<2.5	<.25
2B	<2	0.1	5	<5	<0.5		<0.2	<0.1		<3	7.1	370	<3	<0.3	<2.5	<.25
3A	<2	0.3	10	<5	<0.5		<0.2	<0.1		<3	1.7	70	<3	<0.3	<2.5	<.25
3B	<2	0.2	8	<5	<0.5		<0.2	<0.1		<3	1.8	72	<3	<0.3	<2.5	<.25
4A	<2	0.5	20	<5	<0.5		<0.2	<0.1		<3	2.3	77	<3	<0.3	<2.5	<.25
4B	<2	0.5	20	<5	<0.5		<0.2	<0.1		<3	2.3	74	<3	<0.3	<2.5	<.25
5A	<2	0.3	20	<5	<0.5		<0.2	<0.1		<3	1.4	74	<3	<0.3	<2.5	<.25
5B	<2	0.3	20	<5	<0.5		<0.2	<0.1		<3	1.5	83	<3	<0.3	<2.5	<.25
6	<2	0.2	10	<5	<0.5		<0.2	<0.1		<3	3.0	190	<3	<0.3	<2.5	<.25

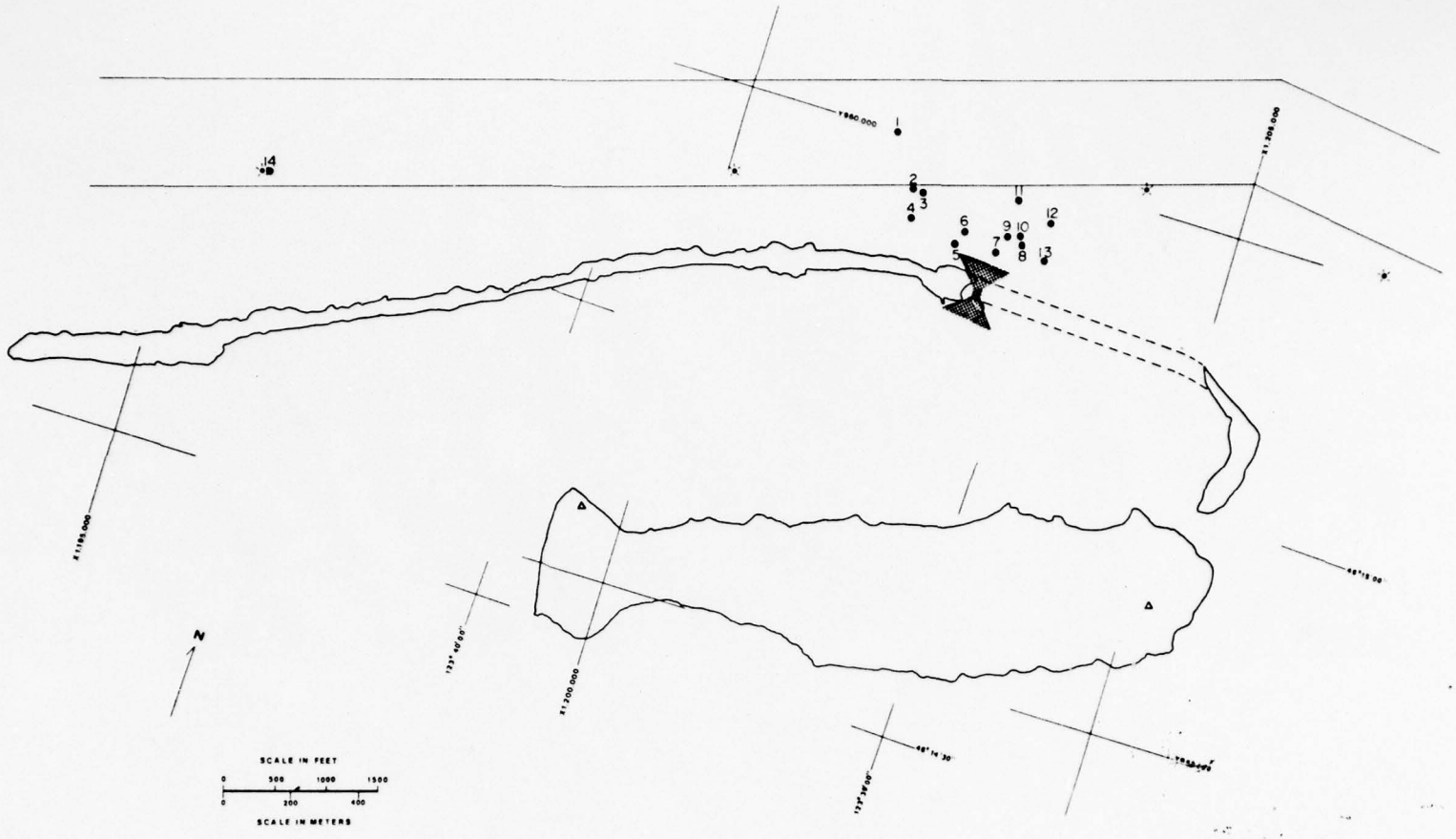


Figure B5. Stations for suspended sediment survey (grab samples), Miller Sands, 16 July 1975. Shaded area shows approximate location of outwash zone from the dredge-discharge pipe.

Table B6

Suspended Sediment Survey (Grab Samples), Miller Sands, 16 July 1975

SUSPENDED SEDIMENT SURVEY (GRAB SAMPLES),

STA NO.	DEPTH M	LAT	LONG	SUSP SED CN MG/L
1	0	461525.2	1233925.0	17
1	9	461525.2	1233925.0	22
2	0	461520.5	1233920.6	17
2	6	461520.5	1233920.6	22
3	0	461520.6	1233919.2	17
3	6	461520.6	1233919.2	21
4	0	461518.6	1233919.7	39
5	0	461517.2	1233912.6	26
5	2	461517.2	1233912.6	41
6	0	461518.5	1233912.0	16
6	4	461518.5	1233912.0	19
7	2	461517.6	1233907.0	20
8	0	461519.0	1233903.7	16
9	3	461519.3	1233906.0	20
10	0	461519.7	1233904.5	18
11	0	461523.2	1233906.0	18
11	6	461522.7	1233906.0	24
12	0	461522.0	1233900.7	16
12	6	461522.0	1233900.7	22
13	0	461518.5	1233900.0	19
13	3	461518.5	1233900.0	21
14	0	461501.1	1234047.3	18
14	0	461501.1	1234047.3	17
14	10			17
14	10			18

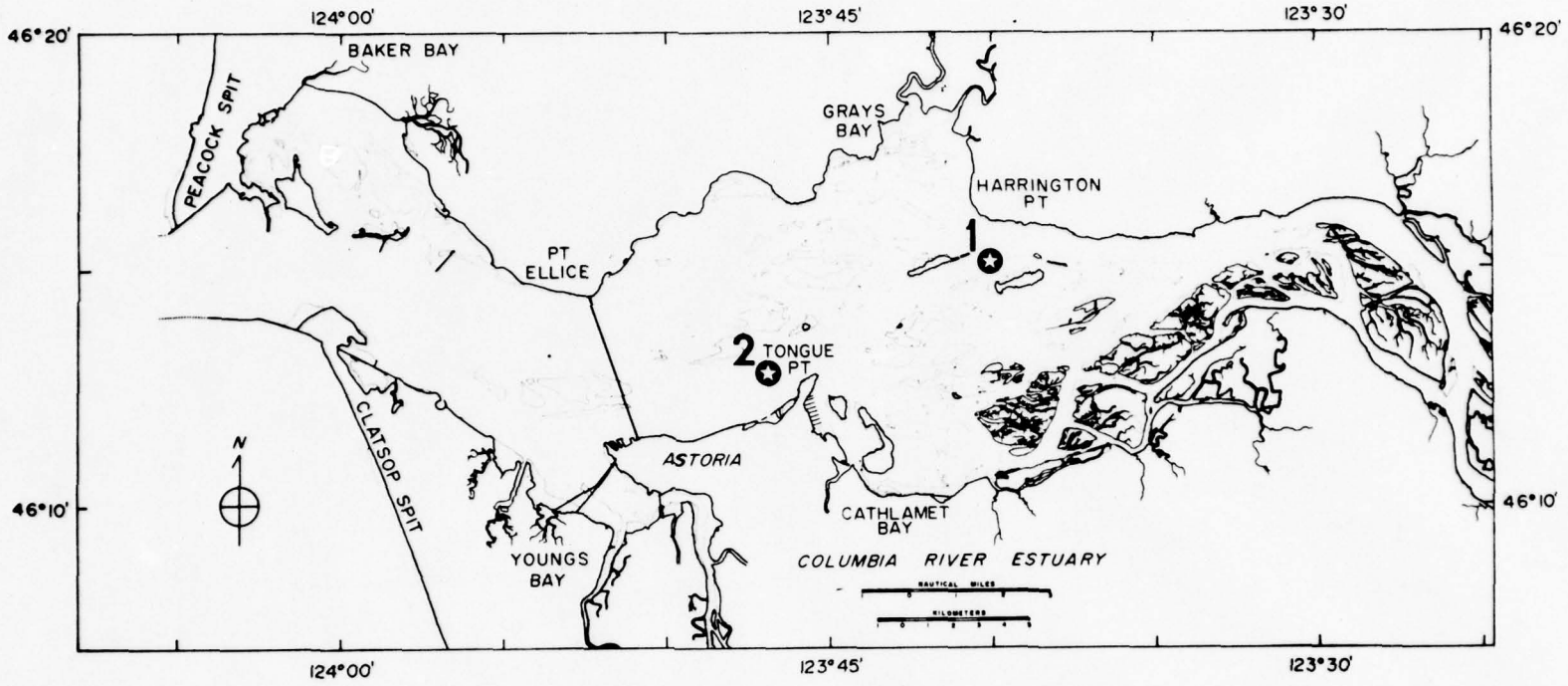


Figure B6. Station locations for water quality survey (*in situ* samples), Miller Sands, 17 June-20 October 1975 (1 is for Miller Sands and 2 is for Tongue Point).

Table B7

Water Quality Survey (*In situ* Samples), Miller Sands,

17 June-20 October 1975

STA NO	DATE D/M/Y	TIME PD	BTM DPTH M	SMPL DPTH M	SAL PPT	TEMP C	DO MG/L	NH4 UG/L	NO3 UG/G	NO2 UG/G	TAN UG/G	PO4 UG/G	TAP UG/G	SILICATE MG/G
TONGUE POINT														
30	170675	0945	12	0	0.0	15.65	10.8	11.0	3.1	0.8	80.0	15.1	25.9	3.94
30			12	5	0.0	15.65	10.8	9.9	2.5	1.5	80.2		24.9	3.94
30			12	10	0.0	15.65	9.9	9.0	3.3	0.8	85.4	14.9	23.1	3.80
17	270875	1345	12	0	0.25	18.88	9.0	5.2	5.0	0.6	60.5	12.1	1.5	
17			12	5	2.41	18.84	7.9	12.0	5.9	0.8	62.3		19.2	
17			12	10	3.66	18.41	7.8	13.0	13.9	0.7	79.9	11.8	45.8	
3	201075	1315	12	0	1.99	14.61	8.8	24.2	100.4	3.1	99.1	25.7	67.5	3.40
3			12	5	4.08	14.51	9.2	27.2	113.2	2.5	102.0	28.8	67.8	3.46
3			12	10	7.12	14.30	8.6	39.1	99.4	1.3	106.4	31.0	63.2	2.77
MILLER SANDS														
31	170675	1030	18	0	0.0	15.55	11.0	28.0	1.7	1.8	86.9	21.4	28.4	4.17
			18	5	0.0	15.55	11.1	15.0	3.1	0.8	86.9	19.8	26.8	4.03
			18	10	0.0	15.55	11.0	17.0	2.5	1.4	84.9	19.8	25.3	4.09
			18	15	0.0	15.55	11.0	17.0	2.7	2.2	83.9	19.2	23.2	4.14
4A	201075	1450	18	0	0.06	14.97	9.3	8.0	102.3	2.9	177.5	28.2	40.0	
			18	5	0.06	14.97	9.3	8.1	102.8	2.7	180.2	29.4	36.9	
			18	10	0.07	14.97	9.3	5.7	103.3	2.5	95.9	30.7	31.0	
			18	15	0.08	14.97	9.3	6.7	99.1	2.5	95.3	26.0	53.6	
4B			18	0				5.7	99.5	3.5		33.5		
			18	5				4.1	97.2	3.2		32.2		
			18	10				4.2	97.6	3.1		31.9		
			18	15				3.6	97.9	3.1		29.1		

B DESIGNATES SAMPLES THAT WERE PASSED THRU GFC FILTERS PRIOR TO ANALYSIS.

Table B7 (continued)

STA NO	DATE DD D/M/Y	SMPL DPTH M	PART N UG/L	PART C UG/L	PART C/N RATIO	CHLOR A UG/L	CHLOR B UG/L	CHLOR C UG/L	PHAEO A UG/L	PH	TOC MG/L
TONGUE POINT											
30	170675	0	189	1750	9.2					8.21	2.98
		5	169	1470	8.7					8.30	2.61
		10	203	1340	6.6					8.25	3.04
17	270975	0	77	598	7.7	6.76	0.1	1.43	6.28	7.99	
		5	117	855	7.3	3.11	0.1	0.60	7.61	7.78	
		10	145	1105	7.6	3.12	0.2	2.84	5.51	7.81	
3	201075	0				5.21	0.0	2.29	5.51	7.82	
		5	52	453	8.7	4.73	0.0	1.84	5.76	7.86	
		10				6.26	0.0	2.05	8.02	7.97	
MILLER SANDS											
31	170675	0	57	420	7.4					8.05	2.78
		5	155	1130	7.3					8.24	3.00
		10	127	861	6.8					7.81	2.66
		15	87	584	6.7						3.05
4A	201075	0								7.87	
		5	47	388	8.3	6.56	0.0	2.87	4.66	7.87	
		10	31	248	8.0	6.69	0.0	2.46	2.91	7.89	
		15	62	608	9.8	6.18	0.0	2.77	3.42	7.93	

Table B7 (concluded)

STA NO	NAME	DATE D/M/Y	LOCATION PARAMETERS LATITUDE	LONGITUDE
30	TONGUE PT	170675	46 12 45	123 47 00
17	TONGUE PT	270875	46 12 48	123 46 48
3	TONGUE PT	201075	46 12 54	123 46 42
31	MILLER SANDS	170675	46 15 24	123 39 48
4	MILLER SANDS	201075	46 15 24	123 39 54

Table B8

Follow-up Nutrient Measurements, 29 Jan 76[1]

Replicate	No_3-N µg/l	PO_4-P, µg/l	SiO_4-Si mg/l
1	382	50	4.87
2	384	49	4.87
3	385	51	4.88

[1]Samples were collected at Station 1 (Figure B6). The unfiltered water was analyzed within 24 hours of collection. No preservatives were added; samples were kept refrigerated prior to analysis.

PART III: DATA ON SEDIMENT ANALYSES

INTRODUCTION

Two types of sediment samples were collected: surface grabs and cores (see Figures B7 and B8 for station locations). Specific information about core locations is provided in Table B9. The results of sediment analyses are arranged in three parts: physical, chemical, and radiochemical.

Physical Results

The physical analytical results consist of size distribution data for both surface grab samples collected for the sediment texture survey (Table B10 and Figure B9) and selected core sections (Table B11). All particle size data are tabulated as percent by size class in phi units, where

$$\text{phi} = -\log_2 (\text{diameter in mm}).$$

The column headings in phi size class and corresponding millimeter equivalents are shown below:

Column Heading (phi units)	Millimeter equivalent	Column Heading (phi units)	Millimeter equivalent
<0	>1	5-6	0.032-0.016
0-1	1-0.5	6-7	0.016-0.008
1-2	0.5-0.25	7-8	0.008-0.004
2-3	0.25-0.125	8-9	0.004-0.002
3-4	0.125-0.063	>9	<0.002
4-5	0.063-0.032		

Chemical Results

Chemical analyses were performed on "total" sediment, i.e. unsqueezed sediment samples, and on interstitial water squeezed from sediment samples. Total sediment results are tabulated in Table B12, and interstitial results are found in Table B13. See Figure B8 and Table B9 for station locations.

Total Sediment. An explanation of column headings and clarifying comments concerning results shown in Table B12 for total sediment is given below. Headings explained in the introduction to Part II of this addendum are not repeated here.

Column Heading	Meaning	Comment
MED DIAM	median diameter	median diameter of sample in phi units (see discussion of phi units above).
SORT	sorting	sorting parameter in phi deviation measure; a small value indicates good sorting while a high value indicates poor sorting.
CEC	cation exchange capacity	given in milliequivalents (meq)/gram
FE, MN, ZN, CU, PB, NI, CD, CR, CO	standard chemical symbols for the metals	All metal data are given in µg/g with the exception of Fe which is tabulated as percent (PCT). Hg is also included in the last column.
TON	total organic nitrogen	given in µg/g as N; determined by CHN analyzer.
TOTP	total phosphorus	µg/g as P.
NH_4	extractable ammonium	µg/g as N.
TOC	total organic carbon	µg/g carbon; determined by CHN analyzer.

EX.CA	extractable calcium	meq/gram; extracted with NH_4Ac
EX.MG	extractable magnesium	meq/gram; extracted with NH_4Ac
EX.NA	extractable sodium	meq/gram; extracted with NH_4Ac
EX.K	extractable potassium	µg/g; extracted with NH_4Ac
EXTR.NO_3	extractable nitrate	reported as µg/g N
EXTR.PO_4	extractable phosphate	reported as µg/g P
EH	redox potential	given in millivolts
pH	pH	
FREE S	free sulfide	determined by direct insertion of sulfide electrode in the field.
TOTAL S	total sulfide	
WATER CNT	water content	results given in weight percent
HG	mercury	µg/g

Interstitial Water. All metal results are in units of mg/liter (Table B13). The nutrient results are as indicated in the column headings. TAN and TAP are given in mg/l as N and P as determined by nitrate and phosphate analysis following UV oxidation, which is presumed to represent total dissolved nitrogen and phosphorus. DOC is for dissolved organic carbon. It should be noted that the nutrient samples (interstitial water) for cores SC 3 through SC 7 were lost or misplaced; thus, no data are shown for these samples.

Radiochemical Results.

Results of radioanalyses for selected core sections are given in Table B14. The results are given in picocuries/gram along with the standard deviation (1 sigma) of the analysis. The analyses were performed on total sediment.

