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DREDGING OF PCB-CONTAMINATED SEDIMENTS NEW BEDFORD HARBOR/ACUSHNET RIVER ESTUARY, MA

GEOTECHNICAL ENGINEERS INC.

DREDGING OF PCB-CONTAMINATED SEDIMENTS
NEW BEDFORD HARBOR/ACUSHNET
RIVER ESTUARY, MA

Submitted to

New England Governors' Conference, Inc.
Boston, Massachusetts

Submitted by

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Project 82990
September 7, 1982

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1. EXECUTIVE SUMMARY

The purpose of this investigation was to identify feasible dredging techniques for the removal of sediments contaminated with polychlorinated biphenyls (PCB's) from the New Bedford Harbor and Acushnet River Estuary. This investigation included laboratory testing on sediments obtained from the tidal flats near a historic source of PCB contamination, and a literature review of: the history of PCB contamination in the general area, local sediment characteristics, and dredging, transporting, and disposing of contaminated sediments.

This investigation was sponsored by the New England Governors' Conference, Inc. with primary funding from the U. S. Water Resources Council, secondary funding and technical guidance from the Massachusetts Office of Coastal Zone Management, and in kind services contributed by the five coastal New England states and New York. This work is part of a larger analysis of dredge management needs in New England.

Information developed during this and previous studies indicate that surface sediments of the Acushnet River Estuary and New Bedford Harbor are contaminated with high levels of PCB's from two industrial operations and a wastewater treatment facility. The area of contamination extends from the tidal flats at the northernmost extreme of the estuary in the inner harbor to an area in the vicinity of the New Bedford municipal wastewater outfall in the outer harbor, a distance of over six miles. These sediments contain PCB's in levels up to 190,000 ppm, or 19 percent. Contamination has caused eighteen thousand acres to be closed to lobstering, and a lesser, yet significant, area to be closed to the taking of finfish and shellfish.

PCB's are only slightly soluble in water and are readily adsorbed from aqueous solutions and held strongly in place by fine-grained sediments. Therefore, the mobility of these contaminants when sediments are moved will depend greatly upon the amount of resuspension of the sediments during dredging and transportation. To minimize environmental impacts dredging and transportation techniques must be selected to minimize resuspension of contaminated sediments.

Surface sediments consist primarily of black, organic silts and clays. Vertical movement of PCB's within the fine-grained surface sediments is likely to be low. Although the vertical extent of PCB contamination throughout the harbor is not precisely known, data indicate that PCB's are most concentrated in the top 10 cm, and are not likely to be present in elevated concentrations at depths greater than about 1 m.

Surface sediments are most likely to be classified as Category Three, Type C by the Mass. Division of Water Pollution Control due to the excessively high contents of PCB's, copper, lead, zinc, chromium, and other metals (Category Three), and due to the generally high percentage of silt, clay, oil and grease, and water (Type C).

Assuming that an average of 2 ft of surface sediment is contaminated, it is estimated that to remove 90% of the PCB's from the inner harbor would require dredging about 4-1/2 million cu yds of material; removal of 90% of the PCB's from the outer harbor would require dredging an additional volume of about 1-1/2 million cu yds of contaminated sediments.

The primary dredging types include mechanical, hydraulic, and pneumatic. Each of the three general dredging types could be used in an environmentally safe manner with the pneumatic and hydraulic dredge methods providing the least chance for resuspension of sediments. Watertight mechanical (clamshell) methods may also be environmentally safe when used in conjunction with silt curtains.

Dredged material is transported generally by pipeline, barge, truck, or rail depending on the dredge type and distance to the disposal site.

Dredge spoils (and other materials) containing 50 ppm or greater of PCB's are regulated by the EPA. EPA specifies three alternate disposal methods for such materials which include much of the harbor sediments: (1) incineration, (2) disposal in an approved chemical landfill, and (3) some other disposal method approved by the EPA Regional Administrator.

Incineration of dredged material is technically feasible but would likely be prohibitively expensive.

There are, at present, no chemical landfills in New England approved by the EPA for disposal of PCB dredge spoils. The closest approved chemical landfills are about 500 miles from the project area in New York State, and disposal space in those chemical landfills is extremely limited. Even if disposal space is available at the New York landfills, transportation and disposal costs would likely be prohibitively expensive.

Among the other disposal options, the most feasible options at this time appear to be open water or land disposal at sites specially set aside for dredged spoils. Land disposal in a properly engineered clay encapsulated excavation or pile with leachate collection and treatment systems would provide adequate environmental isolation of contaminated sediments. Open ocean dumping of sediments does not provide the level of containment as an encapsulated landfill, but would remove the materials to a more remote environment.

Although technical solutions are available, it is impossible to recommend a specific dredging, transportation, and disposal option until a disposal site is identified. This is because dredging and transportation techniques are directly tied to each other and to the ultimate disposal site.

Further input from the public and the many federal, state, and local regulatory agencies will be required to select a disposal site or sites before meaningful recommendations regarding dredging and transportation techniques can be made. Cost benefit analysis between several disposal site alternatives and associated dredging and transportation techniques should then be performed.

2. INTRODUCTION

2.1 Purpose

The purpose of this investigation was to identify feasible dredging techniques for the removal of contaminated sediments from the New Bedford Harbor and Acushnet River Estuary and to complement ongoing dredge spoil studies being made by state, federal, and private organizations in the area. It was also the intent of this investigation to obtain more detailed knowledge about sediment characteristics in the tidal flats north of the inner harbor, and general knowledge about the rest of the harbor sediments (Figs. 1 and 2).

2.2 Scope

This investigation was divided into two major tasks. Task I consisted of collecting and analyzing available information on the physical and chemical characteristics of the contaminated sediments in the estuary. In addition, laboratory tests were performed on seven sediment samples which were obtained from the tidal flats near a historic source of contamination.* These tests included:

a. Bulk analysis for metals, oil and grease

b. Grain-size analysis

c. Composite elutriate tests for metals, oil and grease, and PCB's.

d. Composite EP toxicity test

e. Solid phase bioassay

The results of the laboratory testing program are discussed in detail in the Appendix.

Task II consisted of a literature review to identify and evaluate available dredging techniques to provide preliminary recommendations on methodologies available to dredge and transport contaminated sediments from the estuary in an environmentally safe manner. In addition, we took a general look at some of the options available for disposing of the dredged sediments.

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*Funding for the collection of samples was provided by Massachusetts Office of Coastal Zone Management.

2.3 Authorization

Work performed for this investigation was authorized by a contract dated June 24, 1982 between the New England Governors' Conference, Inc. and Geotechnical Engineers Inc.

2.4 Background

The New England Governors' Conference, Inc. (NEGC), with primary funding from the U. S. Water Resources Council and in kind services contributed by the five coastal New England states and New York, has been charged with the task of concluding the New England/New York Long Range Dredge Management Study originally begun by the former New England River Basins Commission. The primary goals of the Dredge Management Program are to identify and assess the effects of dredging on each state and region, develop procedures for use by the states in setting priorities for dredging projects, and develop long-range regional and subregional dredge management strategies. As part of this program, the NEGC in conjunction with the Massachusetts Office of Coastal Zone Management has elected to focus on investigating dredging techniques for the PCB-contaminated sediments in the New Bedford Harbor/Acushnet River Estuary.

New Bedford, Massachusetts is a port city located on Buzzards Bay approximately 55 miles south of Boston. With a population of 98,500, New Bedford is Massachusetts' fourth largest municipality.

A major source of contamination in the harbor sediments is polychlorinated biphenyls or PCB's. PCB's are a class of compounds produced by the chlorination of biphenyls and are registered in the U. S. under the trade name Aroclor. PCB compounds are only slightly soluble in water, lipids, oils, and organic solvents, and are resistant to both heat and biological degradation. They have been used principally in the electrical industry in capacitors and transformers (MDPW, undated).

Extensive PCB contamination of New Bedford Harbor (Fig. 1) was documented in 1976 when the Environmental Protection Agency conducted a New England-wide PCB survey and found high levels of PCBs in various harbor locations. Testing revealed that two industrial operations were discharging wastewaters containing PCBs to New Bedford Harbor by direct discharge and indirectly via the New Bedford Municipal wastewater treatment facility. Discharge from one of the industrial operations has been nearly eliminated while discharge from the others has been significantly reduced; however, the discharge of PCBs from New Bedford's municipal wastewater treatment plant remains significant. Recent studies have shown that 300 to 700 pounds of PCBs are being discharged per year (Weaver, 1982).

The area of PCB contamination extends from the northernmost extreme of the Acushnet River Estuary to an area in the vicinity of the New Bedford municipal wastewater outfall, a distance of over six miles. The Division of Water Pollution Control and Coast Guard have been mapping PCB concentrations in the Harbor and in Buzzards Bay (Acushnet River Estuary PCB Commission, 1982). The sediments underlying the entire 985-acre inner harbor contain high levels of PCBs. Most of the heavily contaminated sediment (greater than 50 ppm*) is north of the I-195 bridge and is found in the top 2 feet of the harbor sediments. The harbor sediments contain PCBs in levels up to 190,000 parts per million, or 19 percent; concentrations in the thousands of ppm are common in the tidal flats near the Aerovox Incorporated plant (Weaver, 1982). These sediments exceed the federal hazardous waste criteria by several orders of magnitude.

The water column in New Bedford Harbor has been measured to contain PCBs in the parts per billion range (well in excess of EPA's 1 part per trillion guideline) (Weaver, 1982).

Widespread contamination of the Acushnet River Estuary environs has resulted in the accumulation of PCBs in many marine species. Eighteen thousand acres have been closed to the harvesting of lobsters due to PCB pollution. Lesser, yet significant, areas are closed to the taking of finfish and shellfish. Finfish in the area have been found to contain concentrations exceeding 150 ppm. (The FDA standard for edible finfish and shellfish is 5 ppm.) Limited human blood analyses suggest that the blood of heavy fish eaters and industrially exposed individuals contain elevated levels of PCB's (Weaver, 1982).

Concern over uptake and accumulation by most of these organisms is directed to unknown chronic effects, bioaccumulation in complex food webs, and, particularly, chronic effects on human consumers. Some of the effects on human health that may be attributable to low-level exposures to PCB's are abnormal fatigue, abdominal pain, numbness of limbs, swelling of joints, chronic cough, headaches, dermatological abnormalities, and anemia. The International Agency for Research in Cancer believes that there is enough suggestive evidence to regard PCB's as carcinogenic, pending confirmatory evidence (Weaver, 1982).

Because of the documented toxicity of PCB's and the demonstrated potential for their biological accumulation, dredging, transportation, and disposal methods for sediments contaminated with high levels of PCB's must be selected to minimize further transport and biological exposure to these materials.

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*Sediment containing 50 ppm or greater of PCBs must be regulated by the EPA.

3. CHARACTERIZATION OF SEDIMENTS

3.1 General Geology

The seabed in the study area consists of the drowned valley of the Acushnet River which cuts a NNW-SSE trending trough from New Bedford Harbor to Buzzards Bay. A drowned tributary of the Acushnet separates Sconticut Neck from the smaller ridge which forms Fairhaven Shoals. Another drowned tributary of the Acushnet extends around Clark Point Peninsula and into Clark Cove. The seabed in the estuary and harbor area is generally shallower than about 25 ft with the exception of the harbor channel which is dredged to about 30 ft (Summerhayes, 1977).

Test borings by the U. S. Army Corps of Engineers (ACE) indicate that bedrock in the area consists of granitic gneiss which is overlain by 8 to 9 ft of glacial till and/or 6 to 9 ft of gravelly sediment. These materials in turn are buried by varying thicknesses of sands and silts.

Sediments are generally thinnest over topographic highs and thickest in troughs. Where bedrock is deepest in the buried channel of the Acushnet and dredging has not occurred, up to 60 ft of unconsolidated sediments have accumulated. Sediment thicknesses in dredged areas are substantially thinner.

3.2 Surface Sediments

Muddy sediments (silt and clay) cover the floor of the drowned valley of the Acushnet River and occupy topographic depressions, while sand and gravel or bare rock occur on the submarine ridges. Surface sediments are usually darker, finer-grained, shellier and contain more organic matter than the buried sediments. The New England Division of the U. S. Army Corps of Engineers (unpublished report) analyzed 15 cores collected from the harbor and navigation channel and found that all of the samples examined, except three, were classified as a black, organically enriched silt with more than 70 percent fines* (mud) (Summerhayes, 1977).

As part of this investigation, surface samples were obtained from the tidal flats north of the inner harbor (Fig. 2). These samples consisted primarily of oily, organic, sandy silts. Percent fines ranged from 45% to close to 100% and averaged over 75%.

The major depocenter of mud in the drowned Acushnet Valley is in the inner harbor (Zones A and B on Fig. 1). Surface silts

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*Fines are soil particles that pass through a No. 200 mesh sieve, the openings of which are 74 microns (0.074 mm) square.

are thickest near the head of the harbor, north of the New Bedford-Fairhaven Bridge, where there is up to 15 ft of dark, organically enriched silt. Much of the navigation channel is floored with muddy sediment, except near the hurricane barrier where sandy sediments occur, probably because tidal currents are strong enough to prevent the settling of fines. Organic muds in the navigation channel are believed to contain substantial amounts of gas produced by the decay of organic matter. Similar organically enriched muds form a low mound around the sewer outfall off of Clark Point (Summerhayes, 1977).

On the ridge crests and on the steeply sloping margins of the outer harbor are fine sands and gravels. Where gravel-sized material is present in muddy samples, it is usually in the form of whole or fragmented mollusk shells. These coarse deposits and the muddy sediments flooring the depressions are separated in several places by narrow transitional zones where muddy sands and muddy gravels occur. These transitional sediments take the place of muds in the depressions that run up into Clark's Cove and east of Fairhaven Shoals.

3.3 Sedimentation Rates

Summerhayes, 1977, states that silt and clay are being transported into the estuary in suspension by landward-moving bottom currents that are driven by wave and tidal energy. These fine sediments come from Buzzards Bay, but may originate out on the continental shelf. Before the entrance to the harbor was almost completely blocked by a hurricane barrier, these sediments were accumulating in the harbor at rates of about 1-2 cm/yr in the deeps, and less than 0.5 cm/yr in the shallows. Construction of the barrier in 1966 reduced the efficiency of tidal flushing, causing the rate of siltation to increase. The present rate of sedimentation in the deeper portions of the harbor is estimated to be 4 cm/yr (Summerhayes, 1977).

3.4 PCB Contamination

PCB was formerly discharged at two locations in New Bedford. One discharge was on the west side of the Acushnet River, north of the Coggeshall Street Bridge. The second discharge was south of the hurricane barrier, on the west side of the outer harbor. Quantities of PCB's are at present being discharged in effluent from the New Bedford Wastewater Treatment Plant on Clark Point (Weaver, 1982).

Biota exhibit the highest PCB levels in the harbor area and decreasing levels seaward. The median PCB values of lobsters and bottom feeding fish in the harbor area are greater than the

FDA limit of 5 ppm wet weight. Outside the harbor area, median PCB values generally drop below the FDA limit, although many samples still exceed 5 ppm (Malcolm Pirnie, 1981).

The geographical extent of the PCB contamination in the harbor and into Buzzards Bay and the depth of the contamination vertically into the sediments is not precisely known. However, sampling and PCB testing conducted by the U. S. Coast Guard, Providence, RI confirm extremely high levels of PCB's in the top 10 cm of surface sediments of the tidal flats (Fig. 2) near a historic PCB source area north of the inner harbor. The greatest concentrations of PCB's appear to be located in the tidal flats near Aerovox, in the channel north of the Coggeshall Street Bridge, on the west side of the inner harbor near Pope's Island, on the east side of the inner harbor near Fairhaven Marine, in the flats southwest of Palmer Island, in the northwest portion of the outer harbor, and in the sediments at the end of the wastewater treatment plant outfall (Malcolm Pirnie, 1981).

Sufficiently extensive sampling has not yet been completed to determine the precise extent of PCB distribution in the estuary and harbor. Therefore, a meaningful PCB concentration contour map could not be prepared. However, it is known that PCB's are strongly bound to the solid phase in typical sediment-water systems and have an affinity for fine-grained sediments. Therefore, it is reasonable to expect that major concentrations of PCB's will be present where there are significant accumulations of fine-grained sediments, i.e., the deeper parts of the harbor.

Malcolm Pirnie, Inc., 1981, estimated volumes of contaminated bed material in the Acushnet River-New Bedford Harbor area based on a depth of contamination of 2 ft and a depth of removal by dredging of 3 ft. Dredged material volumes and PCB recovery for inner and outer harbor dredging are presented on Table 1.

3.5 Metals

Heavy Metals Distribution - The sediments in New Bedford Harbor and the navigation channel contain significant quantities of heavy metals resulting from industrial discharges. The most enriched sediments are surface deposits of silt and clay. The large surface areas of these fine-grained particles tend to adsorb pollutants and incorporate them into the sediment (Summerhayes, 1977).

As part of this study, bulk analyses of surface sediments were performed on 14 sediment samples collected from the tidal flats in the Acushnet River Estuary in the vicinity of a historic source of contamination as discussed in the Appendix.