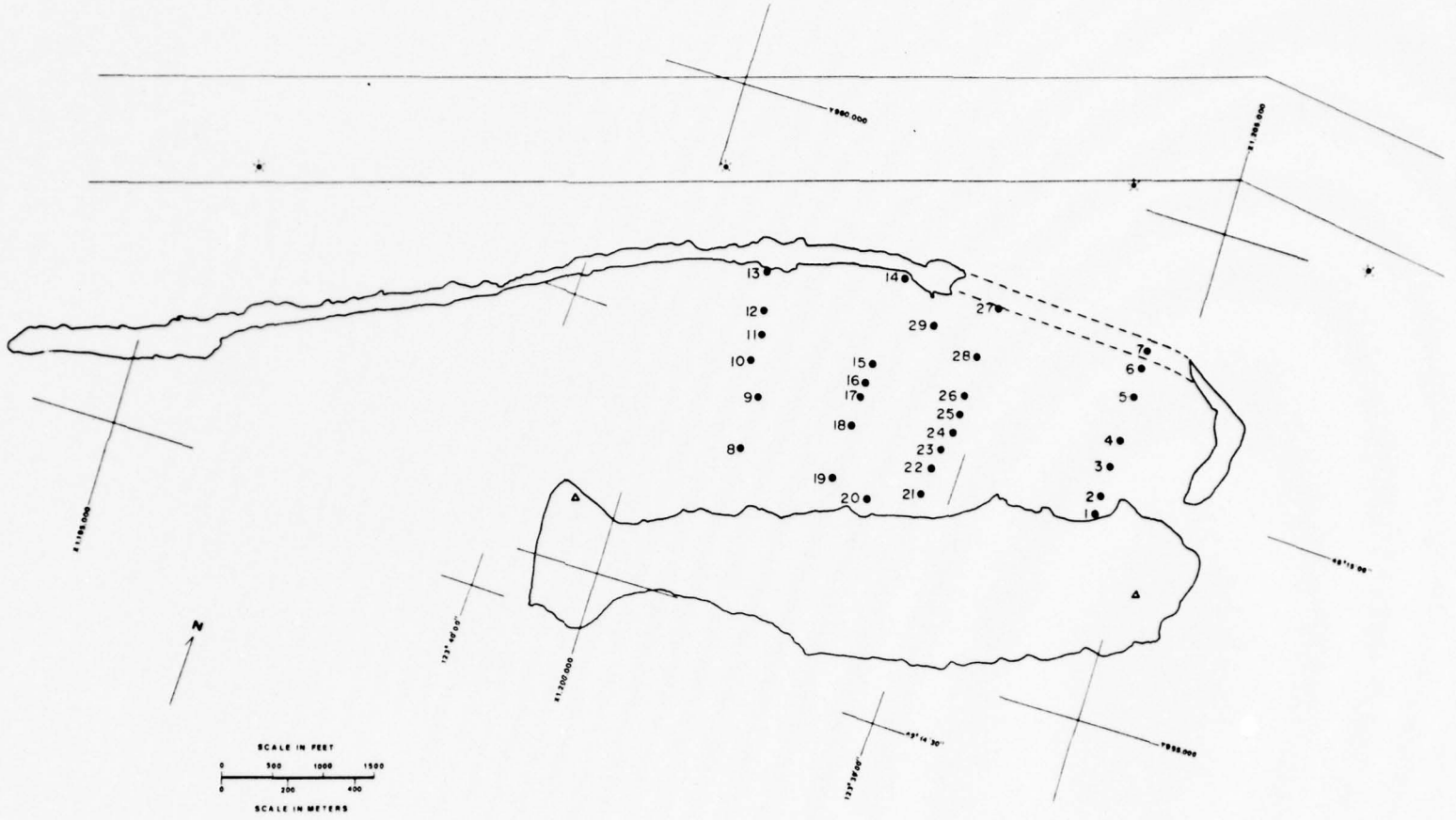


Figure B7. Station locations for sediment texture survey, Miller Sands, 18 June-29 November 1975

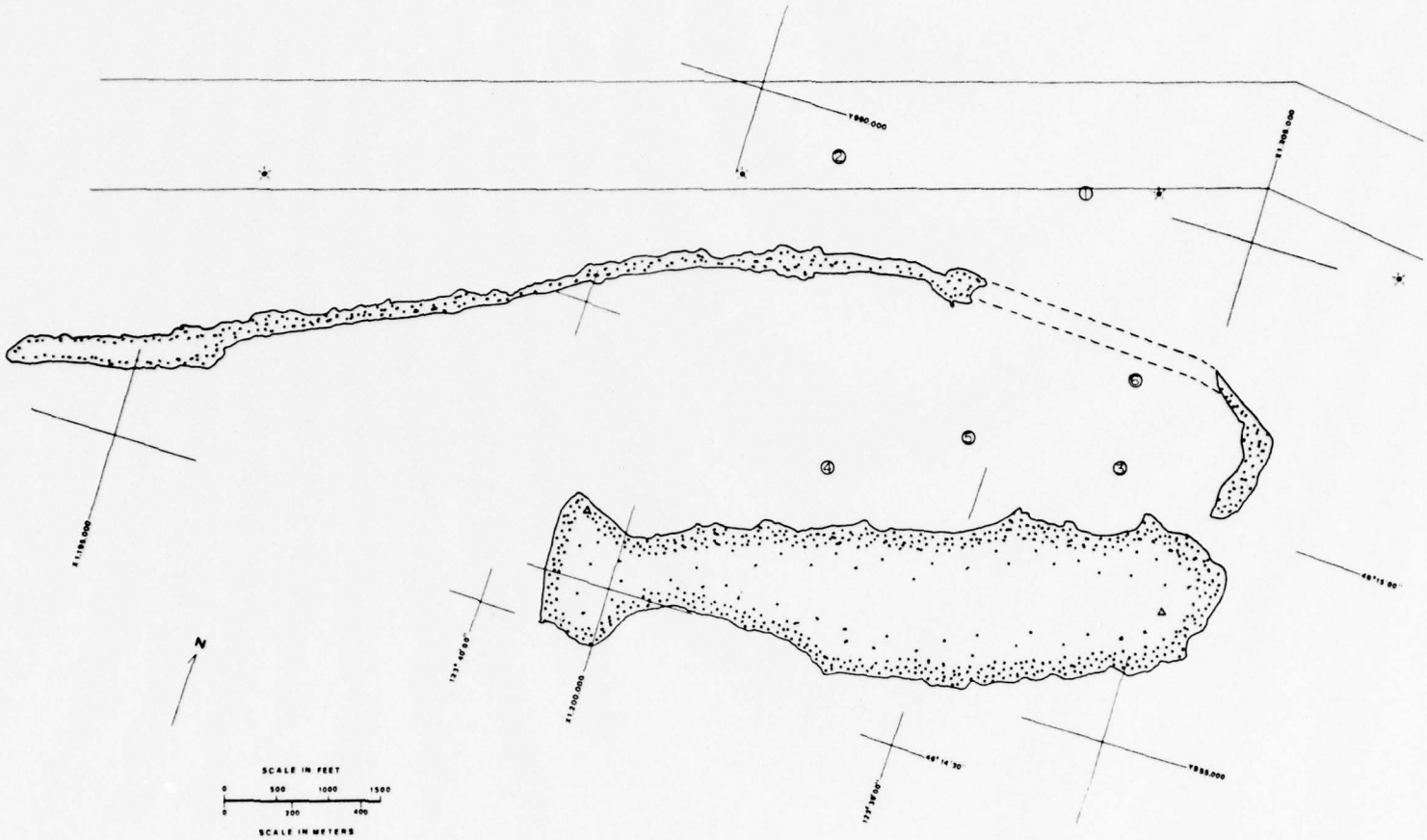


Figure B8. Station locations for core samples, Miller Sands, 21 June and 1 July 1975

Table B9

Sediment Core Locations, Miller Sands, 21 June and 1 July 1975

Core No.	Location		Date Collected (da/mo)	General Description
	Latitude	Longitude		
SC01	46°15'25.7"	123°38'59.3"	21/06	dredging zone in ship channel
SC02	46°15'21.2"	123°39'33.3"	21/06	dredging zone in ship channel
SC03	46°15'02.3"	123°38'42.6"	01/07	east end of cove adjacent to NHFS benthic sampling station B2
SC04	46°14'53.2"	123°39'21.0"	01/07	mid cove near NMFS benthic station B4
SC05	46°15'00.2"	123°39'03.7"	01/07	mid cove near NMFS benthic station B3
SC06	46°15'10.6"	123°38'44.6"	01/07	far northeast corner of cove
SC07	*46°14'	123°48'	01/07	Snag Island (control site)

*Approximate location.

Table B10

Sediment Texture Survey (Grab Samples),

Miller Sands, 18 June-29 November 1975

STA NO	LAT	LONG	PHI SIZE CLASS, PERCENT <0	0-1	1-2	2-3	3-4	>4	DATE COLLCTD
TS01	461458.6	1233840.2	2	11	58	27	2	0	180675
TS02	461456.7	1233840.2	0	1	17	54	19	9	180675
TS03	461501.7	1233840.2	0	1	6	36	31	26	180675
TS04	461504.3	1233840.3	1	1	6	45	29	18	180675
TS05	461508.7	1233840.5	0	0	7	65	15	13	180675
TS06	461511.6	1233840.5	1	4	9	15	19	52	180675
TS07	461513.5	1233840.6	1	2	10	57	20	10	180675
TS08	461451.3	1233930.6	0	1	37	53	6	3	020775
TS09	461456.5	1233930.7	0	1	32	24	23	20	020775
TS10	461459.7	1233933.3	0	0	2	24	47	27	020775
TS11	461502.5	1233933.0	0	0	1	25	61	13	020775
TS12	461504.7	1233934.0	0	0	4	41	42	13	020775
TS13	461508.3	1233935.3	0	0	0	18	55	27	020775
TS14	461512.2	1233916.6	0	1	2	23	51	23	020775
TS15	461503.3	1233917.0	0	0	1	15	57	27	020775
TS16	461503.5	1233917.0	0	1	2	9	47	41	020775
TS17	461500.0	1233917.0	0	0	4	29	29	38	020775
TS18	461457.0	1233917.0	0	1	20	63	14	2	020775
TS19	461451.6	1233915.2	0	0	1	39	39	21	020775
TS20	461451.0	1233914.0	0	0	7	41	20	32	020775
TS21	461453.0	1233904.5	0	7	43	18	13	19	020775
TS22	461455.6	1233904.2	0	1	6	18	29	46	020775
TS23	461457.7	1233903.6	0	1	12	29	21	37	020775
TS24	461459.6	1233903.0	0	1	26	40	12	21	020775
TS25	461501.6	1233902.7	0	0	12	37	20	31	020775
TS26	461503.5	1233903.2	0	1	10	38	23	28	020775
TS27	461512.6	1233902.5	0	0	3	37	44	14	080875
TS28	461507.4	1233903.0	0	1	32	41	23	3	080875
TS29	461508.9	1233910.4	0	1	1	24	56	18	080875
TS30	461514.9	1233858.9	5	7	40	44	4	0	291175
TS31	461514.6	1233903.0	4	8	56	29	2	1	291175
TS32	461508.0	1233939.0	2	4	59	34	1	0	291175
TS34	461507.6	1233942.0	1	4	47	42	5	1	291175

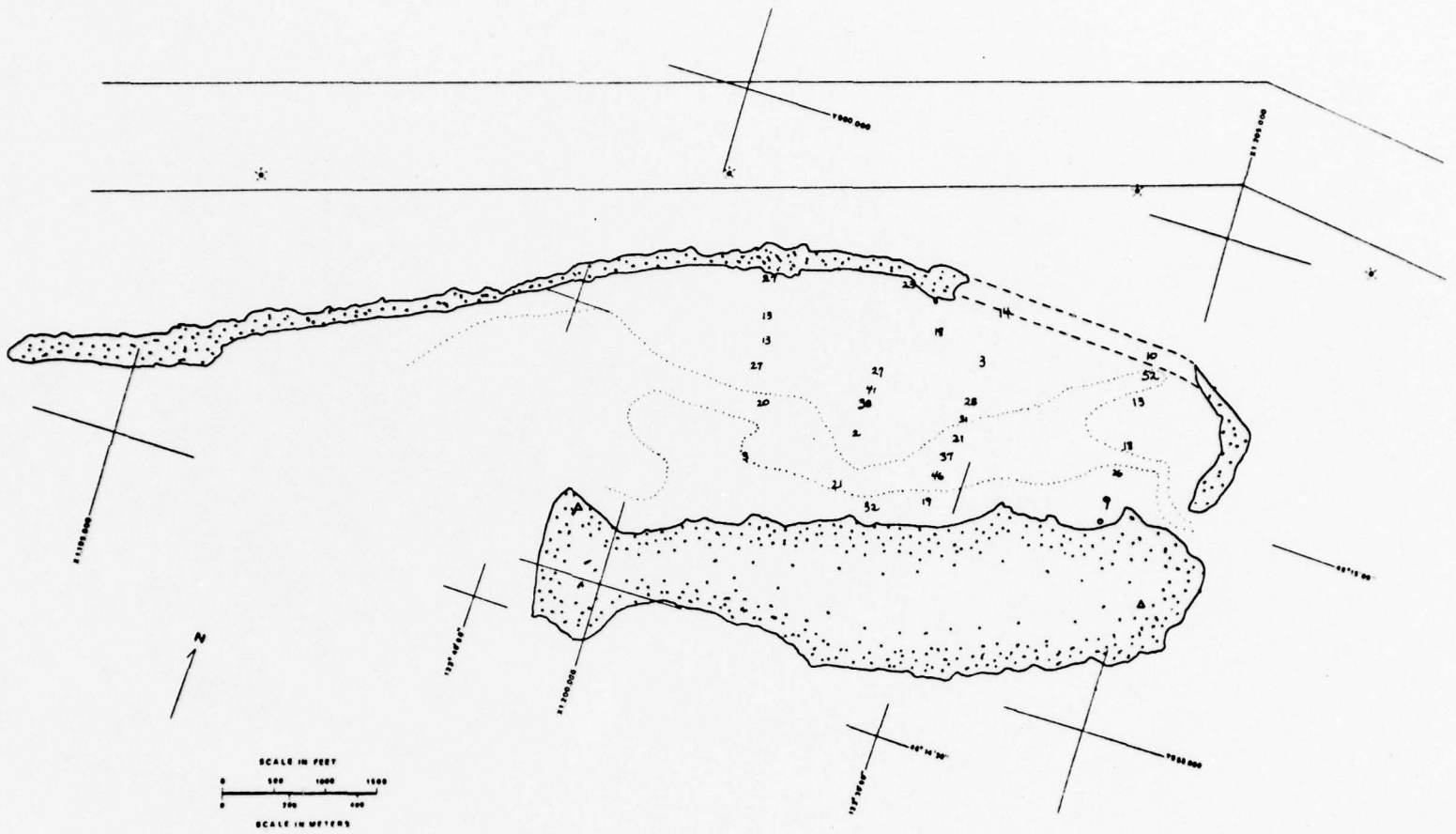


Figure B9. Percent fines (<0.063 mm) at stations shown in Figure B7

Table B11

Texture Analysis of Core Samples, Miller Sands,

21 June and 1 July 1975

CORE NO	SECT DPTH CM	PHI SIZE CLASS, PCT <0	0-1	1-2	2-3	3-4	>4
SC01	0-5	0	14	57	28	1	0
SC01	10-15	0	6	51	41	2	0
SC01	15-20	0	3	57	38	2	0
SC02	0-5	0	11	67	21	1	0
SC02	10-15	2	31	52	14	1	0
SC02	20-25	5	32	44	17	2	0
SC02	30-35	1	19	58	20	1	0

CORE NO	SECT. DPTH CM	TYPE ANAL.	PHI SIZE CLASS, PERCENT <0	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	>9
SC03	0-5	NATIVE	0.0	0.6	2.4	37.7	31.1	9.7	6.3	4.3	1.9	1.9	4.1
SC03	0-5	DISPERSED	0.0	0.3	1.9	38.1	31.2	7.0	6.7	4.0	2.1	2.2	6.5
SC03	25-30	DISPERSED	1.3	9.4	55.6	24.4	7.7	1.6*					
SC04	0-5	DISPERSED	0.2	2.9	51.3	32.4	10.4	2.8*					
SC04	25-30	DISPERSED	0.1	4.5	34.6	44.1	15.1	1.6*					
SC05	0-5	NATIVE	0.1	0.9	1.6	21.9	34.1	13.7	9.9	6.0	3.2	2.6	6.6
SC05A	0-5	DISPERSED	0.0	0.2	0.9	22.0	32.3	12.7	10.8	5.9	3.8	2.3	9.1
DC05B	0-5	DISPERSED	0.2	0.5	1.2	22.1	30.8	14.2	9.9	7.2	3.4	2.4	8.9
SC05C	0-5	DISPERSED	0.0	0.1	1.2	20.8	33.1	15.0	10.2	5.7	3.2	2.4	8.3
SC05	25-30	DISPERSED	0.0	0.4	0.1	9.1	48.0	22.6	6.9	4.4	1.6	1.4	5.5
SC06	0-5	NATIVE	0.2	0.5	2.3	6.2	23.2	18.0	18.0	11.4	3.6	6.6	10.0
SC06	0-5	DISPERSED	0.0	0.1	1.8	2.9	21.4	12.6	17.3	13.9	8.4	3.7	17.9
SC06	25-30	DISPERSED	0.9	0.2	21.6	38.5	23.6	15.2*					
SC07	0-5	DISPERSED	0.0	1.0	40.8	49.4	7.2	1.6*					
SC07	25-30	DISPERSED	0.0	1.1	34.0	53.6	9.2	2.1*					

* VALUES WITH STARS ARE IN >4 PHI CLASS

Table B12

Chemical Analyses on Total Sediment (Core Samples),

Miller Sands, 21 June and 1 July 1975

CORE NO	SECT. DEPTH CM	MED DIAM. PHI	SORT.	CEC MEQ/G	FE PCT	MN UG/G	ZN UG/G	CU UG/G	PB UG/G	NI UG/G	CD UG/G	CR UG/G	CO UG/G
SC01	0-5	1.66	0.58	0.028	0.42	92	22.0	2.3	0.5	1.4	.05	1.5	3.7
SC01	10-15	1.90	0.56	0.030	0.49	123	34.0	2.0	1.6	3.1	.05	3.0	4.3
SC01	15-20	1.88	0.50	0.028	0.37	80	24.0	2.3	0.9	3.8	.05	1.6	3.2
SC02	0-5	1.60	0.59	0.024	0.38	87	20.0	2.0	1.4	2.9	.05	1.7	3.4
SC02	10-15	1.30	0.65	0.032	0.48	111	23.0	2.5	0.8	3.6	.05	1.5	4.0
SC02	20-25	1.29	0.81	0.025	0.44	107	23.0	2.3	1.8	4.5	.05	1.6	3.7
SC02	30-35	1.53	0.63	0.026	0.45	105	23.0	2.1	1.2	6.6	.05	1.8	4.2
SC03	0-5	3.30	1.66	0.216	0.807	271	83.5	11.2	10.0	8.4	.58	1.5	5.5
SC03	25-30	1.78	0.79	0.034	0.492	192	33.8	4.3	4.0	5.1	.25	2.6	3.6
SC04	0-5	1.95	0.74	0.080	0.490	288	37.4	4.6	3.3	5.0	.15	0.9	3.7
SC04	25-30	2.25	0.78	0.041	0.541	165	36.5	4.4	3.6	6.2	.17	1.4	4.1
SC05	0-5	3.85	2.01	0.251	0.842	503	112.0	12.6	13.8	8.8	.64	4.3	5.9
SC05	25-30	3.90	1.10	0.290	0.806	230	57.8	15.3	12.6	9.3	.24	4.0	5.3
SC06	0-5	5.65	2.77	0.409	1.043	446	178.9	20.8	21.9	11.2	1.31	5.1	7.7
SC06	25-30	2.75	1.06	0.066	0.507	76	25.8	5.0	3.8	5.7	.10	1.2	3.9
SC07	0-5	2.15	0.58	0.032	0.444	215	37.0	3.5	4.1	6.0	.24	5.3	4.0
SC07	25-30	2.23	0.58	0.041	0.527	189	29.3	3.9	4.4	6.4	.30	4.0	4.7

Table B12 (continued)

CORE NO	SECT. DEPTH CM	TON UG/G	TOTP UG/G	NH4 UG/G	TOC UG/G	EX.CA MEQ/G	EX.MG MEQ/G	EX.NA MEQ/G	EX.K UG/G	EXTR. NO3 UG/G	EXTR. PO4 UG/G
SC01	0-5	72	752	0.17	480	0.029	0.007	0.0009	36	1.66	6
SC01	10-15	77	759	0.41	400	0.037	0.009	0.0009	54	1.87	6
SC01	15-20	63	786	0.94	290	0.025	0.006	0.0007	44	1.87	6
SC02	0-5	70	760	0.95	420	0.024	0.006	0.0004	36	0.83	5
SC02	10-15	76	759	0.20	540	0.037	0.008	0.0004	44	1.04	5
SC02	20-25	90	808	0.26	240	0.029	0.006	0.0004	44	1.66	6
SC02	30-35	59	772	0.29	400	0.034	0.009	0.0007	54	1.45	6
SC03	0-5	870	2800	41.7	8900	0.086	0.027	0.0045	136	3.53	15
SC03	25-30	140	683	18.4	810	0.030	0.008	0.0042	64	21.82	8
SC04	0-5	180	1190	0.89	1600	0.038	0.010	0.0010	54	23.27	8
SC04	25-30	100	871	9.9	560	0.030	0.009	0.0026	44	9.97	6
SC05	0-5	170	1290	54.3	1710	0.131	0.040	0.0021	152	4.57	10
SC05	25-30	740	1070	119.4	8500	0.125	0.038	0.0109	244	3.95	9
SC06	0-5	1260	1100		15000	0.104	0.032	0.0015	124	1.87	10
SC06	25-30	120	723	14.6	620	0.042	0.012	0.0010	44	17.25	8
SC07	0-5	130	80		820	0.030	0.008	0.0007	36	8.94	6
SC07	25-30	90	720		590	0.037	0.012	0.0007	48	6.23	8

Table B12 (concluded)

CORE NO	SECT. DEPTH CM	EH MV	PH	FREE S UG/G	TOTAL S UG/G	WATER CNT PCT	HG UG/G
SC01	0-5	390	7.8	0	3	33	0.012
SC01	10-15	430	7.5	0	3	33	0.015
SC01	15-20	450	8.0	0	3	41	0.018
SC02	0-5	420	8.0	0	3	15	0.009
SC02	10-15	420	7.8	0	3	21	0.012
SC02	20-25	430	8.0	0	3	26	0.007
SC02	30-35	430	7.9	0	3	26	0.009
SC03	0-5	400	7.6	0	3	37	0.070
SC03	25-30	160	7.4	0	12	24	0.019
SC04	0-5	350	7.3	0	3	24	0.020
SC04	25-30	250	7.0	0	3	25	0.016
SC05	0-5	140	7.2	0	16	51	0.097
SC05	25-30	130	7.2	0	9	35	0.066
SC06	0-5	70	7.2	0	16	39	0.052
SC06	25-30	110	7.6	0	3	27	0.010
SC07	0-5	380	7.9	0	3	23	0.030
SC07	25-30	160	7.5	0	5	26	0.021

Table B13

Chemical Analyses on Interstitial Water (Core Samples),

Miller Sands, 21 June and 1 July 1975

CORE NO	SECT. DEPTH CM	FE MG/L	MN MG/L	ZN MG/L	CU MG/L	PB MG/L	NI MG/L	CD MG/L	CR MG/L	CO MG/L
SC01	0-5	<0.1	<0.01	<0.03	0.006	<0.002	<0.005	<0.0002	<0.003	<0.003
SC01	10-15	<0.1	<0.01	<0.03	<0.003	<0.002	<0.005	<0.0002	<0.003	<0.003
SC01	15-20	<0.1	0.11	<0.03	<0.003	<0.002	<0.005	<0.0002	<0.003	<0.003
SC02	0-5	0.1	0.04	<0.03	0.012	<0.002	<0.005	<0.0002	<0.003	<0.003
SC02	10-15	0.3	<0.01	<0.03	<0.003	<0.002	<0.005	<0.0002	<0.003	<0.003
SC02	20-25	<0.1	<0.01	<0.03	0.004	<0.002	<0.005	<0.0002	<0.003	<0.003
SC02	30-35	<0.1	<0.01	<0.03	0.002	<0.002	<0.005	<0.0002	<0.003	<0.003
SC03	0-5	4.6	3.40	0.23	0.004	<0.002	0.019	0.0031	<0.003	0.005
SC03	25-30	1.5	0.25	0.65	0.015	<0.002	0.011	0.0030	<0.003	<0.003
SC04	0-5	<0.1	<0.01	0.11	0.005	<0.002	<0.005	0.0021	<0.003	<0.003
SC04	25-30	60.2	28.0	<0.03	<0.003	<0.002	0.050	<0.0002	<0.003	0.019
SC05	0-5	18.8	13.5	0.15	0.002	<0.002	0.018	0.0012	<0.003	0.010
SC05	25-30	47.6	13.7	0.14	0.002	<0.002	0.030	0.0009	<0.003	0.006
SC06	0-5	21.3	8.2	0.10	0.002	<0.002	<0.005	0.0007	<0.003	0.008
SC06	25-30	2.7	1.01	1.29	0.041	<0.002	0.016	0.0028	<0.003	<0.003
SC07	0-5	<0.1	<0.01	0.26	<0.003	<0.002	<0.005	0.0004	<0.003	<0.003
SC07	25-30	9.5	2.29	0.11	0.019	<0.002	0.016	0.0015	<0.003	<0.003

Table B13 (concluded)

Core No.	Sect. Depth	NH_4-N mg/l	NO_3+ NO_2-N mg/l	PO_4-P mg/l	TAN mg/l	TAP mg/l	DOC mg/l
SC01	0- 5	0.085	0.11	0.069	0.15	0	2.8
	10-15	0.10	0.16	0.064			2.8
	15-20	0.086	0.11	0.046	0.20	0.026	2.7
SC02	0- 5	0.15	0.22	0.071	0.18	0.008	4.3
	10-15	0.051	0.11	0.046	0.16	0.004	4.1
	20-25	0.15	0.069	0.034	0.13		2.5
	30-35	0.015	0.12	0.030	0.17	0.005	4.1

No data for cores SC03 through SC07.

Table B14

Radiochemical Analyses on Selected Core Samples,

Miller Sands, 1 July 1975

CORE NO	SECT. DEPTH CM	K40 PC/G	CS137 PC/G	CO60 PC/G	EU152 PC/G
SC05	0-5	14.7 +- 0.4	0.56 +- 0.04	0.77 +- 0.04	0.27 +- 0.09
SC05	5-10	13.5 +- 0.2	0.34 +- 0.03	0.39 +- 0.03	0.17 +- 0.06
SC05	10-15	13.6 +- 0.3	<0.01	0.05 +- 0.02	<0.01
SC05	15-20		<0.01	<0.01	<0.01
SC05	20-25		<0.01	<0.01	<0.01
SC05	25-30	13.3 +- 0.4	<0.01	<0.01	<0.01
SC06	0-5	13.2 +- 0.3	0.38 +- 0.02	0.38 +- 0.03	0.20 +- 0.06
SC06	5-10	15.3 +- 0.3	0.14 +- 0.02	0.30 +- 0.02	<0.01
SC06	10-15	15.1 +- 0.2	0.15 +- 0.02	0.16 +- 0.02	0.12 +- 0.04

PART IV: DATA ON SOIL ANALYSES

INTRODUCTION

With the exception of some special follow-up samples, all soil samples were collected adjacent to 22 locations previously established and marked by Woodward-Clyde Consultants.* Approximate locations are shown in Figure B10 (See Woodward-Clyde, final report to the Corps of Engineers, in press, for exact locations). All of the sample site labels or designations used in this section correspond to those assigned by Woodward-Clyde.

The data in this section consist of physical and chemical results for total soil only; i.e., no interstitial water analyses were made. The term ISLAND is used in the tabulated data to refer to those samples collected on the main island. The samples referred to as MARSH were taken from five intertidal sites. These samples carry the letter prefix CP for "clip plot," QT for "Quadrat-terrestrial," and QA for "Quadrat-aquatic." (CP stations are those for which Woodward-Clyde monitored plant production rates).

Physical Analyses

The physical data consist of size distribution data (Table B15) and profile photographs (Figure B11 and B12). The size distribution data are arranged as previously described for sediment and are all based on dry sieve analysis.

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*Personal communication, D. White, 730 S.W. Third, Suite 112, Portland, OR 97204.

Chemical Analyses

Column headings and explanations for the chemical results are the same as those as described in the introduction to Part III of this addendum for sediment chemical analyses. An additional column habeled AVAIL ZN refers to available zinc (determined by an extraction procedure described in Soil Testing Lab procedures included in Addendum A). A fertilization guide based on the soil test results is also included. In addition, Table B17 contains the results of some follow-up fertility analyses of samples collected from the new fill site and the marsh grass test plots (see Figure B13 for station locations). The soil test report and fertilization guide is included as Figure B14.

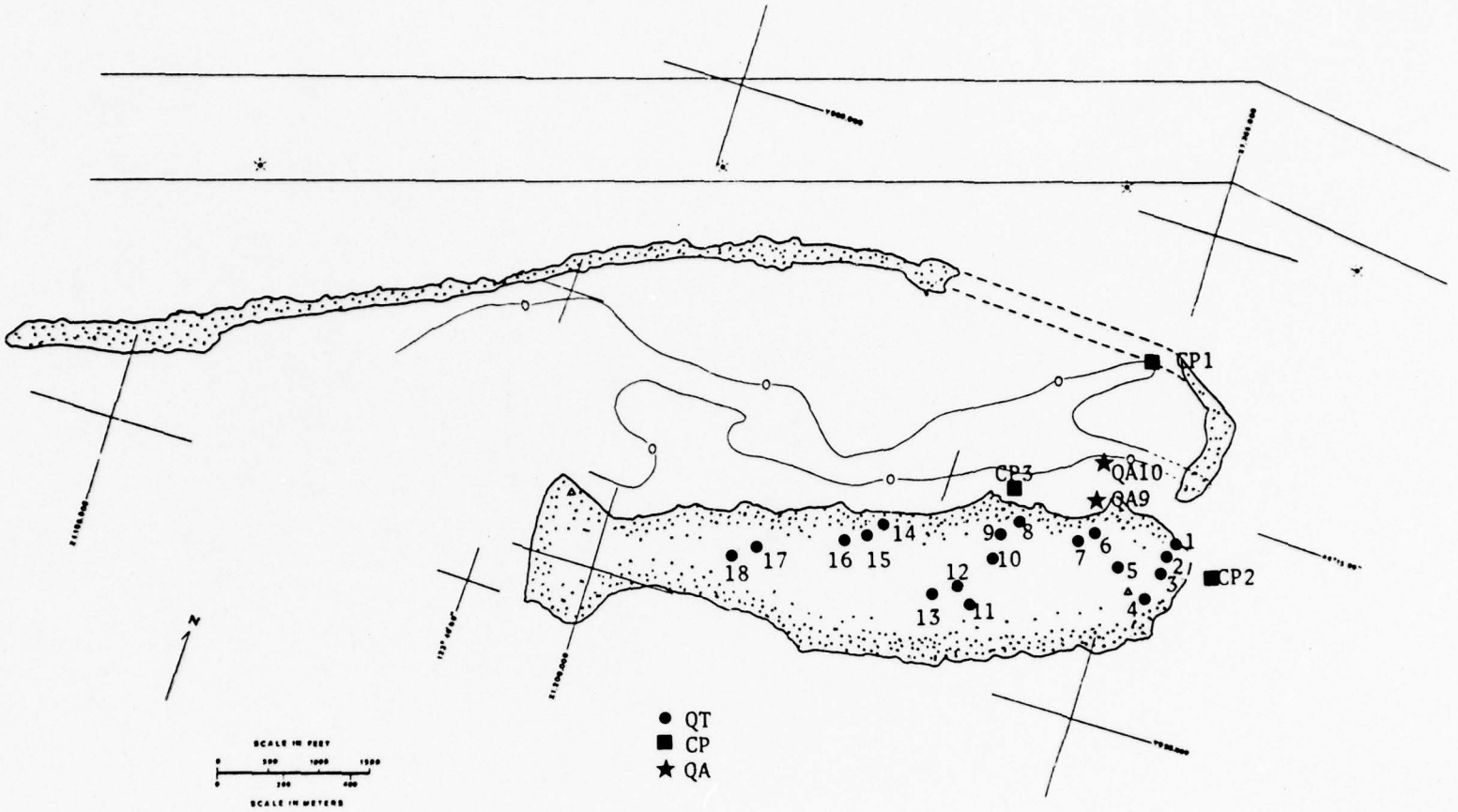


Figure B10. Station locations for soil samples, Miller Sands
17 July and 8 August 1975

Table B15

Texture Analyses of Soil Samples, Miller Sands,

17 July and 8 August 1975

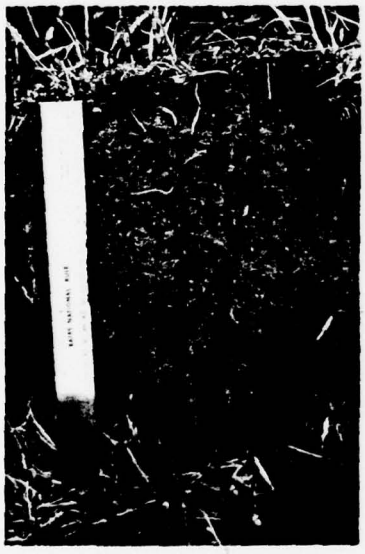
SAMPLE NO	SECT DPTH CM	PHI SIZE CLASS, PCT <0	0-1	1-2	2-3	3-4	>4
ISLAND							
QT01	5-15	2	22	35	35	5	1
QT02	5-15	1	4	35	50	9	1
QT03	5-15	1	10	46	38	5	0
QT04	5-15	0	1	25	64	9	1
QT05	5-15	0	4	40	49	6	1
QT06	5-15	21	18	35	24	2	0
QT07	5-15	1	7	46	42	4	0
QT08	5-15	1	4	42	46	6	1
QT09	5-15	1	25	40	24	7	2
QT10	5-15	2	14	46	33	4	1
QT12	5-15	0	3	53	37	6	1
QT13	5-15	1	5	62	26	5	1
QT14	5-15	4	9	42	36	7	2
QT15	5-15	1	7	50	36	5	1
QT16	5-15	1	12	50	33	4	0
QT17	5-15	1	6	44	42	6	1
QT18	5-15	0	9	58	24	8	1
MARSH							
CP01	0-5	1	2	13	35	18	31
CP01	20-25	0	0	3	58	34	5
CP02	0-5	0	1	5	17	39	38
CP02	20-25	1	2	31	54	10	2
CP03	0-5	1	6	36	47	9	2
CP03	20-25	1	2	19	61	16	1
QA09	0-5	1	1	8	34	23	33
QA09	20-25	1	3	20	57	16	3
QA10	0-5	1	1	4	36	38	20
QA10	20-25	0	2	25	61	10	2



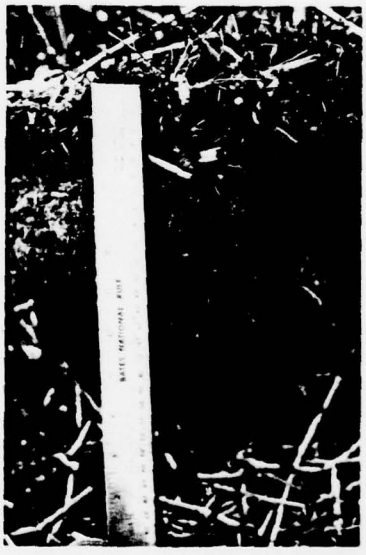
QT 2



QT 3

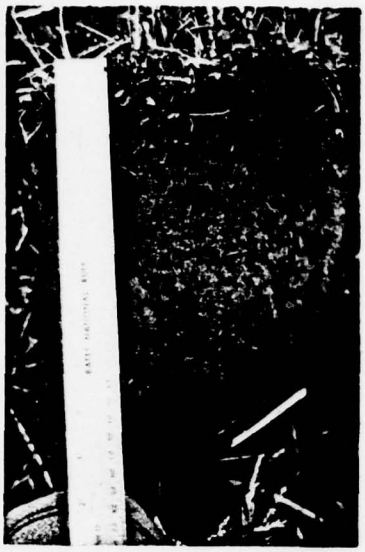


QT 4

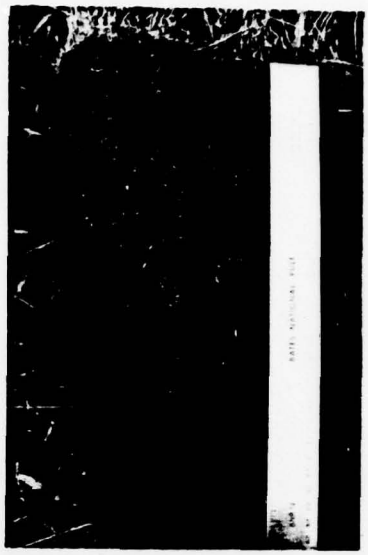


QT 5

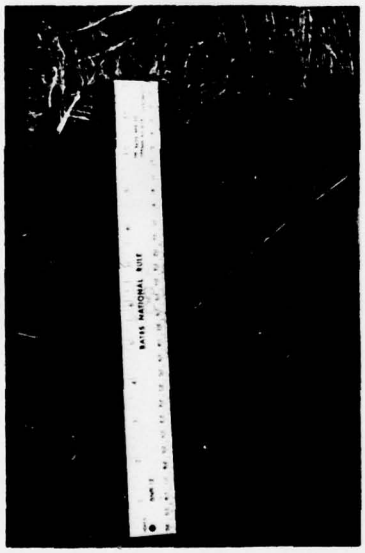
Figure B11. Photographs of soil profiles (main island), quadrats QT 2-18, 17 July 1975