The results of the bulk analyses indicate high concentration of metals at all but 2 of the 14 sampling stations (Table 2). Particularly high concentrations of copper, lead, and zinc were found at eight stations, cadmium and chromium at six stations. Concentrations of zinc exceeded 3,500 ppm (dry weight) at four stations, copper exceeded 1,000 ppm at three stations, and lead equaled or exceeded 1,000 ppm at three stations.

This data correlates well with data by Summerhayes, 1977, who found that the principal contaminants in the inner harbor are copper, chromium, lead, and zinc. Copper was the most abundant metal. Chromium, copper, and zinc were reported to locally comprise more than one percent of the dry weight of sediments in the harbor. The Division of Water Pollution Control sampling data indicate that the sediments just north and south of the Coggeshall Street Bridge are most enriched by metals. Copper occurs in greatest concentrations just south of the bridge, in close proximity to a metal discharge on the western bank. Near the Coggeshall Street Bridge as much as 8,054 parts per million of copper was in one sample. The thickest copper-rich deposits are in deeper parts of the harbor; the copper-rich deposits are thinner in shallower areas and seaward (Summerhayes, 1977).

The navigation channel also contains metal-enriched sediments, although not at levels as high as the inner harbor. Moving away from the channel, metal concentrations in sediments indicate no enrichment above typical background levels measured in central Buzzards Bay (Malcolm Pirnie, 1981).

Although there is a net landward movement of silt and clay in bottom currents, contaminated sediments still slowly migrate from the harbor, probably by eddy diffusion of resuspended particles. Summerhayes, 1977, estimates that 24 percent of the metals discharged into the inner harbor have been transported to Buzzards Bay by this mechanism and have formed a carpet 10 to 20 cm thick in some areas of Buzzards Bay.

3.6 Classification

The Massachusetts Division of Water Pollution Control has adopted certain criteria for classifying dredged material based on chemical and physical characteristics. These criteria were adopted in 1978 to provide interim guidance for the evaluation of dredging and dredge material disposal projects in Massachusetts waters.

Table 3 presents the classification of dredge spoils by chemical constituents, and Table 4 presents classification by physical characteristics.

Based on the excessively high content of PCB's, copper, lead, zinc, chromium, and other metals, most of the estuary and harbor surface sediments would be classified Category Three on Table 3; the generally high percentage of silt, clay, oil and grease, and water would classify the sediments as Type C on Table 4.

3.7 Impacts on Dredging and Transportation

The presence of PCB's and heavy metals in sediments raises concern about the release of these materials into the environment and their effects on public health and environmental quality. However, under most conditions, PCB's and heavy metals are only slightly soluble in water, easily adsorbed from aqueous solutions, and strongly held in place by fine-grained sediments. Therefore, the mobility of these contaminants when sediments are moved will depend greatly upon the amount of resuspension of the contaminated sediments during dredging and transportation, which, in turn, will vary with the dredging and transportation techniques employed.

All types of dredging cause agitation and some resuspension of sediments. The increased suspended load in nearby waters can create a threat to water quality because of the presence of heavy metals and PCB's. Resuspended PCB's tend to concentrate in organic materials, such as wood chips and oils, and form a scum on the water's surface. Because the harbor sediments contain such materials, PCB's will be released into the water column during the dredging process. The magnitude of this release will depend upon the amount of sediment disturbance and resuspension that takes place. Dredging and transportation techniques must be selected to minimize resuspension of contaminated sediments thereby minimizing environmental impacts.

Table 5 identifies the normally approvable techniques for dredging, filling, placing, and disposing of dredged materials of various classifications. From Table 5 we see that for Category Three, Type C material the normally approvable methods of dredging are hydraulic and mechanical. Normally approvable disposal methods include pipeline and/or barge; sidecast disposal will not normally be approvable.

The relative merits of these and other less common dredging and transportation techniques are discussed in Chapters 4 and 5.

4. DREDGING

The types of dredges in use today can be divided into three categories: mechanical, hydraulic, and pneumatic. Descriptions of these three types are presented below with discussions about their applicability to the cleanup of the New Bedford Harbor.

When assessing the various methods, it is important to understand that dredging contaminated sediments is a specialized form of dredging. The objective is to completely remove a specified layer of material while minimizing resuspension of material into the water column. It is also desirable to minimize the quantity of material to be transported and handled at the disposal site.

4.1 Mechanical Dredges

Mechanical dredges include the dipper, clamshell, chain bucket, and dragline dredges (Figs. 3 and 4). The common feature of mechanical dredges is that they dig into and scoop up the sediment. Mechanical dredges are typically barge-mounted and use a derrick and system of cables for maneuvering the scoop. The dredged material is lifted above the waterline and is generally deposited into a hopper barge.

The primary advantage of dredging sediments by mechanical methods is the relatively small disturbance to the dredged material caused by the dredging, i.e., the sediments are not thoroughly stirred up and mixed with free water. This reduces the total amount of material to be handled and transported. Mechanical dredging also reduces the amount of contaminated water to be treated and reduces or possibly eliminates the need for an intermediate settling basin before final disposal.

However, conventional mechanical dredges have several major disadvantages which generally preclude their use for contaminated sediment removal. The scoops or buckets are open at the top and leak at the bottom so that there is generally a significant amount of spillage and resuspension of contaminated sediment as the dredge material is lifted up through the water column. Also, it is difficult to control the location and depth of penetration of the scoop bucket when it is operated by cables. This results in uneven removal of the contaminated sediment layer.

There have been recent attempts to modify the mechanical dredging system to overcome these disadvantages. For example, Mitsubishi Steel Mfg. Co. Ltd. has developed a closed-type clamshell bucket designed specifically for contaminated sediment removal (Fig. 5). It uses hard rubber seals along the shell edges to prevent leakage and, according to a company brochure, has a cover (presumably to minimize spillage) and a built-in mechanism to prevent overdredging. It is not known whether the specialized clamshell has been used in an application similar to the proposed New Bedford Harbor cleanup.

4.2 Hydraulic Dredges

Hydraulic dredging is performed by disturbing the dredge material with an auger or cutterhead, mixing it with water to form a slurry, and pumping the slurry to a disposal or transfer site. Often mudshields or "dustpans" are mounted at the intake to reduce the amount of turbidity. Hydraulic dredges are usually barge-mounted. Passes are made by either swinging the intake in a series of arcs, or by advancing the barge in a straight line. Common types of hydraulic dredges include cutterhead, plain suction, dustpan, sidecaster, hopper, and Mudcat (Figs. 6 and 7).

Hydraulic dredging is generally the least expensive form of dredging and, if controlled, can yield relatively low turbidity in the water column. Hydraulic dredging also affords greater control over the location and depth of cut, particularly for the "straight pass" setups, as compared to the mechanical dredge.

The major disadvantage of hydraulic dredging is the requirement to mix approximately four parts water to one part sediment to form a pumpable slurry. This results in a large quantity of contaminated water-soil mixture to be transported and contained. Elutriate tests conducted for this study show that excess water will contain large amounts of PCB's adsorbed to particles in suspension. Therefore, intermediate settling basins and the use of flocculents and water filtration equipment will likely be required to render excess water acceptable for discharge back to the environment.

The ability to effectively separate the contaminated sediment from the excess water has been demonstrated in the Duwamish Waterway cleanup, which is discussed in Section 7. A case history which involves the proposed use of a dustpan hydraulic dredge is also discussed in Section 7 under the section "James River, Virginia."

4.3 Pneumatic Dredges

Pneumatic dredges use unbalanced hydrostatic head to draw sediment and some water into a submerged containment chamber.

Compressed air is then used to discharge the sediment into a pipeline to the surface. With this method, the sediment has considerably less water mixed with it than with hydraulic methods. The pneumatic dredge may be suspended from a barge or, as discussed in a case study below, mounted on a submerged tractor. Two commercially available pneumatic dredges are the Amtec Pneumatic Pump dredge, originally developed in Italy (Fig. 8), and the Oozer Pump dredge, developed in Japan (Fig. 9).

In addition to the lower quantity of water used in the slurry, pneumatic dredges produce relatively low turbidity in the water column. Pneumatic dredges also afford good control over the location and depth of cut.

The major disadvantages of the pneumatic dredge may be cost and availability. Due to the limited experience with pneumatic dredging in this country, another disadvantage may be the requirement to provide special training for the work crews at the site.

A well-documented cleanup of PCB's, using a pneumatic dredge, occurred in 1976 in the Duwamish Waterway in Seattle Harbor. A second cleanup using pneumatic methods is currently underway in California. Both of these case histories are discussed in Section 7. For more details on the various mechanical, hydraulic, and pneumatic dredges available refer to Malcolm Pirnie, 1978.