QT 6



QT 7

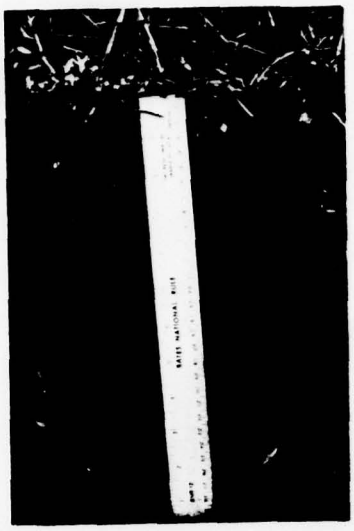


QT 8

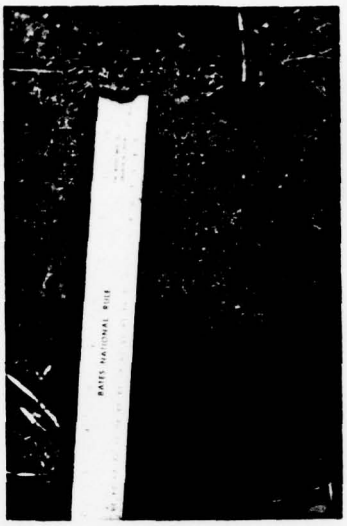


QT 9

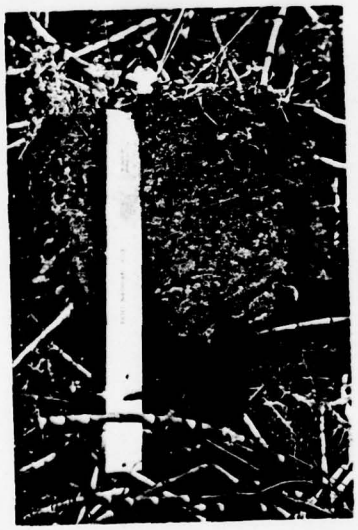
Figure B11 (continued)



QT10



QT11



QT12

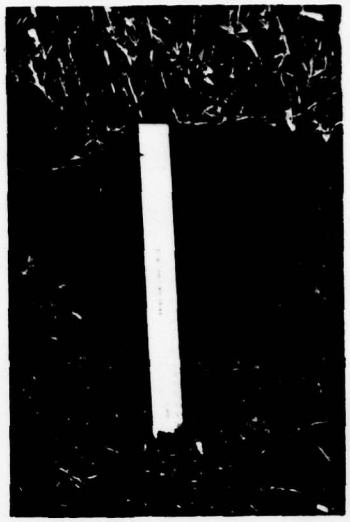


QT13

Figure B11 (continued)



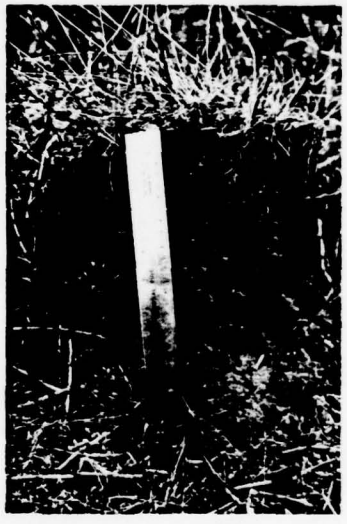
QT14



QT15



QT16



QT17

Figure B11 (continued)

Reports results of major nutrient measurements for the main stem



QT18

Figure B11 (concluded)



QA9



QA10

Figure B12. Photographs of soil profiles, Miller Sands (Marsh), quadrats QA9 and 10, 8 August 1975.

Table B16

Chemical Analyses on Soil Samples, Miller Sands,

17 July and 8 August 1975

SAMPLE ID	DEPTH CM	MED DIAM PHI	SORT PHI	CEC MEQ/G	FE PCT	MN UG/G	ZN UG/G	CU UG/G	PB UG/G	NI UG/G	CD UG/G	CR UG/G	CO UG/G
ISLAND													
QT01	5-15	1.75	1.22	0.040	0.414	70	<1.0	2.5	1.1	4.4	<.1	2.3	3.4
QT02	5-15	2.16	0.67	0.042	0.419	80	1.9	2.5	1.1	5.5	<.1	2.9	3.5
QT03	5-15	1.86	0.69	0.043									
QT04	5-15	2.34	0.53	0.054	0.469	100	3.2	3.0	0.8	5.6	<.1	3.4	3.8
QT05	5-15	2.10	0.59	0.042									
QT06	5-15	1.34	1.35	0.033	0.338	66	<1.0	2.1	0.4	3.7	<.1	1.2	2.9
QT07	5-15	1.92	0.65	0.032									
QT08	5-15	2.06	0.64	0.034	1.098	61	1.4	1.9	0.9	4.8	<.1	2.2	2.8
QT09	5-15	1.61	0.91	0.050									
QT10	5-15	1.78	0.73	0.036	0.398	70	<1.0	2.1	0.8	5.0	<.1	2.0	3.1
QT12	5-15	1.91	0.60	0.036	0.392	67	<1.0	1.8	0.3	5.3	<.1	2.6	3.3
QT13	5-15	1.77	0.60	0.042									
QT14	5-15	1.60	1.01	0.039	0.399	70	<1.0	2.7	0.5	5.4	<.1	3.1	3.2
QT15	5-15	1.84	0.68	0.042									
QT16	5-15	1.78	0.68	0.034	0.372	70	<1.0	2.6	0.0	4.4	<.1	2.3	3.1
QT17	5-15	1.99	0.99	0.044									
QT18	5-15	1.77	0.71	0.035	0.433	76	<1.0	2.8	1.0	6.6	.3	5.5	3.4
MARSH													
CP01	0-5	2.97	1.55	0.108	0.700	436	81.9	10.4	13.1	7.7	0.8	8.7	7.1
CP01	20-25	2.85	1.20	0.051	0.458	102	18.3	4.0	4.9	4.7	0.4	5.8	4.8
CP02	0-5	3.71	1.07	0.148	0.812	326	103.0	12.3	15.4	7.2	0.8	15.5	6.9
CP02	20-25	2.28	0.61	0.046	0.388	218	27.3	3.2	4.3	4.5	0.3	4.7	3.8
CP03	0-5	2.13	0.67	0.039	0.367	121	4.7	2.9	2.8	4.3	0.3	4.7	3.5
CP03	20-25	2.47	0.65	0.032	0.376	121	8.3	3.1	3.1	4.5	3.3	4.8	3.8
QA09	0-5	3.30	1.03	0.125	1.190	408	103.0	6.9	17.3	8.0	0.6	12.1	6.9
QA09	20-25	2.46	0.69	0.044	0.493	70	13.6	4.1	3.3	6.1	0.3	4.8	4.1
QA10	0-5	3.22	0.87	0.106	0.771	246	57.9	6.1	9.6	8.6	0.3	9.3	6.1
QA10	20-25	1.35	0.56	0.059	0.492	73	20.6	4.2	4.0	5.7	0.3	9.3	4.2

Table B16 (concluded)

SAMPLE ID	DEPTH CM	TKN UG/G	TOTAL P UG/G	NH4 UG/G	TOC PCT	EX.CA MEQ/G	EX.MG MEQ/G	EX.NA MEQ/G	EX.K UG/G	EXTR NO3 UG/G	EXTR PO4 UG/G	PH	AVAIL ZN UG/G
QT01	5-15	100	858	0.42	0.14	0.029	0.009	0.0010	26	0.42	10	6.3	<0.2
QT02	5-15	200	743	0.52	0.37	0.029	0.009	0.0019	64	0.52	6	5.1	<0.2
QT03	5-15	200	779	0.52	0.18	0.025	0.007	0.0013	54	0.62	8	5.0	
QT04	5-15	100	732	0.94	0.09	0.032	0.011	0.0010	96	0.83	6	5.3	<0.2
QT05	5-15	100	825	0.31	0.00	0.025	0.009	0.0009	64	0.31	5	5.3	
QT06	5-15	100	742	0.73	0.18	0.021	0.007	0.0010	54	0.31	5	5.2	<0.2
QT07	5-15	100	760	0.31	0.00	0.019	0.007	0.0007	26	0.42	5	5.1	
QT08	5-15	100	867	1.30	0.00	0.021	0.006	0.0009	44	1.45	6	5.2	<0.2
QT09	5-15	100	870	0.00	0.09	0.030	0.010	0.0009	54	0.62	7	6.4	
QT10	5-15	400	734	0.21	0.00	0.024	0.008	0.0009	32	0.52	7	6.4	
QT12	5-15	100	700	1.30	0.14	0.025	0.008	0.0010	36	1.45	5	5.3	
QT13	5-15	100	851	0.00	0.00	0.029	0.011	0.0009	48	0.42	7	6.5	
QT14	5-15	100	757	0.00	0.00	0.024	0.008	0.0009	26	0.21	5	5.3	
QT15	5-15	200	669	0.62	0.27	0.027	0.008	0.0010	44	1.35	5	5.2	
QT16	5-15	100	777	0.73	0.05	0.024	0.007	0.0007	48	1.35	5	5.7	
QT17	5-15	200	641	1.00	0.18	0.025	0.008	0.0010	48	0.62	5	5.2	
QT18	5-15	100		0.31	0.09	0.027	0.011	0.0010	26	0.62	6	6.5	
MARSH													
CP01	0-5	600	1140	0.83	0.96	0.074	0.021	0.0023	60	23.10	10	5.0	17.9
CP01	20-25	100	983	1.40	0.32	0.040	0.011	0.0015	16	1.21	7	6.4	2.5
CP02	0-5	1000	1230	5.30	2.30	0.099	0.030	0.0028	98	1.70	10	5.4	
CP02	20-25	100	780	1.60	0.27	0.25	0.011	0.0013	8	1.50	5	4.8	1.8
CP03	0-5	10	1070	1.97	0.37	0.030	0.007	0.0015	44	15.80	5	5.4	4.5
CP03	20-25	100	1070	2.20	0.16	0.024	0.006	0.0010	20	0.20	5	5.3	0.9
QA09	0-5	10	1200	9.10	1.70	0.071	0.023	0.0021	64	1.70	7	6.2	
QA09	20-25	10	635	1.70	0.27	0.027	0.010	0.0017	48	0.62	4	4.6	
QA10	0-5	10	865	5.40	0.58	0.064	0.020	0.0019	76	1.00	7	6.4	
QA10	20-25	100	668	2.30	0.27	0.035	0.011	0.0013	26	1.10	7	5.5	

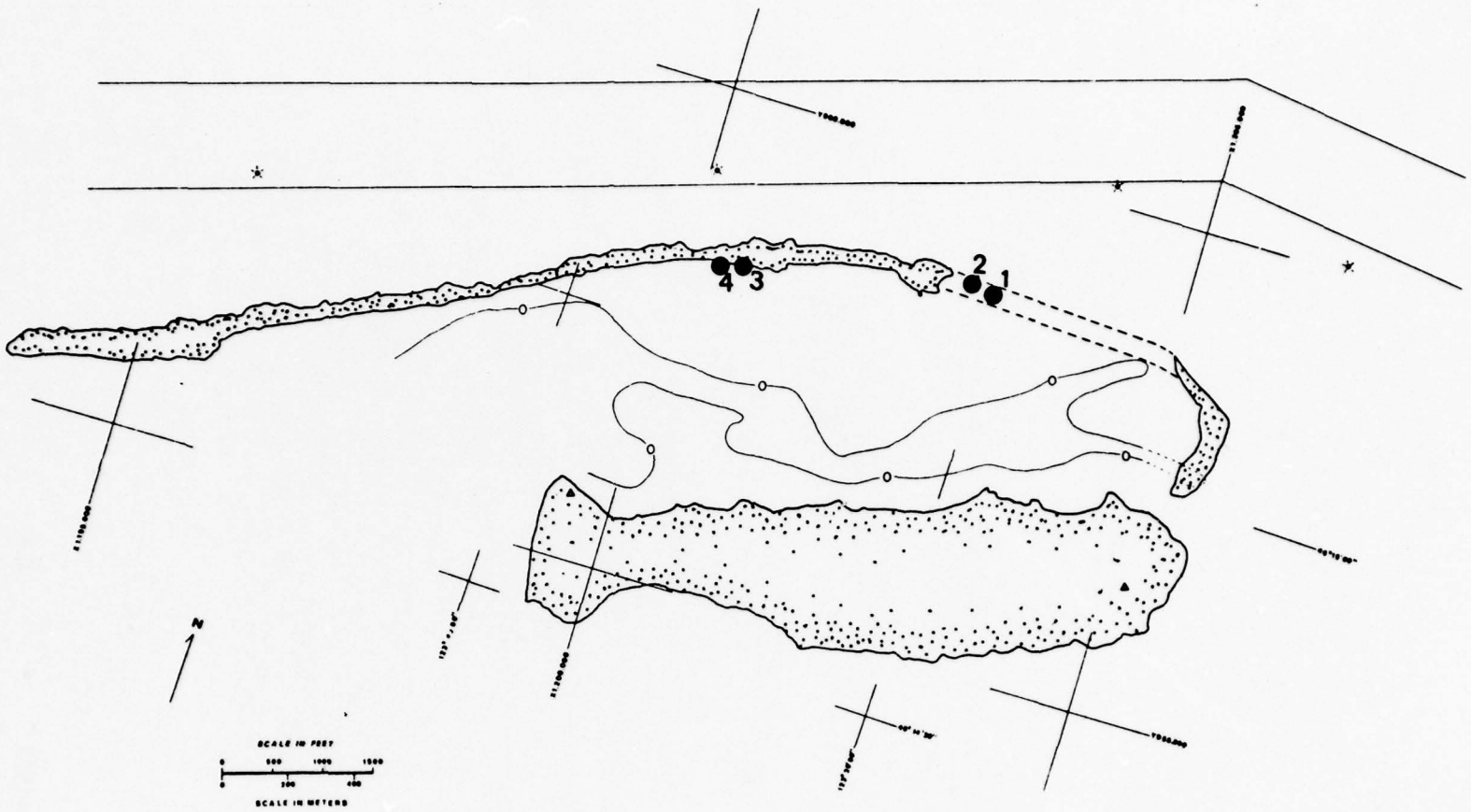


Figure B13. Station locations for follow-up fertility analyses of soil samples, Miller Sands, 29 November 1975

Table B17

Follow-up Fertility Analyses of Soil Samples, Miller Sands, 29 November 1975[1]

SAMPLE NO	MED DIAM PHI	SORT PHI	CEC MEQ/G	EX.CA MEQ/G	EX.MG MEQ/G	EX.NA MEQ/G	EX.K UG/G
NEW FILL							
1	1.95	0.62	0.032	0.029	0.0076	0.0015	36
2	1.70	0.63	0.035	0.025	0.0069	0.0010	36
TEST PLOT							
3	1.80	0.52	0.037	0.034	0.0082	0.0013	48
4	1.98	0.57	0.044	0.030	0.0089	0.0013	54

SAMPLE NO	AVAIL ZN UG/G	BORON UG/G	TKN UG/G	EXTR ENO3 UG/G	NH4 UG/G	EXTR PO4 UG/G	TOC PCT	PH
NEW FILL								
1	1.76	0.16	100	0.83	2.0	7		6.8
2	1.54	0.22	30	0.42	1.9	5	0.11	6.8
TEST PLOT								
3	2.0°	0.13	40	0.21	0.3	5	0.16	7.1
4	2.31	0.23	100	2.08	3.1	6	0.27	6.8

[1]Sample Locations:

		Latitude	Longitude
New Fill:	1	46°15' 8.9"	123°39'10.4"
	2	46°15'14.9"	123°38'58.9"
Test Plot:	3	46°15'14.6"	123°39' 3.0"
	4	46°15' 8.0"	123°39'39.0"

AGRICULTURAL E... RIMENT STATION
SOIL TEST FORM—S110 JANUARY 1975

OREGON STATE UNIVERSITY—Soil T... Laboratory—Corvallis, Oregon 97331
WESTERN OREGON

Extension ...rvice

SOIL SAMPLE INFORMATION (To be completed by grower) IMPORTANT—Read and follow instructions on reverse side

(1) Name Vernon G. Johnson

(2) Farm location Miller Sands Ils. County Clatsop Date 6 Dec 75

Address School of Oceanography, Oregon State Univ.