4.4 Silt Curtains

Under certain conditions, silt curtains can be used around dredging and disposal operations to contain turbid water. Silt curtains are impervious, vertical barriers that extend from the water surface to about 1 ft above the sediment level. The curtains typically consist of a flexible, nylon-reinforced vinyl fabric that is suspended from a system of floats at the water surface. The bottom edge of the curtain is held down by weights.

Experience with several installations (JBF Scientific, 1976) has shown that when the water current is less than 0.5 knots, the turbidity in the water column outside the curtain can be up to 90% less than the turbidity inside the curtain. Silt curtains can be used in currents up to 1.0 knot; however, they become much less effective. While tidal currents are reported to be as high as 122 cm/sec (2.4 knots) through the harbor entrance (Summerhayes, 1977), the use of silt curtains could be considered in those areas of the New Bedford Harbor having current speeds less than 1.0 knot. These areas would have to be determined by an additional investigation.

5. TRANSPORTATION OF DREDGED MATERIAL

Once dredged, the contaminated sediment must be transported safely and efficiently. Due to the high cost of long distance transport, disposal sites which are located more than a few miles away will require the construction of nearby intermediate rehandling sites. The intermediate sites will be used for separating and treating supernatant water and consolidating the solids. Several modes of transport are discussed below.

5.1 Floating Slurry Pipeline

If hydraulic or pneumatic dredging is used, the primary transport mode will be via a floating slurry pipeline. Booster pumps may be required along the pipeline to help move the material.

When crossing a channel, it will be necessary for the pipeline to be depressed to avoid interference with boat traffic. Methods for the immediate detection of leaks will need to be developed, and the equipment necessary for repairs will need to be readily available. Joints between sections of pipe will need to be securely tightened and leak tested. The pipeline will need to be anchored securely to prevent excessive deflection caused by wind and currents. Also, the pipeline will need to be strong enough to withstand moderate storm conditions. During large storms, it will be necessary to shut down operations.

5.2 Barge

Barges will be used in conjunction with mechanical dredging to transport material from the dredge to the intermediate rehandling site, or to the final disposal site if it is located near the coast. Barges may also be used for transporting between the rehandling site and the final disposal site. Barges are not normally used to receive material from hydraulic dredges due to the large quantities of dredged slurry to be handled.

Barges can be loaded and unloaded either mechanically, as with a crane and clamshell, or by hydraulic pumping. During loading and unloading, care must be taken to avoid spillage over the sides of the barge. The holding compartments on each barge must be watertight and covered. Bottom dump barges are not suitable for transporting contaminated sediment.

5.3 Truck or Rail

If the final disposal site is located inland, trucks or rail cars can be used. The trucks will be either tank trucks or large dump trucks; rail cars may be either tank cars or hopper cars. All trucks or rail cars must be watertight and covered. Frequent checks for leaks on the gates or valves will be required.

Hopper cars or dump trucks will be loaded and unloaded mechanically; tankers will be loaded and unloaded hydraulically. The ability to pump the waste after rehandling will thus affect the selection of tank cars. Provisions to clean the exterior of each truck or rail car of any spilled sediment or water before leaving the rehandling or disposal site will be required.

6. DISPOSAL OPTIONS

6.1 General

Three alternate disposal methods are specified by the EPA for material containing PCB's in concentrations of 50 parts per million to 500 parts per million such as exist in New Bedford-Fairhaven Harbor. These methods are: incineration, disposal in an approved chemical landfill, and use of some other disposal method which is approved by the EPA Regional Administrator for the region in which the PCB's are located. For other disposal methods, applications to the Regional Administrator must indicate that disposal by incineration or chemical landfill are not reasonable, and that the alternate disposal method proposed will provide adequate protection to health and the environment.

6.2 Incineration

Incineration of dredged material is technically and environmentally possible but prohibitively expensive. In studies conducted by the New York State Department of Environmental Conservation concerning the cleanup of PCB-contaminated sediments, it was found that fuel costs alone for the incineration of sediments would have been about $10 per yard. The U. S. EPA's consulting engineer on the PCB sediment cleanup project in Waukegan, IL investigated several incineration technologies and reported that costs for incineration could be well in excess of $100 per cubic yard. To remove 90% of the PCB contamination in the inner harbor would require dredging about 4-1/2 million cubic yards. Further, it is believed that available technology would require extensive testing and development to meet EPA requirements and transport to a suitable incinerator would increase exposure of the environment to contaminants. Incineration, therefore, is not likely to be a feasible alternative for disposal.

6.3 Chemical Landfill

There are eight landfills in the United States which are aproved by the Environmental Protection Agency for disposal of PCB solids which includes dredge spoils. There are none in New England. The Commonwealth of Massachusetts is currently investigating a hazardous waste landfill for Massachusetts. The possibility of locating a landfill site exclusively for this project independent of the statewide effort seems unlikely.

The closest approved landfills to the New Bedford site are in New York State. One is located in Niagara Falls and is operated by SECOS International, Inc.; the other is in Model City and is operated by SCA Chemical Systems, Inc. Both are approximately 500 miles from the project site.

The availability of disposal space is extremely limited. For example, the SECOS facility has currently opened for use a secure landfill cell which is only three acres in size. Only a small portion of this area is set aside for PCB-contaminated materials. The material disposed of in this facility is usually highly concentrated industrial wastes packed in metal drums for stacking and burial. Because of the great demand for disposal sites and the extensive regulatory procedures involved, disposal costs would be very high.

6.4 Other Disposal Options

a. Biodegradation

Biodegradation was considered as a disposal option for both the Hudson River and Waukegan, IL PCB sediment cleanup programs. It was found that the possibility of using naturally occurring micro-organisms to reclaim PCB-contaminated dredged spoils was an unproven technology and that sufficient information does not exist to properly assess the feasibility of biodegradation as a disposal alternative (U. S. EPA, 1981, and MDPW, 1980).

b. Open Ocean

Open water disposal of dredged material is commonly practiced in all of the New England Coastal states. However, under Massachusetts regulations open ocean disposal of Type III-C dredged material is permitted only at low energy, silty sites and this only after bioassay performed in accordance with established EPA procedures, indicates no significant biological impact. If a significant biological impact is found, this material is unsuitable for open water disposal. A bioassay conducted with sediments from the tidal flats area north of the Inner Harbor indicated a significant biological impact. However, these materials are the most highly contaminated and would likely be mixed with other less contaminated sediments for disposal. As no bioassay data are as yet available for the bulk of the contaminated sediments, the ocean disposal option should not be precluded.

Given the compelling necessity to find a suitable disposal option and the scarcity of viable options and disposal sites, ocean disposal may turn out to be a feasible disposal option. Adverse environmental effects associated with ocean dumping can be minimized by capping with relatively uncontaminated materials. Further discussion of ocean disposal of contaminated material can be found in Refs. 5, 15, 16, 19, 20, and 21.

c. Land or In-Harbor Disposal With Bulkheading

In Massachusetts, disposal of Category Three, Type C dredge spoils is generally restricted to land or in-harbor disposal with bulkheading. Contaminated sediments could be contained in a specially engineered encapsulation or contained landfill in such a manner that it is permanently removed from the environment. This was found to be the most practical method of disposal for the Hudson River cleanup program (Section 7). Major considerations in the design of the Hudson River encapsulation included an impermeable clay dike, subgrade, and cover with a leachate underdrain, collection, and treatment system (Fig. 10). The relatively impermeable clay materials provide a natural barrier to the migration of water, and also provide an excellent barrier to PCB migration as PCB's are known to adhere strongly to fine-grained sediments. The leachate underdrain system provides an excellent method of monitoring the performance of the system and of ensuring collection of any percolating contaminants.

At the present time, no hazardous waste disposal sites are licensed in the Commonwealth. However, technically, upland disposal or temporary storage is a viable disposal alternative for the New Bedford Harbor dredging. Preliminary examination of the geohydrologic characteristics of surficial soils indicate that relatively impermeable glacial tills occur along the harbor and extend inland for some distance. These materials would likely provide sufficient liner materials for encapsulation due to a high percentage of fines which tend to hold PCB's and decrease permeability. Using proper materials and employing design features such as impermeable liners and covers, leachate collection and treatment systems, settling ponds, flocculants, and water filtration systems, it is likely that one or several effective permanent disposal or temporary storage facilities could be constructed in the New Bedford area.

The major problem associated with upland disposal is the absence of a nearby, undeveloped, open land site large enough to contain the dredge spoils. As shown on Table 1, to remove 50% of the PCB contaminated sediments from the inner harbor alone would require storage space for 400,000 cubic yards of dredged materials. This number would be significantly larger if hydraulic dredging were used as spoils would be mixed with about four parts water to one part sediment.

Removal of 90% of the sediments from the inner harbor would require upland storage space for 3,500,000 cubic yards of dredged materials. Again, this number would be significantly higher for hydraulic dredge methods. A disposal pile 20 ft high would cover at least 108 acres.

No upland sites of this size are believed to be available adjacent to the harbor. Transporting such large volumes to sites just outside the harbor area may be cost prohibitive or environmentally unacceptable, but should be considered in more detail. In addition, in-harbor disposal with bulkheading should be considered.

7. CASE HISTORIES IN CONTAMINATED SEDIMENTS

7.1 Upper Hudson River, New York

Several studies have been recently made to evaluate the feasibility of dredging PCB-contaminated sediments along a 40 mile stretch of the Upper Hudson River (Refs. 9, 14, 23, 24, 28, 29, 30, 31). The sediments consist primarily of silty sand.

For a full dredging effort, the total volume of contaminated material to be removed is 14,500,000 cu yds. The methods of dredging being considered include the hydraulic cutterhead dredge and the mechanical clamshell dredge. Cost estimates for full dredging, which is estimated to achieve 91 to 97% recovery of all PCB's from the study area, range from $158 to 306 million (1978 costs). Partial dredging of "hot spots" (areas with PCB concentrations greater than 50 ppm) is estimated to cost $21 million at 1978 costs. Partial dredging will result in the removal of about 36% of the PCB's in the study area, with a total volume of dredged contaminated material estimated at one million cubic yards.

Land disposal methods are being considered for the final disposal of the spoil. Major considerations in the design of the Hudson River project include complete encapsulation with an impermeable clay dike, subgrade, and cover with a leachate drainage collection and treatment system (Fig. 10). Forty potential disposal sites with a total area of 3,200 acres have been identified for a full dredging effort. The land requirement for contaminated material from the hydraulic system is estimated to be 1,120 acres. The mechanical system has been estimated to require approximately 720 acres. Return flow treatment processes similar to those used for the Duwamish Waterway project are being considered for the supernatant water (Section 7.3).

7.2 Waukegan Harbor, Illinois

The sediments in Waukegan Harbor, Lake Michigan, contain some of the highest known concentrations of PCB's in the country, with measured concentrations up to 250,000 ppm (25%) (U.S. EPA, 1981). The contaminated sediment area is about 37 acres.

The sediments consist of a top soft "muck" layer, an intermediate sand layer, and an underlying silty clay layer. The muck layer ranges in thickness from 0 to about 10.5 ft. Most of the PCB's are contained in the muck layer and available data show that the contamination extends through the entire thickness of the layer. The EPA estimates a total volume of 168,000 cubic yards of sediment to be removed. This includes all sediment with PCB concentrations greater than 10 ppm.

The EPA has proposed that the harbor be dredged by either hydraulic or pneumatic methods. Silt curtains would be used to isolate the dredging area. The dredged spoils will be transported via pipeline to temporary settling lagoons where it would be dewatered. Excess water will be treated to remove residual PCB's and returned to the harbor containing PCB concentration less than 1ppb. The dewatered sediments will be removed to a permanent storage facility.

Lagoon construction will be similar to that of a secure landfill with impermeable clay liners and leachate collection systems. A 6-in.-thick layer of sand is being considered for placement above the clay liner to facilitate dewatering of the sediments.

Water treatment will consist of (1) settling of the sediments in the lagoon, (2) allowing excess water to overflow a weir placed at one end of the lagoon into a smaller sedimentation basin where a polymer will be added to coagulate and settle fines, (3) pumping the sedimentation basin water through pressure filters, and (4) conveying filter effluent through carbon filters to a clear well. The water in the clear well will be monitored for PCB content before it is returned to the harbor. A 1 ppb limitation of PCB concentration for water returned to the harbor will be maintained.

Ultimate disposal plans include a below-ground option with a 5- to 10-ft-thick recompacted clay liner, a leachate collection system and treatment system, and a 3-ft-thick clay cap surfaced with bituminous pavement or concrete for use as a parking lot. The entire facility would be surrounded by a 2-1/2-ft-thick concrete slurry wall to permit dewatering of the site during excavation (30 ft below ground surface) and to act as an additional barrier to contaminant migration.

An alternative secure storage facility considered for the Waukegan project included construction of secure lagoons to a height of about 35 ft above ground with similar liners, caps, and leachate collection systems. This above-ground option would minimize leaching over time, minimize site disruption and material handling, and eliminate the need for a slurry wall. Disadvantasges of this approach are its relative unsightliness, the need for permanent dedication of property to this use only, and a long-term maintenance requirement.

The estimated cost for the proposed dredging operation, including dewatering, water treatment, loading onto trucks, and site restoration is about $10 million. Disposal costs would add $6 to $33 million to this amount (1981 costs).

7.3 Duwamish Waterway, Seattle Harbor, Washington

A Pneuma Model 600 pneumatic dredge, mounted on a pivoting spud barge, was used in 1976 to remove 80-90% of an estimated 27,000 cu yd of PCB-contaminated sediment in the Duwamish Waterway in Seattle Harbor. The contamination occurred at the end of a pier when a transformer containing PCB was dropped during barge loading. The overall area requiring dredging was about 350,000 sq ft (8 acres). The depth of dredging was about 2 ft over most of the contaminated area with depths up to 10 ft at the point of spill. The complete operation lasted slightly less than two months.

Turbidity was monitored downstream during the dredging operation by the University of Washington, Department of Oceanography. Their final report indicated that the dredging cleanup caused no significant dispersion of PCB into the Duwamish Harbor and estuary.

The Pneuma Model 600 was supplied by Amtec Development Company of Chicago, Illinois. The dredge, along with 2,000 ft of 10-in. I.D. discharge pipe, was transported from Chicago to Seattle by truck. The dredge was mounted onto a small boat which was attached perpendicularly to a 120-ft-long pivoting spud barge. This enabled the dredge to swing in a large arc during each dredge cut. The propellers of the small boat were used to maneuver the dredge back and forth. The width of the intake on the pneumatic dredge was 10 ft.

The contaminated slurry was mixed with a flocculant (Nalco #7134) and discharged into specially prepared disposal pits, located approximately one half mile south of the spill. The flocculant decreased the settling time of the solids. After the solids were settled, the supernatant water was run through a "Filterite" #264 MSO filter and an activated charcoal filter. It was then discharged back into the Duwamish River. Testing by the EPA indicated that general PCB concentration in the sludge was 8-10 ppm. The concentration in the supernatant water was 4 parts/billion prior to filtering and 50 parts/trillion after filtering.

7.4 California Aqueduct

A large pneumatic dredging operation by the State of California, Department of Water Resources is presently underway to remove asbestos-contaminated sediment from the California

Aqueduct (Ref. 12). The dredged length of the aqueduct is approximately 150 miles. The width is approximately 100 ft. The volume of material to be dredged is about one million cubic yards.

A pneumatic dredge, mounted on a remote-controlled underwater tractor, is being used for the dredging. Production is presently about 290 cu yd/hr with an on-line time of about 20 hr/day. The dredged material is transported via 8-1/2-in.-I.D. PVC pipe into disposal pits which have been excavated alongside the aqueduct. The "free" water content of the slurry is about 40 to 55%. Turbidity caused by the dredging, as measured at monitoring stations up- and downstream from the dredge, has been minimal. For this type of contaminant, treatment of the water and dredged spoils was deemed unnecessary. The water is allowed to percolate through the disposal pits, and the pits are covered with fill and planted.

The depth of water is about 28 ft. The tractor is remote-controlled by a cable which extends from the tractor to ground surface. The location of the tractor is monitored by sonar. Sensors are mounted near the intake structure of the pneumatic pump to monitor the depth of cut during each pass.

Overall operating costs are currently (1982) running about $8 to $10/cu yd. Since this includes the initial development costs, this figure is expected to come down to about $4 to $5/cu yd. If a dredging system similar to this is considered for the New Bedford Harbor, the added cost of more complex disposal methods must be considered.

7.5 James River, Virginia

A study is currently underway by the Norfolk District, Corps of Engineers, to compare the dredging performance of two types of hydraulic dredges for the removal of sediments in the James River, Virginia (Refs. 8, 34). The sediments have been contaminated with the toxic pesticide "Kepone." The two dredges to be compared for efficiency are the dustpan and the cutterhead hydraulic dredges. The dustpan dredge will be a cutterhead dredge that has been equipped with a 28-ft-wide dustpan and modified for straight line dredging. The cutterhead dredge will be a conventional unit, using a rotating cutter and making swing arc cuts rather than straight line swaths. Both dredges will be maneuvered with a system of cables and winches.