(3) Send additional report to:

City Corvallis, Ore. Zip 97331 Phone 754-2826

(4) Sampled by V. G. Johnson

(5) Grower sample no.	(6) Soil tests desired	(7) Crop to be grown	(8) Age of planting (Years)	(9) Area size sampled (Acres)	(10) Crop last grown and yield	(11) Irrigated (yes or no)	(12) Fertilizer applied last year: Kind	(12) Fertilizer applied last year: Amount	(13) Lime applied: Year	(13) Lime applied: Amount	(14) Sampling depth (in.)	(15) Soil series	(16) Texture of surface soil	(17) Nature of land	(18) Drainage
A		upland grass		200	none	no	none		none		6		sand		good
B		marsh grass											sand		

SOIL TEST REPORT (To be completed at the laboratory)

Grower sample no.	Lab no.	pH	P (ppm)	Extractable cations: K (ppm)	K (meq/100g)	Ca (meq/100g)	Mg (meq/100g)	Total bases (meq/100g)	SMP buffer	B (ppm)	Organic Matter	Total N	Nitrate ppm	Grain size mm	Extr. Zn ppm
A		6.3	6	46	0.12	2.6	0.84	3.66			0.1 %	0.012%	0.71	0.28	<0.19
B			6	46	0.12	3.1	0.71	3.97			0.11%	0.01%	1.43	0.33	2.0

GUIDE TO FERTILIZATION (To be completed by County Extension Agent)

Grower sample no.	Crop	Lime (Tons/Acre-100 score lime basis)	Suggested application of plant nutrients (Pounds/Acre): Nitrogen (N)	Phosphorus (P2O)	Phosphorus (P)	Potassium (K2O)	Potassium (K)	Sulfur (S)	Boron (B)	Zinc (Zn)			
A	upland grass	none	50	50		50		20	none	10			
B	marsh grass	none	50	50		50		20	none	none			

Remarks A is the mean of 17 samples collected from various locations covering the non-vegetated portion of the main island and were all taken adjacent to the Woodward-Clyde vegetation quadrats.

B is the mean of 7 samples taken from the ship channel in the zone from which the new fill material was taken and should be representative of the material which will come to substitute for the artificial marsh planting site.

Figure B14. Soil test report and fertilization guide for Miller Sands island and marsh substrates.

Table B18. Chlorinated hydrocarbon levels in selected soil and sediment samples, Miller Sands, 1975.[1]

Sample ID	Section Depth, cm	A-1254 µg/g	p,p'-DDE µg/g	p,p'-TDE µg/g
Sediment				
SC01	0-5	<1	<0.03	--
SC02	0-5	<1	<0.03	--
SC03	0-5	2	0.9	--
SC05	0-5	14	2.4	4
Soil				
QT07	5-15	<1	<0.03	--
QT13	5-15	<1	<0.03	--

[1]All values are reported on a dry weight basis, A-1254 means Aroclor®1254.

ADDENDUM C

ANNOTATED BIBLIOGRAPHY OF AQUATIC ENVIRONMENTAL CONDITIONS AT MILLER SANDS ISLAND, COLUMBIA RIVER, OREGON

Compiled and Edited
by
Duane L. Higley, Vernon G. Johnson
and
Karla J. McMechan

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INTRODUCTION

This bibliography includes published materials and unpublished reports describing aquatic environmental conditions existing in or similar to those found in the brackish to freshwater regions of the Miller Sands area. It is divided into three major subject categories: physical, chemical, and biological conditions. The physical and chemical sections of the bibliography provide articles discussing Columbia River sedimentology, mineralogy, and hydrology. Notes or abstracts on the pertinence of each reference to the Miller Sands work are included.

Little has been published on the biology of the Columbia River estuary. A substantial literature does exist, however, which describes the fauna (especially the invertebrates) typical of such temperate-zone estuaries, and a selection of this literature is provided in the biological section. The most extensive field studies concerning the ecology of temperate-zone estuaries were conducted in England from 1920-1950. These studies, and more recent autecological work, have been reviewed in Green *The Biology of Estuarine Animals,* (1968) and in McLusky, *The Ecology of Estuaries,* (1971). Because this section is so extensive, the annotations consist primarily of excerpts from the author(s)' own abstracts. Thus, they present the reader with an overview of the subject matter itself.

PHYSICAL CONDITIONS

1. Barnes, Clifford A., Alyn C. Duxbury, and Betty-Ann Morse. 1972. Circulation and selected properties of the Columbia River effluent at sea. Pp. 41-80 in A.T. Pruter and D.L. Alverson, eds., The Columbia River Estuary and Adjacent Ocean Waters. University of Washington Press, Seattle.

   Contains information on regional wind patterns for the Oregon-Washington coast.

2. Callaway, R.J. 1971. Applications of some numerical models to Pacific Northwest estuaries. Pp. 29-97 in Proceedings of the 1971 Technical Conference on Estuaries in the Pacific Northwest. Circular 42, Engineering Experiment Station, Oregon State University, Corvallis, Oregon.

   Contains information on tidal range and stage, current velocity, and tidal reversal for the lower Columbia River and estuary from the mouth to river mile 150.

3. Conomos, T. John, and M. Grant Gross. 1972. River-ocean suspended particulate matter relations in summer. Pp. 176-202 in A.T. Pruter and D.L. Alverson, eds., The Columbia River Estuary and Adjacent Ocean Waters. University of Washington Press, Seattle.

   Contains discussion of factors influencing suspended sediment concentrations and composition of suspended matter in the estuary. Presents information that may be useful in interpreting sedimentation patterns and associated sediment chemistry in the vicinity of Miller Sands.

4. Glenn, J.L. 1973. Relations Among Radionuclide Content and Physical, Chemical, and Mineral Characteristics of Columbia River Sediments, with a section on Sand and Gravel Mineralogy by R.O. Van Atta. *U.S. Geological Survey, Professional Paper* 433-M. U.S. Government Printing Office, Washington, D.C. (Stock No. 2401-00297). 52 pp.

   Contains information on sand and clay size fraction mineralogy for Lower Columbia River sediment. Mineralogy at Miller Sands should be similar.

5. Hubbell, D.W., and J.L. Glenn. 1973. Distribution of Radionuclides in Bottom Sediments of the Columbia River Estuary. *U.S. Geological Survey, Professional Paper* 433-L. U.S. Government Printing Office, Washington, D.C. (Stock No. 2401-00247). 63 pp.

Contains sediment texture data for surface sediment and cores taken along transects in the estuary both above and below the Miller Sands site. One of the transects passes through the lower end of the new portion of the Miller Sands Island. Geomorphic and stratigraphic relations are discussed. Information should be useful as a comparison for particle size data at the Miller Sands site and for interpreting sedimentation patterns and natural variability of sediment texture in the vicinity of Miller Sands.

6. Hubbell, D.W., J. L. Glenn, and H.H. Stevens. 1971. Studies of sediment transport in the Columbia River estuary. Pp. 190-226 in Proceedings of the 1971 Technical Conference on Estuaries in the Pacific Northwest. Circular 42, Engineering Experiment Station, Oregon State University, Corvallis, Oregon.

   Reports suspended sediment data for the Columbia River estuary and discusses factors influencing spatial and temporal variation in turbidity and sediment discharge. Contains some important considerations when interpreting suspended sediment data in this system.

7. Lutz, G.A., D.W. Hubbell, and H.H. Stevens, Jr. 1975. Discharge and Flow Distribution in the Columbia River Estuary. *U.S. Geological Survey, Professional Paper* 433-P. 31 pp.

   Report includes measurements of magnitude and direction of water velocity at two stations in the Columbia River estuary during half tidal cycles at different times of the year during 1968 to 1970. One of the stations used was above Miller Sands at river mile 53 and one was near Astoria at river mile 14. These data should help to further define flow reversal in the vicinity of Miller Sands. The authors used the results of the measurements to "calibrate" mathematical models for computing continuous records of discharge near the mouth.

8. Neal, Victor T. 1972. Physical aspects of the Columbia River and its estuary. Pp. 19-40 in A.T. Pruter and D.L. Alverson, eds., The Columbia River Estuary and Adjacent Ocean Waters. University of Washington Press, Seattle.

   Presents data and a discussion of flushing times, river flow, tidal range and velocity, saltwater intrusion and regional climatic contidions. Serves as a general framework for understanding the basic hydraulic characteristics of the estuary.

9. Oregon State University. Ocean Engineering Programs. 1975. Physical Characteristics of the Youngs Bay Estuarine Environs. Final Report to ALUMAX Pacific Aluminum Corporation, November 1973 to April 1975. School of Engineering, Oregon State University, Corvallis, Oregon. 310 pp.

Contains summaries of various types of physical data covering the Columbia River estuary to Harrington Point as well as Youngs Bay area. Also contains some information on local geology (Astoria area) and a summary of weather station data for the Astoria airport. Other sections treat sediment transport, mineralogy, hydrodynamics, and characterization of benthic chemistry for the Bay, which may have some relevance to similar considerations for Miller Sands study.

CHEMICAL CONDITIONS

10. Haertel, Lois, Charles Osterberg, Herbert Curl, Jr., and P. Kilho Park. 1969. Nutrient and plankton ecology of the Columbia River estuary. *Ecology* 50(6):962-978.

"Monthly samples of nutrients, phytoplankton and zooplankton were taken in the Columbia River estuary over a period of 16 months in order to determine distribution with season and salinity, and interrelationships between plankton and nutrients.

"Nitrate and phosphate levels in the river water entering the estuary are high in the winter and show depletion during the summer. Silicate levels are high in the river water at all seasons. During the summer up-welling season nitrate and phosphate levels in the entering ocean water are high. Although nutrient levels in the estuary generally show a linear relationship with salinity, nutrients tend to be enriched in the bottom waters of the central part of the estuary.

"The estuarine phytoplankton is primarily composed of freshwater species, and probably represents a downstream extension of the river flora. Linear regression analysis indicates a strong correlation between phytoplankton abundance and solar radiation." (p. 324)

11. Johnson, Vernon G., and Norman H. Cutshall. 1975. Geochemical Baseline Data, Youngs Bay, Oregon, 1974. Final Report to ALUMAX Pacific Aluminum Corporation, 1 November 1973 through 30 April 1975. Reference 75-7, School of Oceanography, Oregon State University, Corvallis, Oregon. 66 pp.

Contains heavy metal data for surface sediment and cores in Youngs Bay. (Youngs Bay lies just off the main channel of the Columbia River at approximately river mile 15.) There is some discussion of heavy metal distribution patterns. These data may serve as a reference for similar analyses made at the Miller Sands site.

12. Park, P. Kilho, Magdalena Catalfomo, George R. Webster, and Barry H. Reid. 1970. Nutrients and carbon dioxide in the Columbia River. *Limnology and Oceanography* 15(1):70-79.

Reports results of major nutrient measurements for the main stem of the Columbia River and its tributaries from December 1965 to January 1967. The farthest downstream station was approximately 25 miles upstream from Miller Sands. Discusses nutrient chemistry in the Columbia River system in general and discusses cause-effect relationships for observed seasonal maxima and minima.

13. Park, P. Kilho, Charles L. Osterberg, and William O. Forster. 1972. Chemical budget of the Columbia River. Pp. 123-134 in A.T. Pruter and D.L. Alverson, eds., The Columbia River Estuary and Adjacent Ocean Waters. University of Washington Press, Seattle.

Reports results of monthly measurements of alkalinity, pH, dissolved oxygen, total carbon dioxide, phosphate, silicate, nitrate, nitrite, and salinity in the Columbia River estuary at four stations for the years 1966 and 1967. The farthest upstream location was at river mile 23, just below Miller Sands in the main channel. Authors discuss phytoplankton-nutrient-water quality relationships for the estuary and attempt to explain the observed seasonal variation in certain nutrient parameters.

14. Park, P. Kilho, George R. Webster, and Roy Yamamoto. 1969. Alkalinity budget of the Columbia River. *Limnology and Oceanography* 14(4):559-567.

15. White, Stan M. 1970. Mineralogy and geochemistry of continental shelf sediments off the Washington-Oregon coast. *Journal of Sedimentary Petrology* 40(1):38-54.

Mineralogical and trace metal data for Columbia River estuary sediments as well as for adjacent shelf sediments are reported. Sample sites in the estuary were all in the main ship channel and included several stations in the vicinity of Miller Sands. The author discusses elemental content of the estuarine sediment samples and contrasts them with levels found for nearby shelf sediment and elsewhere. The results for the Columbia River samples should serve as a useful reference for expected major elemental and trace metal content of dredged material from the ship channel in the estuarine portion of the lower river. The discussion of trends in trace metal concentrations for the shelf-estuary zone may be useful for interpreting the sediment trace metal results for the Miller Sands project.

BIOLOGICAL CONDITIONS

General Estuary Studies

16. Alexander, W.B., B. A. Southgate, and R. Bassindale. 1932. The salinity of the water retained in the muddy foreshore of an estuary. *Journal of the Marine Biological Association of the United Kingdom* 18:297-298.

    "It has been found that the water retained in the muddy foreshore of an estuary at low tide is more saline than the estuary water itself at the same distance from the sea. It is suggested that this retention of salt by the bottom and shore deposits may be a factor favouring the growth of burrowing animals in the central part of an estuary." (p. 298)

17. Caspers, Hubert. 1967. Estuaries: Analysis of definitions and biological considerations. Pp. 6-8 in George H. Lauff, ed., Estuaries. Publication No. 83, American Association for the Advancement of Science, Washington, D.C.

18. Darnell, Rezneat M. 1961. Trophic spectrum of an estuarine community, based on studies of Lake Pontchartrain, Louisiana. *Ecology* 42(3):553-568.

    "The Lake Pontchartrain community is a broadly open system exchanging nutrients, producers, and consumers with adjacent freshwater and saltwater areas as well as with neighboring marshes and swamps. ... The most conspicuous single food item in the diets of the consumers of this community is organic detritus with its attendant bacteria.... Individual species do not appear to conform to specific trophic levels.... An alternative model of the trophic relations of the community is presented which represents the observed food of each species in the form of a spectrum...The really abundant consumer species of the Lake Pontchartrain community comprise 2 groups: those which feed heavily upon organic detritus and those which exhibit a broad range of food tolerance." (p. 556-7)

19. Darnell, Rezneat M. 1967. Organic detritus in relation to the estuarine ecosystem. Pp. 376-382 in George H. Lauff, ed., Estuaries. Publication No. 83, American Association for the Advancement of Science, Washington, D.C.

20. Fenchel, Tom. 1972. Aspects of decomposer food chains in marine benthos. *Verhandlungen der Deutsche Zoologische Gesellschaft* 65(1971):14-23.

    "Evidence indicating that detritus feeders are in fact living on the microflora associated with the dead plant material is reviewed. It is probable that the only significant primary decomposers of

dead plant material in the sea are bacteria. The rate of decomposition is limited by diffusion of oxygen and by the availability of mineral nutrients. Through their mechanical activity and by regenerating nutrients detritus feeders increase the rate of decomposition. By leveling out the effects of temporal variation in primary production and by securing a quick reabsorption of dissolved nutrients a large importance of detritus seems to be in stabilizing the ecosystem." (p. 14)

21. Fox, Denis L. 1950. Comparative metabolism of organic detritus by inshore animals. *Ecology* 31(1):100-108.

"Biochromes, such as red, orange or yellow carotenoids or greenish breakdown products of chlorophyll, provide valuable means of studying the comparative biochemistry of nutrition and assimilation.... Comparisons are drawn between two typical marine detritus feeders: (a) mussels, which filter vast quantities of water annually... and (b) the beach-annelid, *Thoracophelia*, colonies of which cycle tons of sand annually through the alimentary tract." (p. 107)

22. Green, J. 1968. *The Biology of Estuarine Animals*. Sidgwick and Jackson, London. 401 pp.

23. Hargrave, Barry T. 1972. Aerobic decomposition of sediment and detritus as a function of particle surface area and organic content. *Limnology and Oceanography* 17(4):583-596.

"Oxygen uptake by microbial populations on mud, sand, and various types of detritus was measured in short-term experiments in aerated water at 20°C... Detritus consumed up to three orders of magnitude more oxygen per dry weight than sand; uptake rates were inversely related to particle diameter. The logarithm of oxygen uptake was directly related to the logarithm of particle organic content.... The negative linear correlation on logarithmic axes of area, organic carbon and nitrogen and bacterial plate counts with sediment particle size is similar to that observed for measures of oxygen uptake. Bacteria cover only a few percent of particle surfaces. This may result in the narrow range of measures of microbial community respiration on an areal basis." (p. 583)

24. Hopkins, J.T. 1964. A study of the diatoms of the Ouse Estuary, Sussex. II. The ecology of the mud-flat diatom flora. *Journal of the Marine Biological Association of the United Kingdom* 44: 333-341.

"...the ecological factors influencing the distribution of eleven species of mud-flat diatoms were investigated. The three important factors were considered to be: the resistance to desiccation near the M.H.W.L., the ability to live under short periods of

illumination near to the M.L.W.L., and the ability to tolerate the organic materials present in the black sulphureous layer." (p. 340-341)

25. Lauff, George H., ed. 1967. *Estuaries*. Publication No. 83, American Association for the Advancement of Science, Washington, D.C. 757 pp.

26. Levinton, Jeffrey. 1972. Stability and trophic structure in deposit-feeding and suspension-feeding communities. *American Naturalist* 106:472-486.

"The present study examines the abundance and composition of the food of boreal and temperate soft-bottom dwelling marine benthos.... A hypothesis is developed which states that suspension feeders live with unpredictable and fluctuating food supplies, whereas deposit feeders experience relatively constant food levels...." The consequences to community structure and population fluctuation are discussed. (p. 472)

27. McLusky, Donald S. 1971. *Ecology of Estuaries.* Heinemann Educational Books, London. 144 pp.

28. Mare, Molly F. 1942. A study of a marine benthic community with special reference to the micro-organisms. *Journal of the Marine Biological Association of the United Kingdom* 25:517-554.

"An attempt has been made to deal briefly but quantitatively with all size groups of the fauna and flora in a marine mud deposit.... Typical figures for the minimal numbers and volumes of living protoplasm per gram of dry mud in the top 1/2 cm layer are given.... Diatoms contribute by far the greatest bulk to the total volume of living micro-organisms.... Food relationships in the microbenthics are suggested...." (p. 549-550)

29. May, Edwin B. 1973. Environmental effects of hydraulic dredging in estuaries. *Alabama Marine Resources Bulletin* 9:1-85.

"Almost all of the sediment discharged by dredges settles very rapidly and is transported by gravity along the bottom as a separate flocculated density layer and potentially harmful components of the mud are not dissolved into the water. There is a limited, temporary reduction in benthic organisms in areas affected by dredging." (p. 1)

30. Meadows, P.S., and J.G. Anderson. 1968. Micro-organisms attached to marine sand grains. *Journal of the Marine Biological Association of the United Kingdom* 48:161-175.

"The distribution, abundance and types of micro-organisms attached to littoral and sublittoral sand grains have been described.... Evidence suggests that abrasion may stop micro-organisms colonizing flat or convex surfaces.... The microbial flora may alter only slightly to depths of 15 cm below the sediment surface, or may change within a few mm. It is sparse towards high water, but differs little between lower littoral and sublittoral sands. The results are discussed in relation to substrate selection by marine invertebrates." (p. 161)

31. Moore, Hilary B. 1931. The muds of the Clyde Sea area. III. Chemical and physical conditions; rate and nature of sedimentation; and fauna; *Journal of the Marine Biological Association of the United Kingdom* 17:325-358.

Vertical distribution of infauna related to substrate character and oxygen content of mud.

32. Muus, Bent J. 1967. The fauna of Danish estuaries and lagoons. Distribution and ecology of dominating species in the shallow beaches of the mesohaline zone. *Meddelelser fra Danmarks Fiskeri- og Havundersøgelser (Ny serie)* 5:(1):1-316.

This work gives "a general description of the faunas existing in sheltered, shallow brackish water localities... (1) The investigated localities can be subdivided into three main topographical categories: sheltered-water bays, lagoons, and estuaries. (2) ...the total of the fauna is treated group by group viewed from quantitative faunistic and ecological standpoints.... The macrofauna is extraordinarily rich in individuals, but poor in species. Dominating among the worms were Oligochaeta and *Nereis diversicolor*. *Crangon crangon* and *Corophium volutator* were followed regularly through many months. Of the Mollusca especially the Hydrobiae were made the subject of studies on distribution and ecology...." The "day and night-activity, feeding and growth of the flounder *Platichthys flesus* were elucidated... (3) The reasons for the low number of species in brackish water are discussed." It is demonstrated..."how the fauna is distributed with respect to individual numbers and weight categories.... The following factors and their importance for the species-distribution are considered: salinity, temperature, oxygen, exposure, vegetation and substratum.... At the end of this section is given a synoptic picture of the fauna as it is developed in the different biotopes of the investigated areas. After this follows a review of the most important seasonally regulated biological events from spring to winter. (4) ...The potential value of the brackish water areas is discussed from economical points of view..." (p. 257-259). This is an excellent and comprehensive review of biology of estuarine habitats. Much of the fauna described is similar to that in temperate North American estuaries.

33. Pugh, G.J.F. 1960. The fungal flora of tidal mud-flats. Pp. 202-208 in D. Parkinson and J.S. Waid, eds., Ecology of Soil Fungi. Liverpool University Press, Liverpool.

34. Rees, Colin B. 1940. A preliminary study of the ecology of a mud-flat. *Journal of the Marine Biological Association of the United Kingdom* 24:185-199.

"Ten stations, from high water to low water, were investigated along a mud-flat.... Quantitative analysis of both macrofauna and microfauna revealed a dense mud population.... The operative ecological factors, including the food cycle, are defined." (p. 198)

35. Sanders, Howard L. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft-bottom community. *Limnology and Oceanography* 5(2):138-153.

"A series of 24 samples was taken...very high indices of faunal affinity were obtained within the series. The silt-clay fraction of the sediment in the 20 samples with high faunal indices varies from 78-91%, and when the contained species were ranked by abundance, the commoner species achieved approximately the same rank from sample to sample.... Thus the community, both numerically and by biomass, is characterized by pronounced dominance of few species." (p. 138)

36. Smallbone, Norma. 1974. Bays and Estuaries of Oregon: A Literature Review of Ph.D. and Master Theses from Oregon State University and the University of Oregon. School of Oceanography, Oregon State University, Corvallis, Oregon. 11 pp.

37. Spooner, G.M., and H.B. Moore. 1940. The ecology of the Tamar estuary. VI. An account of the macrofauna of the intertidal muds. *Journal of the Marine Biological Association of the United Kingdom* 24:283-330.

"The characteristic species which inhabit the mud-flats are listed and the data secured regarding (1) population density, (2) upriver penetration, and (3) vertical distribution, are summarized and related to previous information on these points.... Marine species which penetrate into the estuary tend to show the same intertidal distribution as in marine habitats. All five of the more strictly estuarine species are concentrated in the upper tidal levels." (p. 328)

38. Teal, John M. 1962. Energy flow in the salt marsh ecosystem of Georgia. *Ecology* 43(4):614-624.

Detailed study of primary and secondary production rates, with estimates of respiration. Species grouped by trophic groups. Development of community energy-flow diagram.

39. Zhukova, A.I., and M.V. Fedosov. 1963. Significance of micro-organisms of upper sediment layer of shallow water basin in transformation of organic matter. Pages 711-719 in C.H. Oppenheimer, ed., 1961 Symposium on Marine Microbiology. Charles C. Thomas, Springfield, Illinois.

"...the value of diurnal production of micro-organisms in the near bottom water layer was determined both for the North Caspian and Azov Seas.... The gas conditions of a basin and the number of biogens in water were experimentally demonstrated to be governed by microflora activities on the silt-water interface." (p. 715 and 719)

40. Zobell, Claude E., and Catherine B. Feltham. 1942. The bacterial flora of a marine mud-flat as an ecological factor. *Ecology* 23: 69-78.

"...a detailed study of its bacterial population with particular reference to the effect of bacteria upon physico-chemical and biological conditions...." (p. 76) Importance of bacteria as food, their distribution and abundance in water and mud, and their chemical effects on mud is discussed.

Pacific Coast Estuaries

41. Aldrich, Frederick A. 1961. Seasonal variations in the benthic invertebrate fauna of the San Joaquin River estuary of California, with emphasis on the amphipod, *Corophium spinicorne* Stimpson. *Proceedings of the Academy of Natural Sciences of Philadelphia* 113(2):21-28.

"Dominant littoral species were the Asiatic clam *Corbicula fluminea* (Müller) and the ectoproct *Conopeum commensale* (Kirkp. and Metz). The dominant form living in the river bottom was the tube-dwelling amphipod *Corophium spinicorne* Stimpson.... The incidence of *C. spinicorne* was found to be associated with brackish water and depths where the substrata were predominantly sand, gravel, or clay." (p. 21)

42. Bousfield, E.L. 1957. Ecological investigations on shore invertebrates of the Pacific Coast of Canada, 1955. *Bulletin of the National Museum of Canada* 147:104-155.

"During the period June 25 to September 6, 1955, a preliminary survey was made of the principal invertebrate animals of the shores of Southern Vancouver Island, the islands of the Strait of Georgia, and the mainland of British Columbia. The present report provides

a list of stations visited, hydrographical data obtained, and general observations made on marine ecological conditions and shore biota of the region." (p. 104)

43. Cliff, David D., and John G. Stockner. 1973. Primary and Secondary Components of the Food-Web of the Outer Squamish River Estuary. *Fisheries Research Board of Canada Manuscript Series* No. 1214.

44. Durkin, Joseph T. 1973. A List of Crustacean Shellfish of the Lower Columbia River Between the Mouth and River Mile 108, July to Oct. 1973. Northwest Fisheries Center, U.S. National Marine Fisheries Service. 2725 Montlake Boulevard East, Seattle, Washington 98112. Mimeographed. 4 numbered leaves.

45. Durkin, Joseph T., and Robert J. McConnell. 1973. A List of Fishes of the Lower Columbia and Willamette Rivers. Northwest Fisheries Center, U.S. National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112. Mimeographed. 13 numbered leaves.

46. Eriksen, C.H. 1968. Aspects of the limno-ecology of *Corophium spinicorne* Stimpson (Amphipoda) and *Gnorimosphaeroma oregonensis* (Dana) (Isopoda). *Crustaceana* 14:1-12.

A seaside sand dune lake was studied for its physico-chemical properties in relation to the distribution and composition of benthic and planktonic flora and fauna, with special consideration of *C. spinicorne* and *G. oregonensis*, and chloride concentrations.

47. Filice, Francis P. 1954. A study of some factors affecting the bottom fauna of a portion of the San Francisco Bay area. *The Wasmann Journal of Biology* 12(3):257-292.

A study of the "effects on the fauna of hydrogen ion concentration, salinity, and oxygen content of the water as well as the type of substrate and the presence or absence of domestic and industrial wastes." (p. 287)

48. Filice, Francis P. 1958. Invertebrates from the estuarine portion of San Francisco Bay and some factors influencing their distributions. *The Wasmann Journal of Biology* 16(2):159-211.

No correlation was found between species distribution and pH or O_2, whereas S ‰ and substrate was shown to affect distributions. Species by species accounting of distribution of *Corophium, Mesidotea, Neanthes*, etc., as well as marine and freshwater groups.

49. Haertel, Lois Steben. 1970. Plankton and Nutrient Ecology of the Columbia River Estuary. Ph.D. Thesis. Oregon State University, Corvallis. 71 numbered leaves.

"Monthly samples of nutrients, phytoplankton and zooplankton were taken in the Columbia River estuary over a period of 16 months in order to determine distribution with season and salinity, and interrelationships between plankton and nutrients.... The nutrient levels in the estuary generally show a linear relationship with salinity,... The zooplankton of the estuary are composed of three groups: preferring fresh, oligohaline, and polyhaline waters respectively.... The ologohaline group, principally *Eurytemora affinis*, reaches the greatest population density (100,000/m^3 or more)." (abstract)

50. Haertel, Lois, and Charles Osterberg. 1967. Ecology of zooplankton, benthos and fishes in the Columbia River estuary. *Ecology* 48(3):459-472.

"Analyses of plankton samples indicated that three distinct populations existed in the estuary: a freshwater group, a marine group, and an indigenous estuarine group. The latter consisted principally of a large population of Eurytemora hirundoides.... The majority of the fish and benthic invertebrates found in the estuary are euryhaline...food habits of fishes generally reflect the availability of prey." (p. 459).

51. Haertel, Lois, Charles Osterberg, Herbert Curl, Jr., and P. Kilho Park. 1969. Nutrient and plankton ecology of the Columbia River estuary. *Ecology* 50(6):962-978.

"Monthly samples of nutrients, phytoplankton and zooplankton were taken in the Columbia River estuary over a period of 16 months in order to determine distribution with season and salinity, and interrelationships between plankton and nutrients.... The estuarine phytoplankton is primarily composed of freshwater species.... The estuary zooplankton is composed of freshwater, oligohaline and polyhaline forms. *Eurytemora affinis*, an ologohaline form, is the major zooplankter...." (p. 962)

52. Hazel, Charles R., and D.W. Kelley. 1966. Zoobenthos of the Sacramento-San Joaquin Delta. *California Dept. of Fish and Game, Fish Bulletin* 133:113-133.

"...most of the macrofauna on the bottom consisted of two amphipods, *Corophium spinicorne* and *Corophium stimpsoni*, the Asiatic clam *Corbicula fluminea*, a polychaete, *Neanthes limnicola*, and unidentified Tendipendidae and Oligochaetae.... In the Delta the habitat of *Corophium spinicorne* is on solid surfaces like rock, sticks, logs, or peat. *C. spinicorne* is usually more abundant in shallow water near the shore. The habitat of *Corophium stimpsoni* in the Delta is the fine and fine-medium sand found on the bottom of most Delta tidal channels." (p. 133)

53. Higley, Duane L., and Robert L. Holton. 1975. Biological Baseline Data: Youngs Bay, Oregon, 1974; Final Report to Alumax Pacific Aluminum Corporation, 1 November 1973 through 30 April 1975. Oceanography Reference 75-6. Oregon State University, Corvallis, Oregon. 91 pp.

The invertebrate fauna found in Youngs Bay was of low diversity, and was dominated by brackish water forms, especially *Corophium* sp. (a tube-dwelling amphipod), *Eurytemora* sp. (a planktonic copepod) and harpacticoid copepods. *Corophium* densities exceeded 40,000 per square meter. The larval fish fauna was also of low diversity, being composed primarily of prickly sculpin and smelt (Osmeridae). Some marine (fish) species were captured at the bay entrance; otherwise most species were freshwater, brackish, or anadromous forms. *Corophium* and other benthic forms were more frequently eaten than planktonic forms by trawl-captured fish.

54. Levings, C.D. 1973. Intertidal Benthos of the Squamish Estuary. *Fisheries Research Board of Canada Manuscript Report Series* No. 1218. Pacific Environment Institute, West Vancouver, B.C. 60 pp.

"The benthic fauna on the intertidal zone of the Squamish delta is primarily freshwater of brackish water organisms. An amphipod (*Anisogammarus confervicolus*) and an isopod (*Exosphaeroma oregonensis*) were the most abundant organisms. These organisms were aggregated, at low tide, under sedge rhizomes and debris in the intermediate intertidal zone. The amphipod was a common prey for juvenile salmon in the inner estuary...." (p. 18)

55. McConnell, Robert J., Joseph T. Durkin, David A. Misitano, and Herbert R. Sanborn. 1973. Checklist of Aquatic Organisms in the Lower Columbia and Willamette Rivers. Northwest Fisheries Center, U.S. National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112. Mimeographed. 5 numbered leaves.

56. Misitano, David A. 1973. A Checklist of Zooplankton in the Lower Columbia and Willamette Rivers, July to October 1973. Northwest Fisheries Center, U.S. National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112. Mimeographed. 11 numbered leaves.

57. Misitano, David A. 1974. Zooplankton, Water Temperature, and Salinities in the Columbia River Estuary, December 1971 through December 1972. Data Report 92. U.S. National Marine Fisheries Service, Seattle, Washington. 31 pp.

"Sampling was conducted at seven stations in the Columbia River estuary throughout 1972 to provide baseline information on species diversity, relative abundance and seasonal occurrence of zooplankton, as well as ambient water temperatures and salinities." (p. 1)

58. Oregon State University. Interdisciplinary Studies of the Schools of Engineering and Oceanography. 1974. An Examination of Some Physical and Biological Impacts of Dredging in Estuaries. Interim Progress Report to National Science Foundation (RANN). Corvallis, Oregon. 172 pp. plus appendices.

"The research has focused on 4 major topics: 1) the effects of dredging on estuarine systems, 2) the system properties of estuaries, 3) the ways in which estuarine research can be used effectively by user groups, and 4) the development of concepts and techniques for monitoring impacts of dredging and other alterations to estuaries." Includes a list of invertebrate macrofauna found in Coos Bay, a discussion and literature review on zooplankton and dredging, and the results of a study on benthos and dredging in Coos Bay. (p. 1)

59. Parker, Robert R., and B.A. Kask. 1972a. First Progress Report on Studies of the Ecology of the Outer Squamish Estuary, April 26-27, 1972. *Fisheries Research Board of Canada, Manuscript Report Series* 1192:1-11.

"Sampling of fish, plankton and physical structure in water immediate to the mouth of the Squamish estuary revealed that three strata were present, each a habitat of particular plants and animals." (p. 1) Feeding by fish in each stratum is discussed.

60. Sanborn, Herbert R. 1973. A List of Benthic Animals in the Lower Willamette and Columbia Rivers, August to October 1973. Northwest Fisheries Center, U.S. National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112. Mimeographed. 5 numbered leaves.

61. Sanborn, Herbert R. 1975. An Investigation of the Benthic Infauna at Two Dredge and Four Disposal Sites Adjacent to the Mouth of the Columbia River. Completion Report to the U.S. Army Corps of Engineers and Columbia River Programs Office. Northwest Fisheries Center, U.S. National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112. Mimeographed. 19 numbered leaves.

Description of 5 sample stations, lists of taxa identified, and weights and numerical densities of benthic infauna.

62. Smith, Ralph I. 1953. The distribution of the polychaete *Neanthes lighti* in the Salinas River estuary, California, in relation to salinity, 1948-1952. *Biological Bulletin* 105(2):335-347.

"Salinity and salinity changes have been studied over the range of the polychaete *Neanthes lighti* Hartman in the estuary of the Salinas River, California, during the years 1948-1952.... Over

its range, *N. lighti* is associated with such typically brackish water species as *Neosphaeroma oregonensis* (Dana), *Anisogammarus confervicolus* (Stimpson), and *Corophium spinicorne* Stimpson. Its range only slightly overlaps the ranges of such freshwater forms as *Dugesia* sp., leeches, or odonata larvae." (p. 347)

Amphipod Biology

63. Agrawal, V.P. 1963. Studies on the physiology of digestion in *Corophium volutator*. *Journal of the Marine Biological Association of the United Kingdom* 43:125-128.

"...the pH in the different parts of the gut of *Corophium* has been observed, and a qualitative estimation of the different enzymes has been made. The optimum pH for the activity of the caecal amylase has also been determined." (p. 125)

64. Barnes, W.J.P., J. Burn, P.S. Meadows, and D.S. McLusky 1969. *Corophium volutator*--An intertidal crustacean useful for teaching in schools and universities. *Journal of Biological Education* 3: 283-298.

A good survey of types of work done on *Corophium* in areas of behaviour, habitat selection, responses to light, ionic regulation, and population ecology.

65. Bassindale, R. 1942. The distribution of amphipods in the Severn Estuary and Bristol Channel. *Journal of Animal Ecology* 11:131-144.

"The distribution of the commonest Amphipods in the Severn Estuary is described.... The known distribution of *Gammarus* and *Marinogammmarus* in this and other estuaries is compared...." (p. 143)

66. Bosworth, Weldon S., Jr. 1973. Three new species of *Eohaustorius* (Amphipods, Haustoriidae) from the Oregon coast. *Crustaceana* 25(3):253-260.

"While studying the biology of the genus *Eohaustorius* J.L. Barnard, 1957, on the Oregon Coast, four morphological forms were found, three undescribed in the literature, and the other being *Eohaustorius washingtonianus* (Thorsteinson, 1941)...This report describes the three new species and compares their morphology and habitat to *E. washingtonianus*." (p. 253)

67. Bradley, J. Chester. 1908. Notes on two amphipods of the genus *Corophium* from the Pacific Coast. *University of California Publications in Zoology* 4(4):227-252.

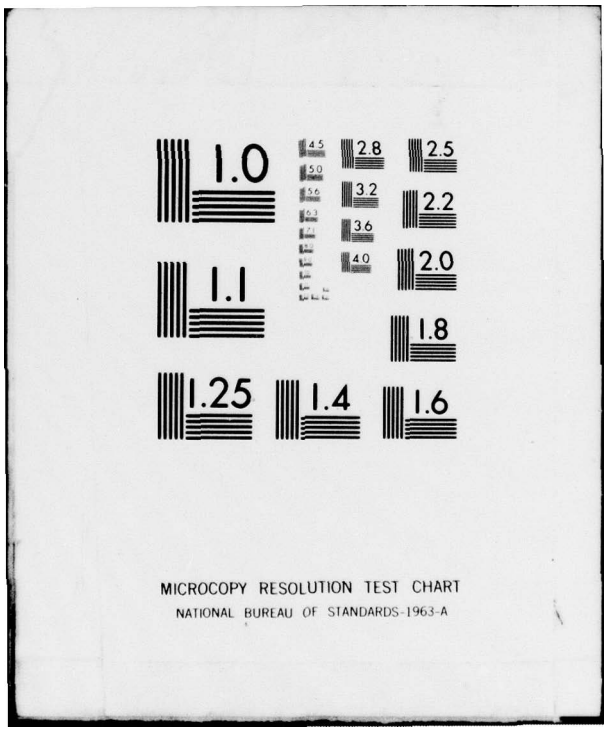
Detailed figures and descriptions of *C. spinicorne* and *C. salmonis*, with key to species of *Corophium*.