A preliminary ACE report by Vann (undated) identifies several advantages of the dustpan dredge. Among them are: straight line method of dredging, constant width of cut, constant dredging speed at constant winch speed, accurate control of dredging depth, maximum containment of material, and reduced turbidity. The disadvantages of the dustpan noted in the report were: dredging accuracy is difficult to control in soft materials; tidal fluctuations necessitate the use of stern anchors; and water jets used to break up sediment at the intake, cannot be used since the material to be dredged (in the James River) is too soft, with a water content of approximately 200 percent.

The final results of this comparison have not been published to date.

7.6 Contacts For Case Studies

The following individuals provided much of the information contained in this report regarding the case studies discussed in this section. Their assistance is gratefully acknowledged.

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8. CONCLUSIONS

In this report we have focused on the technical issues associated with dredging the PCB-contaminated sediments of the New Bedford Harbor area. We have not addressed the many political issues affecting the cleanup project.

Technically, environmentally safe methods are available for dredging, transporting, and disposing of the PCB-contaminated harbor sediments. Each of the three general dredging types could be used in an environmentally safe manner, with the pneumatic and hydraulic dredge methods providing the least chance for resuspension of sediments. Watertight mechanical (clamshell) methods may also be environmentally safe when used in conjunction with silt curtains. Transportation methods will depend upon the dredging method used as discussed in Chapter 5.

Of the disposal options, land disposal in a properly engineered clay encapsulated excavation or pile with leachate collection and treatment systems, will provide adequate environmental isolation of contaminated sediments. However, no hazardous waste landfills are licensed in the Commonwealth at the present time. Contaminated sediments could also be dumped in the ocean and covered with uncontaminated sediments. While this option does not provide the same level of containment as an encapsulated landfill, and would involve resuspension of some contaminated materials, it has the advantage of removing the materials from the densely populated New Bedford area to a more remote environment.

Although technical solutions are available, it is impossible to recommend a specific dredging, transportation, and disposal option until a disposal site is identified. This is because dredging and transportation techniques are directly tied to each other and to the ultimate disposal site.

Further input from the public and the many federal, state, and local regulators will be required to select a disposal site or sites before meaningful recommendations regarding dredging and transportation techniques can be made. Cost benefit analysis between several disposal site alternatives and associated dredging and transportation techniques should then be performed.

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TABLES

TABLE 1 - ESTIMATED CONTAMINATED VOLUMES AND PCB RECOVERY NEW BEDFORD HARBOR, MASSACHUSETTS

Typical PCB Concentration in Dredged Area ppm	Cumulative Volume of Dredged Material cu. yds.	Percent of Total PCB Removed Zones A and B	Zone C
	1. HARBOR AREA (Zones A and B)*		
>30	400,000	50	-
>20	500,000	55	-
>10	1,000,000	70	-
> 1	4,500,000	90	-
	2. OUTER HARBOR AREA (Zone C)*		
45	900,000	-	65
30	1,200,000	-	75
15	1,500,000	-	90

*Zones identified on Fig. 1.

After Malcolm Pirnie, 1981 (Note: Subsequently collected data may alter these original estimates by Malcolm Pirnie.)

Geotechnical Engineers Inc.

Project 82990
August 12, 1982

Table 2. (CONT.)

ERCO ID IC-82-	Sample Description	Grain size (wt %)				Water Content (%)	Oil and Grease (wt%)	Classification[c]
		Gravel	Sand	Silt	Clay			
2178	Station 9 - 0-10 cm	0	11.70	64.49	23.81	69.2	6.5	3c
2179	Station 9 - 38-48 cm	6.24	26.02	48.16	19.58	59.3	11.1	
2180	Station 11 - 0-10 cm	0	31.52	50.99	17.49	55.6	1.68	3c
2181	Station 11 - 26-36 cm	0	31.12	38.00	30.88	54.9	0.23	
2182	Station 16 - 0-10 cm	1.89	52.30	31.36	14.45	35.0	0.061	3c
2183	Station 16 - 33-43 cm	0	1.73	72.82	25.45	42.0	0.005	
2184	Station 21 - 0-10 cm	0	11.76	69.39	18185	52.0	1.41	3c
2185	Station 21 - 29-39 cm	4.23	54.75	46.29	27.73	55.8	0.03	
2186	Station 27 - 0-10 cm	0	52.12	30.45	17.43	54.7	2.97	3c
2187	Station 27 - 34-44 cm	0	10.66	59.63	29.71	56.9	0.02	
2188	Station 29 - 0-10 cm	1.63	15.76	53.93	28.68	66.7	1.83	3c
2189	Station 29 - 84-94 cm	0	2.04	70.43	27.53	46.3	0.01	
2190	Station 31 - 0-10 cm	1.52	9.46	45.15	43.87	66.9	3.47	3c
2191	Station 31 - 21-31 cm	1.17	36.06	44.23	18.51	58.2	1.24	

<u>Concentration Ranges for Classification by Physical Characteristics[c]</u>

	Gravel	Sand	Silt	Clay	Water Content (%)	Oil and Grease (wt%)
Type A	--	--	- - <60[d] - -		<40	<0.5
Type B	--	--	- - 60-90[d] - -		40-600	0.5-1.0
Type C	--	--	- - >90[d] - -		>60	>1.0

TABLE 3 - CLASSIFICATION OF DREDGE OR FILL MATERIAL BY CHEMICAL CONSTITUENTS NEW BEDFORD HARBOR, MASSACHUSETTS

All Units Are In Parts Per Million

	Category One	Category Two	Category Three
Arsenic (As)	< 10	10-20	> 20
Cadmium (Cd)	< 5	5-10	> 10
Chromium (Cr)	< 100	100-300	> 300
Copper (Cu)	< 200	200-400	> 400
Lead (Pb)	< 100	100-200	> 200
Mercury (Hg)	< 0.5	0.5-1.5	> 1.5
Nickel (Ni)	< 50	50-100	> 100
Polychlorinated Biphenyls (PCB)	< 0.5	0.5-1.0	> 1.0
Vanadium (V)	< 75	75-125	> 125
Zinc (Zn)	< 200	200-400	> 400

Category One materials are those which contain no chemicals listed in Table 1 in concentrations exceeding those listed in the first column.

Category Two materials are those which contain any one or more of the chemicals listed in Table 1 in the concentration range shown in the second column.

Category Three materials are those materials which contain any chemical listed in Table 1 in a concentration greater than shown in the third column.

After Massachusetts Division of Water Pollution Control, 1978

TABLE 4 - CLASSIFICATION OF DREDGE OR FILL MATERIAL BY PHYSICAL CHARACTERISTICS NEW BEDFORD HARBOR, MASSACHUSETTS

	Type A	Type B	Type C
Percent silt-clay	< 60	60-90	> 90
Percent water	< 40	40-60	> 60
Percent volawtile solids (NED method)	< 5	5-10	> 10
Percent oil and grease (hexane extract)	<0.5	0.5-1.0	>1.0

Type A materials are those materials which contain no substances listed in Table 2 exceeding the amounts indicated in the first column.

Type B materials are those materials which contain any one or more of the substances listed in Table 2 in the concentration range shown in the second column.

Type C materials are those materials which contain any substance listed in Table 2 in a concentration greater than shown in the third column.

When the Division has reason to suspect that biological contaminants are present (for example, because of the physical parameters), additional testing may be required.

After Massachusetts Division of Water Pollution Control, 1978

TABLE 5 - NORMALLY APPROVABLE DREDGING, HANDLING, AND DISPOSAL OPTIONS NEW BEDFORD HARBOR, MASSACHUSETTS

CHEMICAL TYPE (TABLE 2)	Category One			Category Two			Category Three		
PHYSICAL TYPE (TABLE 3)	A	B	C	A	B	C	A	B	C
Dredging Methods									
Hydraulic	X	X	X	X	X	X	X	X	X
Mechanical	X	X	X	X	X	X	X	X	X
Disposal Methods									
Hydraulic: Sidecast	X	X	O	O	O	O	O	O	O
Hydraulic: Pipeline	X	X	X	X	X	X	X	X	X
Mechanical: Sidecast	X	X	O	O	O	O	O	O	O
Mechanical: Barge	X	X	X	X	X	X	X	X	X
Placement									
Land or in-harbor disposal with bulkheading:	X	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Open ocean disposal at high energy, sandy sites	X	O	O	O	O	O	O	O	O
Open ocean disposal at low energy, silty sites	O	X	(b)	O	(b)	(b)	(b)	(b)	(b)
Unconfined in-harbor	X	O	O	O	O	O	O	O	O
Beach Replenishment	X	O	O	O	O	O	O	O	O
Other Conditions									
Timing and Placement to Avoid Fisheries Impacts (spawning and running periods and areas)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)

Legend:
X = Normally approvable
O = Not normally approvable
(a) = Normally approvable but control of effluent will be required.
(b) = Approvable only after bioassay, performed in accordance with established EPA procedures, indicates no significant biological impact. A statistically comparable project which has successfully passed the bioassay test may be substituted. If a significant biological impact is found, this material is unsuitable for open water disposal.
(c) = Required in all cases.