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68. Enequist, Paul. 1949. Studies on the soft-bottom amphipods of the Skagerak. *Zoologiska Bidrag fran Upsalla* 28:297-492.

"The aims of the investigation were: 1) An inventory of the amphipods from the soft bottoms of the Skagerak with special reference to the sublittoral and archibenthal (the transition area between the littoral and the abyssal)... 2) A study of the feeding methods of the detritus-eating forms... 3) A preliminary study of the content of organic matter in the top layer of the bottom material... 4) A study of the possible correlation between the fluctuating composition of the catches and the content or organic detritus of the bottoms." (p. 437)

69. Fincham, A.A. 1972. Rhythmic swimming and rheotropism in the amphipod *Marinogammarus marinus* (Leach). *Journal of Experimental Marine Biology and Ecology* 8:19-26.

"Swimming activity in the intertidal amphipod *Marinogammarus marinus* (Leach) is controlled by an endogenous rhythm phased with the tides. During the dark period greatest activity is in the hour after the predicted time of H.W.; if H.W. occurred in the light period the activity peak may be delayed until the onset of darkness. There was greater total activity at neap that at spring tides. Water-flow experiments indicate that the rheotropic response was stronger at neap that at spring tides. A flexible neurosecretory cycle controlling rhythmic swimming is proposed as mediating between a central clock and external 'Zeitgeber', such synchronized swimming activity facilitating location of a mate." (p. 19)

70. Gamble, J.C. 1970a. Anaerobic survival of the crustaceans *Corophium volutator, C. Arenarium* and *Tanais chevreuxi*. *Journal of the Marine Biological Association of the United Kingdom* 50: 657-671.

"...all are relatively resistant to anaerobic conditions. All three species survive for longer periods at lower temperatures. In *Corophium* small individuals are shown to be less resistant to anaerobic conditions than large. ...*C. volutator* is slightly more so than *C. arenarium*." (p. 657)

71. Gamble, J.C. 1970b. Effect of low dissolved oxygen concentrations on the ventilation rhythm of three tubicolous crustaceans, with special reference to the phenomenon of intermittent ventilation. *Marine Biology* 6:121-127.

"The pleopod ventilatory activity of the tube-dwelling amphipods *Corophium volutator* (Pallas) and *C. arenarium* Crawford is intermittent. ...the pleopod beat rate of both *Corophium* species is unaffected by low oxygen concentrations. However, the nature of the intermittent ventilation rhythm is altered so that, at low

oxygen concentrations, the pleopods of *Corophium* beat almost continuously." (p. 121)

72. Gee, J.M. 1961. Ecological studies in South Benfleet Creek with special reference to the amphipod *Corophium*. *Essex Naturalist* 1961:291-309.

73. Goss-Custard, J.D. 1970. The responses of redshank [*Tringa totanus* (L).] to spatial variations in the density of their prey. *Journal of Animal Biology* 39:91-113.

"Over the estuary as whole, the density of redshank was positively correlated with the numerical density of its main prey, the amphipod *Corophium volutator*.... The sizes of *Corophium* taken by the birds increased as the sizes in the substrate increased. ...there was an overall trend for the mass of food obtained per minute to increase as the biomass of *Corophium* in the substrate increased." (p. 110)

74. Hargrave, Barry T. 1970. Distribution, growth, and seasonal abundance of *Hyalella azteca* (Amphipoda) in relation to sediment microflora. *Journal of the Fisheries Research Board of Canada* 27:685-699.

"Growth, density, and body size of the deposit-feeding amphipod *Hyalella azteca* (Amphipoda), and its food, epibenthic algae, and sediment microflora, were greatest in shallow water areas of Marion Lake. The vertical distribution of *Hyalella* was limited to the upper 2 cm of sediment cores. Highest concentrations of sedimentary chlorophyll and lowest concentrations of nondigestible lignin-like material also occurred at the sediment surface.... In laboratory substrate-choice experiments, *Hyalella* differentiated between sediments with different concentrations of micro-organisms, and growth depended upon the quantity of microflora in the diet." (p. 685)

75. Hargrave, Barry T. 1971. An energy budget for a deposit-feeding amphipod. *Limnology and Oceanography* 16:99-103.

"An energy budget, with the parameters determined independently, was constructed for *Hyalella azteca* (Amphipoda) feeding on surface sediment from Marion Lake." (p. 99)

76. Hart, T.J. 1930. Preliminary notes on the bionomics of the amphipod, *Corophium volutator* Pallas. *Journal of the Marine Biological Association of the United Kingdom* 16:761-789.

"...while *Corophium volutator* is capable of withstanding great salinity change, its abundant occurrence is strictly limited by the chemical and physical character of the substratum.... *C. volutator* is a characteristic member of a definite type of animal

community. ...the method of selective deposit feeding appeared much more important than suspension feeding. ...females are more numerous than males...." (p. 784-785)

77. Ingle, R.W. 1966. An account of the burrowing behaviour of the amphipod *Corophium arenarium* Crawford (Amphipoda: Corophiidae). *Annals and Magazine of Natural History (Series 13)* 9:309-317.

"In order to compare *Corophium*... (with other amphipoda)...a study was made of the burrowing habits of *Corophium arenarium* Crawford. This species was chosen as it burrows into sand and its behaviour is easier to observe than that of *C. volutator* which burrows into mud... There would seem to be little fundamental similarity between the burrowing behaviour of *C. arenarium* and the species of *Haustorius, Urothoe* and *Bathyporeia* mentioned..." (p. 309, 316)

78. McLusky, Donald S. 1968a. Aspects of osmotic and ionic regulation in *Corophium volutator* (Pallas). *Journal of the Marine Biological Association of the United Kingdom* 48:769-781.

"Experiments have been made to elucidate the problem of hyperosmotic regulation in the mud-dwelling euryhaline amphipod, *Corophium volutator*. The animal produced urine hypo-osmotic to the blood when acclimatized to low salinities, and isosmotic urine at salinities above 20 ‰." (p. 769)

79. McLusky, Donald S. 1968b. Some effects of salinity on the distribution and abundance of *Corophium volutator* in the Ythan estuary. *Journal of the Marine Biological Association of the United Kingdom* 48:443-454.

"In areas with salinities between 2 and 5 ‰ *C. volutator* was present, but in reduced numbers. Breeding occurred only in salinities greater than 7.5 ‰ In areas with salinity greater than 5 ‰ the distribution and abundance of *C. volutator* were controlled by the substrate." (p. 443)

80. McLusky, Donald S. 1969. The oxygen consumption of *Corophium volutator* in relation to salinity. *Comparative Biochemistry and Physiology* 29:743-753.

"No significant differences were found in oxygen consumption, between animals in different salinities.... In all salinities a logarithmic relationship was noted between oxygen consumption and dry weight.... These findings, in conjunction with previous findings, are discussed in relation to the energy requirements of osmoregulation...." (p. 743)

81. McLusky, Donald S. 1970. Salinity preference in *Corophium volutator*. *Journal of the Marine Biological Association of the United Kingdom* 50:747-752.

"A salinity preference range of 10-30‰ has been found in the euryhaline amphipod *Corophium volutator*, by means of simple choice experiments. This preferendum has been shown to be stable, despite acclimation to either low or high salinities. The results are discussed in relation to previous ecological and physiological studies of *C. volutator*." (p. 747)

82. Mathias, Jack A. 1971. Energy flow and secondary production of the amphipods *Hyalella azteca* and *Crangonyx richmondensis occidentalis* in Marion Lake, British Columbia. *Journal of the Fisheries Research Board of Canada* 28:711-726.

Compares density and energy flow parameters of the two amphipods and relates these values to environmental factors (e.g. depth, temperature).

83. Meadows, P.S., and Alison Reid. 1966. The behaviours of *Corophium volutator* (Crustacea: Amphipoda). *Journal of Zoology* 150:387-399.

"The behaviour of *Corophium volutator* (Pallas) is outlined. Swimming, crawling, burrowing and feeding activities are described in detail...." (p. 387)

84. Morgan, Elfed. 1965. The activity rhythm of the amphipod *Corophium volutator* (Pallas) and its possible relationship to changes in hydrostatic pressure associated with the tides. *Journal of Animal Ecology* 34(3):731-746.

"A rhythm of tidal (12.4 h) frequency with activity maxima during the early ebb was observed in the swimming activity of *Corophium volutator* (Pallas), collected intertidally and kept under constant conditions in the laboratory.... *Corophium* collected from generally non-tidal brackish pools at Oxwich were arhythmic,... Rhythmic swimming activity...was induced in arhythmic laboratory *Corophium* by returning them to shore.... It seems that the rhythm of activity is probably entrained by the decrease in pressure as the tide ebbs." (p. 744-5)

85. Shoemaker, C.R. 1949. The amphipod genus *Corophium* on the west coast of America. *Journal of the Washington Academy of Sciences*, (Washington, D.C.) 39:66-82.

Diagnostic descriptions of 13 species of *Corophium* found on the west coast of North America.

86. Waldichuk, M., and E.L. Bousfield. 1962. Amphipods in low-oxygen marine waters adjacent to a sulphite pulp mill. *Journal of the Fisheries Research Board of Canada* 19(6):1163-1165.

"Amphipods taken at the bottom were identified mainly as *Anisogammarus pugettensis*, Dana.... Amphipods taken at the surface were

mostly *Allorchestes angustus* Dana, although there were also a number of *Anisogammarus pugettensis*." (p. 1165)

87. Watkin, E. Emrys. 1941. The yearly life cycle of the amphipod, *Corophium volutator*. *Journal of Animal Ecology* 10(1):77-93.

"By August all the overwintering population had died off and the new broods were in active reproduction.... The average size of the breeding females is around 7 mm, after which the death rate is rapid, an occasional individual reaching a size of 10 mm.... The average size of the males is less than that of the females.... The number of males in relation to the total population of males and females in the groups of 4 mm and over showed a successive decrease from the 4 to the 8 mm groups." (p. 92-93)

Biology of Other Estuarine Invertebrates

88. Barnett, P.R.O. 1968. Distribution and ecology of harpacticoid copepods of an intertidal mudflat. *Internationale Revue der gesamten Hydrobiologie* 53(2):177-209.

"Core samples were taken at various dates in 1956 and 1957 from an intertidal transect across Hamble Spit, a mudflat in Southampton Water. A new method was devised to separate the harpacticoid copepods from the mud. Seasonal temperature changes, salinity, water content and particle sizes of the mud were investigated.... The majority of harpacticoids were restricted to the surface 0.5 cm layer of mud. Five species of harpacticoid showed distinct zonations." (p. 206)

89. Brafield, A.E., and G.E. Newell. 1961. The behaviour of *Macoma balthica* (L.). *Journal of the Marine Biological Association of the United Kingdom* 41:81-87.

"The tellinid *Macoma balthica* moves extensively about the surface of the sand, its activities not being restricted to vertical movements as hitherto supposed. These horizontal migrations comprise a movement towards the sun followed by a movement away from it.... [This] confers the advantage of bringing the animal into contact with surrounding areas while maintaining its station on the shore." (p. 86)

90. Capstick, C.K. 1959. The distribution of free-living nematodes in relation to salinity in the middle and upper reaches of the River Blyth estuary. *Journal of Animal Ecology* 28(2):189-210.

"Two extraction techniques are described.... The nematode populations at six stations in the middle reaches increase the amount of mud in the substratum. The intertidal population densities of *E. brevis* on three transects in the upper reaches decrease at the upper and lower ends of the transects, and as the head of the estuary is approached; it is suggested that this is due to the limiting effect of interstitial salinities." (p. 209)

91. Fahrenbach, W.H. 1962. The biology of a harpacticoid copepod. *La Cellule* 62(3):303-374.

The harpacticoid *Diarthrodes cystoecus* is described. Larval stages, reproductive biology, habitat and feeding are discussed, and detailed descriptions given of internal and external anatomy.

92. Fast, Arlo W. 1971. The invasion and distribution of the Asiatic clam *(Corbicula manilensis)* in a Southern California reservoir. *Bulletin of the Southern California Academy of Sciences* 70(2):91-98.

Population fluctuations correlated with stratification, water level changes, and sediment particle size.

93. Green, J. 1957. The feeding mechanism of *Mesidotea entomon* (Linn.) (Crustacea: Isopoda). *Proceedings of the Zoological Society of London* 129(2):245-254.

"The mouthparts of *Mesidotea entomon* are briefly described. Observations on living animals show that this species is capable of locating and capturing active animals, both on the surface of the substratum and below the surface." (p. 253)

94. Hanna, G. Dallas. 1966. Introduced mollusks of western North America. *Occasional Papers of the California Academy of Sciences* 48:1-108.

95. Harris, Roger P. 1972. Seasonal changes in population density and vertical distribution of harpacticoid copepods on an intertidal sand beach. *Journal of the Marine Biological Association of the United Kingdom* 52:493-505.

"At M.L.W.N. the majority of species showed distinct peaks in population density during the summer.... All the copepods showed pronounced seasonal changes in vertical distribution in the sand." (p. 493)

96. Hauspie, R., and Ph. Polk. 1973. Swimming behaviour patterns in certain benthic harpacticoids (Copepoda). *Crustaceana* 25:95-103.

"A number of species of so-called "benthic" harpacticoids show nocturnal swimming movements, enabling them to occupy new dwelling spaces. Some of the consequences of this are discussed." (p. 102)

97. Hulburt, Edward M. 1957. The distribution of *Neomysis americana* in the estuary of the Delaware River. *Limnology and Oceanography* 2:1-11.

"It was found that *Neomysis* was far more abundant in the deep water.... Moreover, it was more abundant within the estuary than in

the coastal waters.... they tended to accumulate within the estuary due to their avoidance of the out-flowing surface waters.... The up-estuary extent of *Neomysis* was related to the 4 ‰ isohaline..." (p. 1)

98. Israel, Hugh R. 1936. A contribution toward the life histories of two California Shrimps, *Crago franciscorum* (Stimpson) and *Crago nigricauda* (Stimpson). *California Department of Natural Resources, Fish Bulletin* 46:1-28.

"Much of the life histories of *Crago franciscorum* and *Crago nigricauda* are very similar. They move toward the ocean as the spawning season approaches, and the eggs hatch in water of high salinity. The young shrimp are found at some distance from the ocean in shallow water of reduced salinity. As they grow, they move into deeper water.... The females grow more rapidly than the males.... Both species breed at the end of their first year.... Toward the ocean ...only *Crago nigricauda* is found in large numbers. Farther inland *Crago franciscorum* is usually the only species occurring in abundance." (p. 26)

99. Johnson, Martin W., and J. Bennett Olson. 1948. The life history and biology of a marine harpacticoid copepod, *Tisbe furcata* (Baird). *Biological Bulletin* 95:320-332.

Observations on nauplius and adult stages--sexual maturity, generation time, fucundity, mating behaviour, survival.

100. Kost, Angela L., and Allen W. Knight. 1975. The food of *Neomysis mercedis* Holmes in the Sacramento-San Joaquin estuary. *California Fish and Game* 61(1):35-46.

"The most abundant items in the gut were detritus and diatoms. The percentage of detritus relative to diatoms was greater in winter than in summer, and increased with shrimp size.... Certain diatom genera predominated in shrimp from particular locations and in shrimp collected during particular times of the year." (p. 35)

101. Lasenby, David C., and Raymond R. Langford. 1973. Feeding and assimilation of *Mysis relicta*. *Limnology and Oceanography* 18: 280-285.

"Stony Lake animals were rather voracious predators, feeding on *Daphnia* and other cladocerans during their vertical migration at night. Char Lake mysids fed primarily on diatoms and inorganic particles on a moss substrate." (p. 280)

102. Lloyd, A.J., and C.M. Yonge. 1947. The biology of *Crangon vulgaris* L. in the Bristol Channel and Severn Estuary. *Journal of the Marine Biological Association of the United Kingdom* 26:626-661.

Describes habits of the species, osmo-regulation, growth rate, secondary sexual characters, copulation, spawning, adult life history, and migration.

103. Mauchline, J. 1971. The biology of *Neomysis integer* (Crustacea, Mysidacea). *Journal of the Marine Biological Association of the United Kingdom* 51:347-354.

Discussed life cycle, breeding behaviour, and food habits (omniverous).

104. Newell, Richard. 1965. The role of detritus in the nutrition of two marine deposit feeders, the prosobranch *Hydrobia ulvae* and the bivalve *Macoma balthica*. *Proceedings of the Zoological Society of London* 144:25-45.

"Observations on the shore show that the density of the population of the prosobranch *Hydrobia ulvae* and of the bivalve *Macoma balthica* at Whitstable varies considerably with the grade of deposit, dense populations being found in fine deposits and sparse populations in coarse deposits. From laboratory experiments it seems probable that these animals feed by abstracting proteins, which can be assessed as nitrogen, from the bodies of micro-organisms in the deposits and that the micro-organisms are more abundant in fine deposits than in coarse ones. As a result of these conclusions it is suggested that the rapid increase in population density of *Hydrobia ulvae* and *Macoma balthica*, and by inference of other deposit-feeders, toward regions of fine-grained deposits is attributable to the increase in density of the micro-organism population. This in turn, is related to the surface area of the deposits rather than to the abundance of organic debris." (p. 25)

105. Reid, Robert G.B., and Alison Reid. 1969. Feeding processes of members of the genus *Macoma* (Mollusca: Bivalvia). *Canadian Journal of Zoology* 47:649-657.

"The eight species of *Macoma* examined fall into three feeding categories: two are deposit feeders, five are suspension feeders, and one feeds on the surface films of bacteria on sand grains. The type of particle which is found in the stomach depends on the behavior of the siphons, the quality or quantity or mucus secreted by the gills and labial palpa and to some extent on the sorting function of the labial palps." (p. 649)

106. Rinne, John N. 1974. The introduced Asiatic clam, *Corbicula*, in central Arizona reservoirs. *The Nautilus* 88(2):56-61.

"Concentrations of clams increased with depth of water and downlake from inflow areas characterized by greater turbidity (suspended sediment). Densities were highest on rock-rubble slopes and increased directly with complexity (number of components) of substrate." (p. 56)

107. Turner, Jerry L., and William Heubach. 1966. Distribution and concentration of *Neomysis awatschensis* in the Sacramento-San Joaquin Delta. *California Department of Fish and Game, Fish Bulletin* 133:105-112.

Distribution and abundance studied in relation to salinity, rate of water flow, depth, and oxygen.

108. Yonge, C.M. 1949. On the structure and adaptations of the Tellinacea, deposit-feeding Eulamellibranchia. *Philosophical Transactions of the Royal Society of London, Series B* 234(609): 29-76.

"The Tellinacea comprise four families of eulamellibranchs possessing common structural features all associated with the habit of feeding on bottom deposits. The habits and general structure of all available British species of the Tellinacea have been studied; in particular, *Tellina tenuis* (in greatest detail) and *Macoma balthica* (Tellinidae); *Abra alba* and *Scrobicularia plana* (Semelidae); *Donax vittatus* (Donacidae); *Gari tellinella, G. fervensis, Solecurtus chamasolen* and *S. scopula* (Asaphidae). In the Tellinidae and Semelidae the siphons are very long and the inhalent siphon gropes widely over the surface, actively drawing in bottom deposits." (p. 29)

109. Zhukova, A.I. 1963. On the quantitative significance of microorganisms in nutrition of aquatic invertebrates. Pages 699-710 in C.H. Oppenheimer, ed., 1961 Symposium on Marine Microbiology. Charles C. Thomas, Springfield, Illinois.

Studied digestion, assimilation and contribution to nutrition by bacteria for *Nereis* and *Pontogammarus*.

Benthos-Substrate Relations

110. Bader, Richard G. 1954. The role of organic matter in determining the distribution of pelecypods in marine sediments. *Journal of Marine Research* 13:32-47.

"Sediments in the region of Mt. Desert Island, Maine, indicate that their organic content and its state of decomposition, as expressed by $L/R_n \times T.O.$ (where L = refractory organics, R_n = nonrefractory organics, and $T.O.$ = total organics), are primary factors in controlling the distribution of sediment-dwelling pelecypods." (p. 32)

111. Fenchel, T., L.H. Kofoed, and A. Lappalainen. 1975. Particle size-selection of two deposit feeders: the amphipod *Corophium volutator* and the prosobranch *Hydrobia ulvae*. *Marine Biology* 30:119-128.

"...both forms show size selection which alone can explain their coexistence.... *C. volutator* can only utilize bacteria adsorbed to

particles within the size range 6 to 63 μm.... *C. volutator* can utilize bacteria suspended in the water pumped through its burrow...." (p. 119)

112. Fincham, A.A. 1973. The association of amphipods in the shallow-water sand habitat of Stranggord Lough, Co. Down. *Journal of the Marine Biological Association of the United Kingdom* 53(1):119-125.

"Twenty-two species of amphipod belonging to thirteen families were identified;...the overall dominant species was the corophiid *Corophium crassicorne*.... A matrix of indices of similarity between stations based on species composition and of sediment type based on median diameter showed a close correlation...." (p. 119)

113. Gray, John S. 1966. The attractive factor of intertidal sands to *Protodrilus symbioticus*. *Journal of the Marine Biological Association of the United Kingdom* 46:627-645.

"In simple choice experiments *Protodrilus symbioticus* Giard, an interstitial archiannelid, was shown to prefer the sand from its habitat in the natural state to the same sand altered by various physical or chemical treatments.... The attractiveness of natural sand to *P. symbioticus* could be destroyed almost completely by acid cleaning, by heating in water above 50°C or by drying at any temperature." (p. 627)

114. Marzolf, G. Richard. 1965. Substrate relations of the burrowing amphipod *Pontoporeia affinis* in Lake Michigan. *Ecology* 46(5): 579-592.

"*Pontoporeia affinis*, a burrowing amphipod and the predominant macrobenthic invertebrate in the upper Great Lakes, was studied during the summer months of 1960 and 1961 with regard for its association with the bottom sediments.... The distribution of *P. affinis* in the study area showed no significant correlation with depth, particle size, or organic matter estimates of the sediments, but correlated with the number of bacteria in the sediments.... In the laboratory *P. affinis* selected sediment particles smaller than ϕ 1 (0.05 mm)." (p. 579)

115. Meadows, P.S. 1964a. Experiments on substrate selection by *Corophium volutator* (Pallas): depth selection and population density. *Journal of Experimental Biology* 41:677-687.

"An apparatus is described for testing substrate-depth preferences of *Corophium volutator* (Pallas).... *Corophium* burrow in mud whatever its depth, if only depth of mud is available.... Very shallow muds, of 0.5 cm depth are particularly avoided.... ...animals are persuaded to burrow in shallow muds when the surface population density in the deeper muds is at high level (>0.1 animals/cm^2).... Larger animals tend to be found in deeper muds." (p. 687)

116. Meadows, P.S. 1964b. Experiments on substrate selection by *Corophium* species: films and bacteria on sand particles. *Journal of Experimental Biology* 41:499-512.

"A simple method is described for determining the substrate preferences of *Corophium volutator* (Pallas) and *Corophium arenarium* Crawford. If offered a choice of its own substrate with that of the other species each prefers its own.... Level of illumination and colour of substrate have little effect on choice. An animals size and hence its age has little effect on its substrate preferences. *C. volutator* prefers a substrate previously maintained under anaerobic conditions, *C. arenarium* vice versa. Treatments which kill, inactivate, or remove micro-organisms render sands unattractive to *Corophium*.... ...the loss of bacteria from the surface of sand grains...is not necessarily associated with a substrate becoming unattractive." (p. 509)

117. Meadows, P.S. 1964c. Substrate selection by *Corophium* species: The particle size of substrates. *Journal of Animal Ecology* 33: 387-394.

"When offered a choice of sand having different particle sizes, *Corophium volutator* prefers fine to coarse over a range of sizes. On the basis of one experiment *C. arenarium* is indifferent to particle size.... *C. volutator* may be misled as to the nature of the underlying substrate by thin surface layers of different particle size.... It is suggested that *C. arenarium* is somewhat less particular in its choice of substrate than is *C. volutator*." (p. 393)

118. Meadows, P.S. 1967. Discrimination, previous experience and substrate selection by the amphipod *Corophium*. *Journal of Experimental Biology* 47:553-559.

Two choice-preference experiments and 3-month observations on the growth and mortality of *C. volutator* revealed the following: "1. Populations contain no animals that are consistently less discriminating than others in their choice of substrates. 2. Previous experience in atypical substrates does not alter preferences for typical substrates. 3. Animals live slightly longer in very fine-grained substrates than in coarser ones. 4. Their growth rates do not differ over a range of particular sizes. 5. Animals select the smaller grains in "a substrate" to build their tubes with." (p. 558)

119. Rees, C.P. 1975. Competitive interactions and substratum preferences of two intertidal isopods. *Marine Biology* 30:21-25.

"The intertidal isopods *Gnorimosphaeroma oregonensis* (Dana) and *[illegible]osphaeroma amplicauda* (Stimpson) are shown to have differing

preferences for substratum particle-size categories.... These relationships changed upon laboratory manipulation of density ratios, and suggest competitive interaction...." (p. 21)

120. Sanders, Howard L. 1958. Benthic studies in Buzzards Bay. I. Animal-sediment relationships. *Limnology and Oceanography* 3(3): 245-258.

"The number of animals ranged from 1,064 to 12,576/m^2 with a mean number of 4,430. In comparison with certain other areas these numbers appeared small and seemed to be due to the relatively low concentrations of chemical nutrients and modest primary production of the region. Two faunal assemblages were recognized.... It was suggested that clay is probably the most valid criterion for the distribution of deposit-feeders. The distribution of infaunal filter-feeders seemed related to the degree of sorting and the median grain size of the sediment, with largest populations present in well-sorted fine sand." (p. 245)

121. Wieser, Wolfgang. 1956. Factors influencing the choice of substratum in *Cumella vulgaris* Hart (Crustacea, Cumacea). *Limnology and Oceanography* 1:274-285.

"In sand predominantly finer than 150 μ and in mud *C. vulgaris* feeds as a "deposit-feeder," while in sand predominantly coarser than 150 μ it feeds as an "epistrate-feeder" that is, by scraping food off the surface of individual grains. If fractions finer than 150 μ are thoroughly sieved, *C. vulgaris* cannot employ the latter feeding habit because the sand grains are too small for efficient individual handling by the mouth parts. On the other hand, deposit-feeding cannot be employed either since the fine organic debris which in this instance serves as the source of food, has been removed by the process of sieving.... The food content seems to be one of the most powerful stimuli to which sand-inhabiting animals react in choosing substratum." (p. 274)

122. Wieser, Wolfgang. 1959. The effect of grain size on the distribution of small invertebrates inhabiting the beaches of Puget Sound. *Limnology and Oceanography* 4:181-194.

"The intertidal distribution of at least some of the more common species of invertebrates on the beaches is not so much determined by levels of tidal water as by the pattern of distribution of certain grades of substrate.... On the beaches there exist mixtures of sand which constitute barriers separating major faunal components from each other. It is assumed that substrates with a median diameter of approximately 200 constitute such a barrier separating the bulk of interstitial sliders from a great number of burrowing animals. The former can move only in sand coarse enough to maintain an interstitial system; the latter, for mechanical reasons, will

find fine sand more favorable than coarse.... There are various ways in which grain size and shape can influence the distribution of the fauna. These types of relationships are discussed." (p. 181)

Ecology of Fishes in Estuaries

123. Frame, David W. 1974. Feeding habits of young winter flounder (*Pseudopleuronectes americanus*): prey availability and diversity. *Transactions of the American Fisheries Society* 103(2):261-269.

"The principal diet of age I + winter flounder *Pseudopleuronectes americanus* captured in the Weweantic River Estuary, Wareham, Massachusetts was comprised of polychaetes, bivalves, gastropods, and crustaceans. During spring, flounder fed on planktonic crustaceans found within the estuary and during the summer and fall on mollusks and polychaetes at the estuary's mouth..." (p. 261) "Flounders appeared to feed more selectively in spring when they were not demersal...." (p. 264) "They fed primarily on planktonic copepods in spring and shifted to benthic invertebrates in summer and fall." (p. 266)

124. Hartley, P.H.T. 1940. The Saltash tuck-net fishery and the ecology of some estuarine fishes. *Journal of the Marine Biological Association of the United Kingdom* 24:1-68.

"The fish population of the estuaries is essentially marine: its composition changes from month to month with the arrival from, or departure to, the sea of different species of fish.... The flounder (*Pleuronectes flesus*) is the typical fish of the estuaries.... The other species of fish living in the estuary are listed, with remarks upon their periods of estuarine life, growth rates and food.... The relationships between the members of the estuarine fish community are discussed." (p. 66)

125. Hartley, P.H.T. 1948. Observations on flounders *Pleuronectes flesus* L. marked in the estuaries of the Tamar and Lynher. *Journal of the Marine Biological Association of the United Kingdom* 27: 53-59.

"Individual growth rates were found to vary greatly.... In the spring there was an upstream movement of the smaller, immature fish." (p. 59)

126. Kaczynski, V.W., R.J. Feller, J. Clayton, and R.J. Gerke. 1973. Trophic analysis of Juvenile Pink and Chum Salmon (*Oncorhynchus gorbuscha* and *O. Keta*) in Puget Sound. *Journal of the Fisheries Research Board of Canada* 30:1003-1008.

"Epibenthic harpacticoid copepods were the chief prey of the chum and pink salmon.... The stomach contents showed no resemblance to the plankton hauls taken in the same area." (p. 1003)

127. McDonald, J. 1960. The behaviour of the Pacific salmon fry during their downstream migration to freshwater and saltwater nursery areas. *Journal of the Fisheries Research Board of Canada* 17(5): 655-676.

"The downstream migration of sockeye, coho, pink and chum salmon fry is initially nocturnal and appears to be regulated quite precisely by changes in light intensity. Downstream movement is seen to arise from a displacement by the current when firm visual contact with fixed objects in the stream is lost." (p. 655)

128. Manzer, J.I. 1969. Stomach contents of juvenile Pacific salmon in Chatham Sound and adjacent waters. *Journal of the Fisheries Research Board of Canada* 26(8):2219-2223.

Pink and chum salmon ate primarily plankton, while cohos ate fish. Sockeye ate both plankton and fish.

129. Mason, J.C. 1974. Behavioral ecology of chum salmon fry (*Oncorhynchus keta*) in a small estuary. *Journal of the Fisheries Research Board of Canada* 31:83-92.

"Chum salmon fry (*Oncorhynchus keta*) in the estuary of a small coastal stream exploited fresh water, estuarine and marine food chains and, by so doing, were exposed to marked, daily fluctuations in salinity that demanded active selection of fresh water on ebbing tides day and night." (p. 83)

130. Miller, Bruce Stuart. 1965a. Food and Feeding Studies on Adults of Two Species of Pleuronectids (*Platichthys stellatus* and *Psettichthys melanostictus*) in East Sound, Orcas Island (Washington). M.S. thesis, University of Washington, Seattle.

131. Miller, Bruce Stuart. 1965b. Stomach contents of adult starry flounder and sand sole in East Sound, Orcas Island, Washington. *Journal of the Fisheries Research Board of Canada* 24:2515-2526.

"Starry flounder fed mainly on priapulids, nemerteans, polychaetes, and lamellibranchs.... Starry flounder ceased feeding during the months of lowest water temperature.... The stomach of the starry flounder appeared to be used primarily as a holding organ and was emptied in about 9 hrs." (p. 2515)

132. Orcutt, Harold George. 1950. The life history of the starry flounder *Platichthys stellatus* (Pallas). *California Department of Natural Resources, Fish Bulletin* 78:4-64.

Discussed distribution, salinity preference, habitat, food habits, embryology, growth, meristics, and hybridization with other species.

133. Parker, Robert R. 1971. Size selective predation among juvenile salmonid fishes in a British Columbia inlet. *Journal of the Fisheries Research Board of Canada* 28:1503-1510.

"...early sea mortality of pink and chum salmon fry is largely due to predation by juvenile coho (*O. kisutch*) salmon. A series of experiments demonstrates a strong bias toward the smaller individuals of the prey population.... Chums are shown to have an advantage over pinks through slightly earlier entry into the estuary and a larger initial size." (p. 1503)

134. Parker, Robert R., and B.A. Kask. 1972b. Second Progress Report on Studies of the Ecology of the Outer Squamish Estuary, May 16-17, 1972. *Fisheries Research Board of Canada, Manuscript Report Series* 1193:1-15.

"Examination of the stomach contents of the catches revealed that the chums were feeding on amphipods and insects originating in the inner estuary, while the chinook, coho and larger herring had been eating chum fry. The flounders had been eating a marine pelagic amphipod.... These results suggest that, with the exception of the flounders, the food resources utilized by fishes in the outer estuary originated in the inner estuary." (p. 1)

135. Parker, Robert R., and B.A. Kask. 1972c. Third Progress Report on Studies of the Ecology of the Outer Squamish Estuary, June 7, 1972. *Fisheries Research Board of Canada, Manuscript Report Series* 1194: 1-13.

"The herring had been feeding largely on planktonic copepods, while the coho had fed on larval fishes, principally herring and smelt larvae. Other fishes taken had fed largely on an estuarine amphipod." (p. 1)

136. Parker, Robert R., and B.A. Kask. 1972d. Fourth Progress Report on Studies of the Ecology of the Outer Squamish Estuary. *Fisheries Research Board of Canada, Manuscript Report Series* 1195:1-15.

"The complete sampling series (April to July) suggests that fishes in the outer estuary are dependent on two types of food chains. (1) A marine food chain is based on phytoplankton production in early spring.... (2) A second major food source is an amphipod insect complex which depends upon autotrophic and hetrotrophic production in the inner estuary.... There appears to be a shift from the marine based food resource to the estuarine based food resource as the season progresses." (p. 1)

137. Pearcy, William G., and Sharon S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: A nursery ground for marine fishes? *Fishery Bulletin* 72(1):201-213.

"Based on a survey of planktonic fish larvae, the Yaquina Bay estuary appears important as a spawning or rearing ground only for *Clupea harengus pallasi* (Pacific herring) and a variety of small cottids, gobies, and stichaeids.... Of the 44 types of larval fishes found in the bay, *C. h. pallasi* and *Lepidogobius lepidus* (baby goby) were co-dominants each year, 1960-1970, comprising 90% of all larvae collected. There was no evidence of trends in abundances or species composition during the 11-yr. study." (p. 201)

138. Porter, Russell G. 1964. Food and Feeding of Staghorn Sculpins and Starry Flounders in Euryhaline Environment. M.S. Thesis. Humboldt State College. 84 pp.

139. Reimers, Paul E. 1971. The Length of Residence of Juvenile Fall Chinook Salmon in Sixes River, Oregon. Ph.D. Thesis, Oregon State University, Corvallis, Oregon. (Dissertation Abstracts Order No. 71-25, 329). 108 pages.

140. Smith, Howard D. 1972. Juvenile Salmon and Trout in the Nanaimo River and Estuary in Relation to the Proposed Assembly Wharf Expansion. *Fisheries Research Board of Canada, Manuscript Report Series* 1190:1-13.

    Discusses possible consequences of the "proposed 148 acre extension to the forest industry processing and handling facilities, and additional moorage for deep sea vessels in the Nanaimo Harbour...." (p. 1)

141. Sparrow, R.A.H. 1968. A first report of chum salmon fry feeding in fresh water of British Columbia. *Journal of the Fisheries Research Board of Canada* 25(3):599-602.

    Little work to present time has been done on feeding habits and size of juvenile chum salmon in fresh water. Chums captured in the Cowichan River of British Columbia had been feeding extensively on chironomids and cladocerans, and grew appreciably while in fresh water.

142. Westrheim, Sigurd J. 1955. Migrations of starry flounder, *Platichthys stellatus,* tagged in the Columbia River. *Oregon Fish Commission Research Briefs* 6(1):33-37.

    "A total of 1,846 starry flounder was tagged during 1951-53 from a fish trap on the lower Columbia River near Chinook, Washington.... Recoveries were made inside (85) and outside (26) the Columbia River. The inside recoveries were all taken within 15 miles of the tagging site. The outside recoveries were taken 10 to 130 miles from the tagging site." (p. 37)