After Massachusetts Division of Water Pollution Control, 1978

Inner Harbor: Zones A and B

Outer Harbor: Zone C

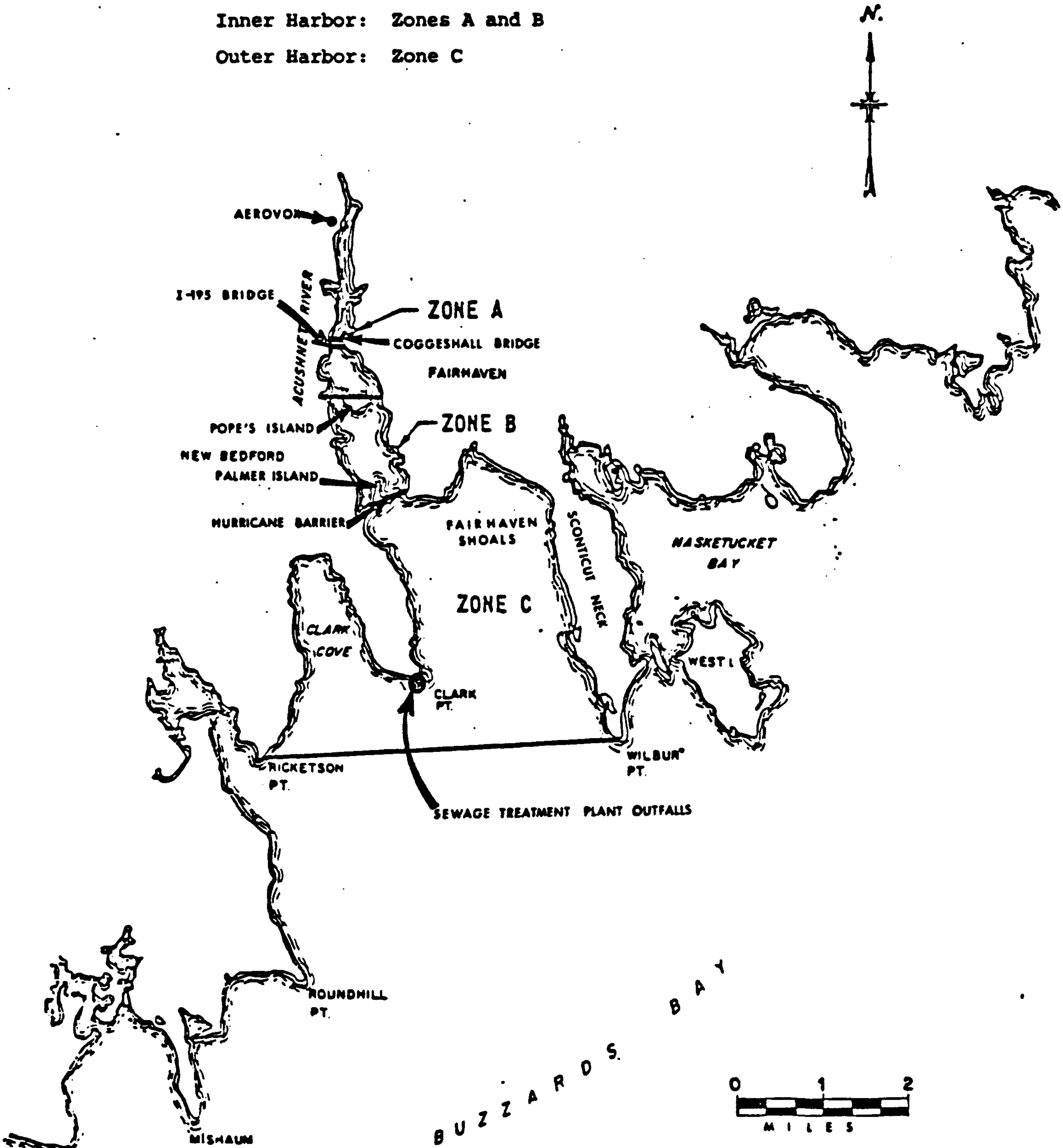


Figure 1: LOCATION OF STUDY AREA

After Malcolm Pirnie, 1981

Project 82990
August 13, 1982

Geotechnical Engineers Inc.

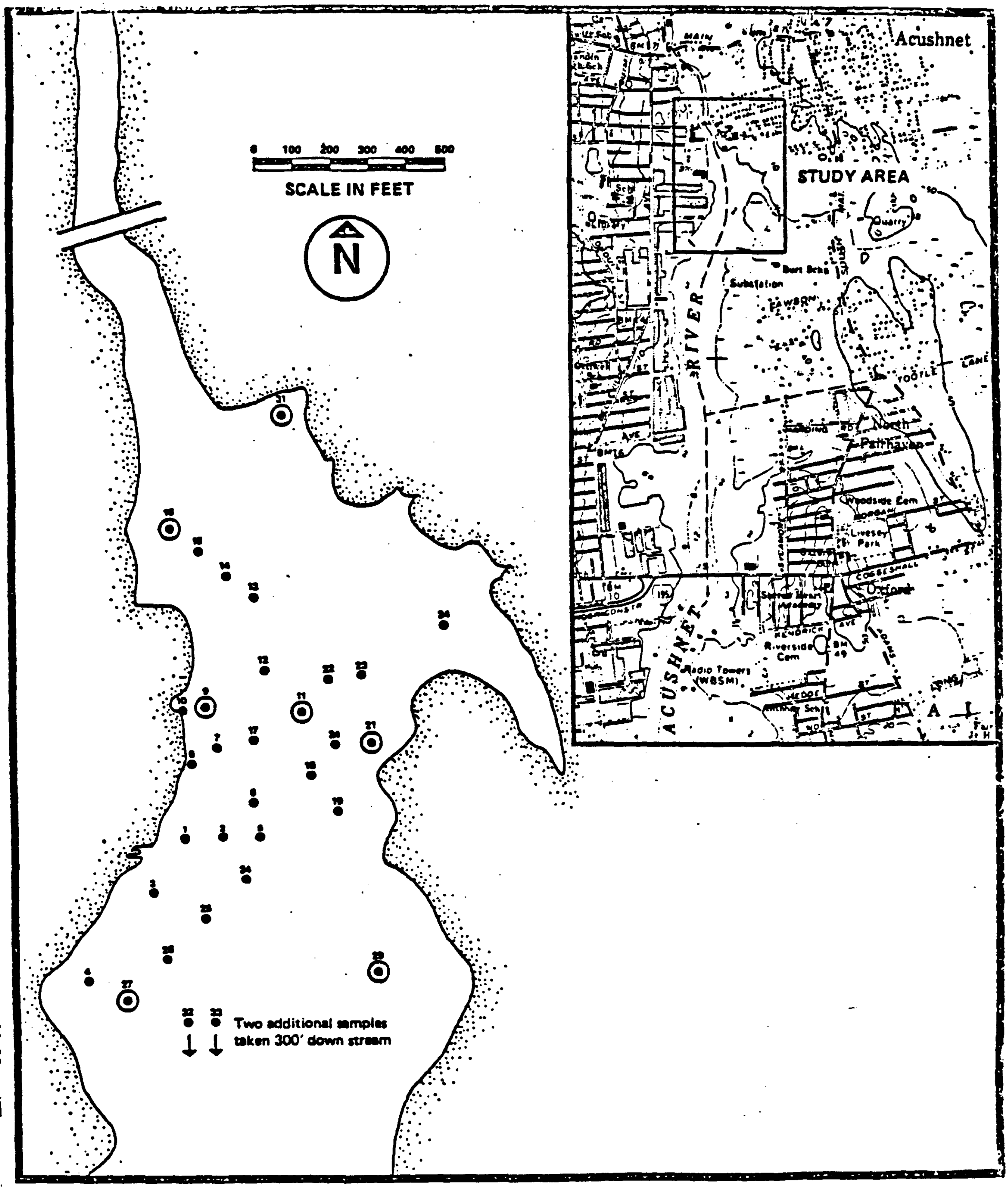
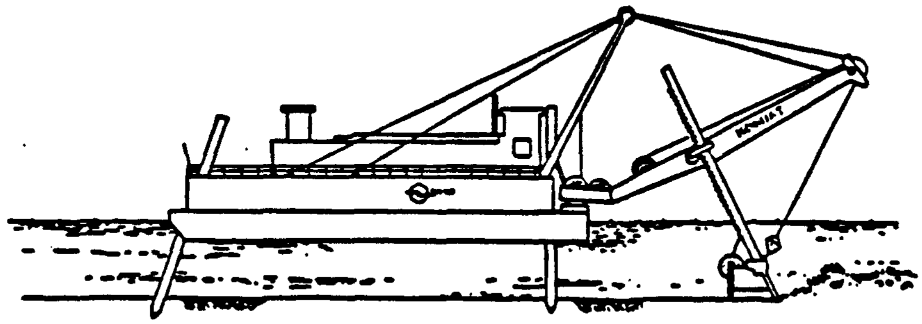


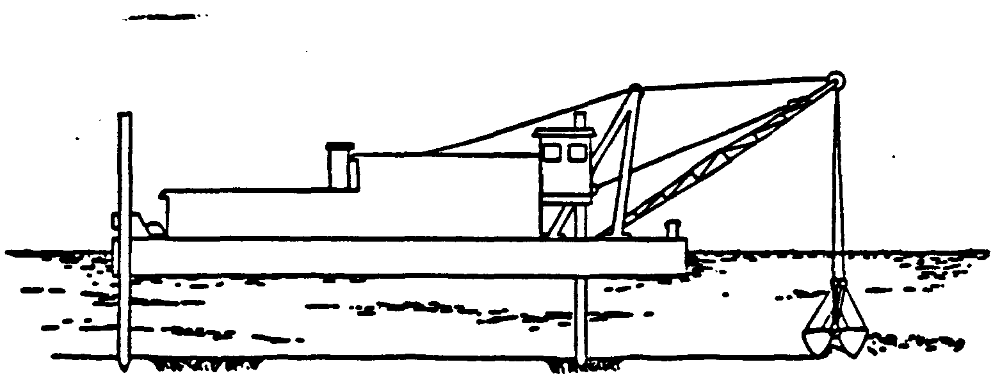
Figure 2. Location of sampling stations in Acushnet River. Stations denoted as ● were occupied by U.S. Coast Guard in April, 1982. Stations denoted as ⊙ were reoccupied by ERCO on July 13, 1982.

Project 82990
August 12, 1982

Geotechnical Engineers Inc.



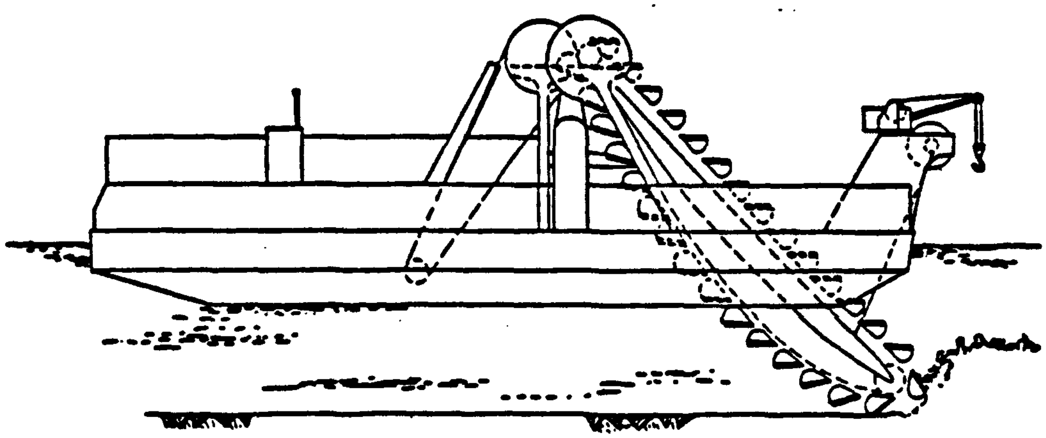
DIPPER DREDGE



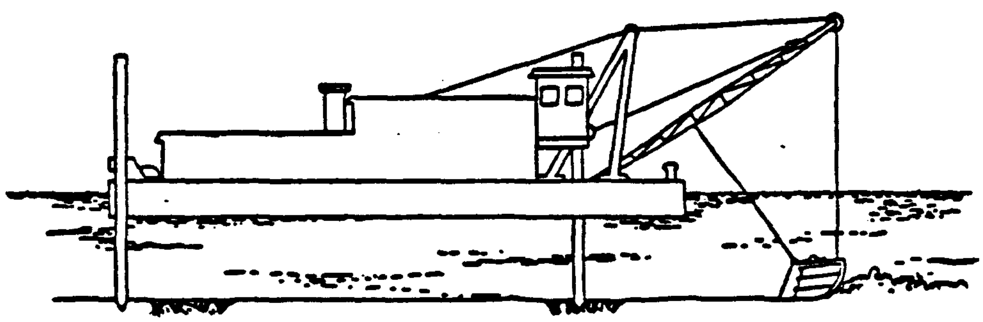
CLAMSHELL DREDGE

Figure 3: MECHANICAL DREDGES

After Malcolm Pirnie, 1978



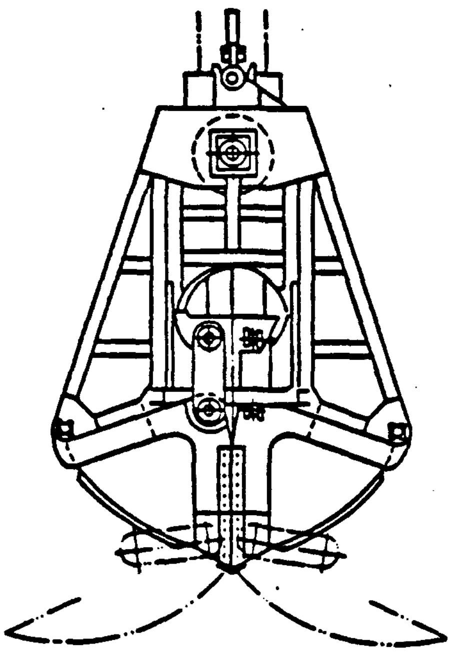
BUCKET DREDGE



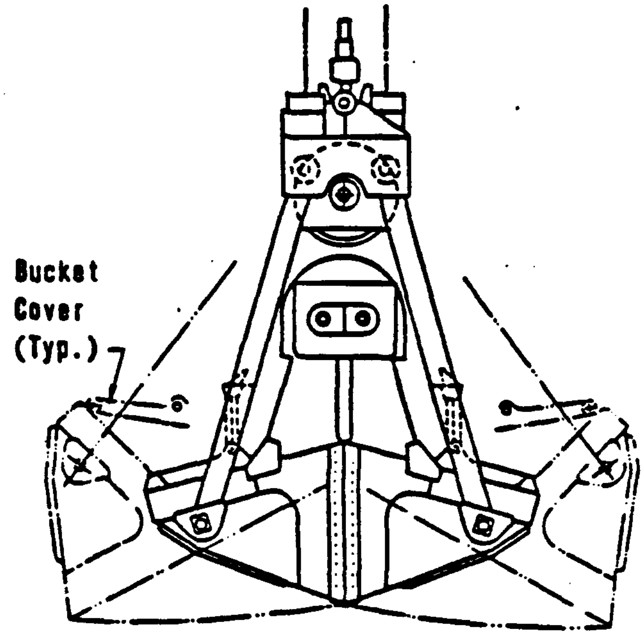
DRAGLINE DREDGE

Figure 4: MECHANICAL DREDGES

After Malcolm Pirnie, 1978

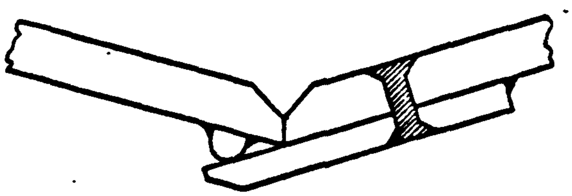


LINK TYPE

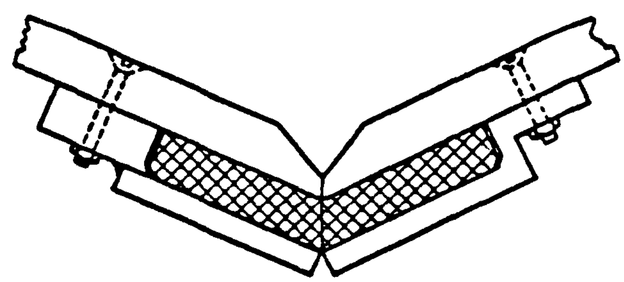


LATERAL DREDGING TYPE

MITSUBISHI CLOSED GRAB BUCKET



TWO-PLANE CONTACT METHOD

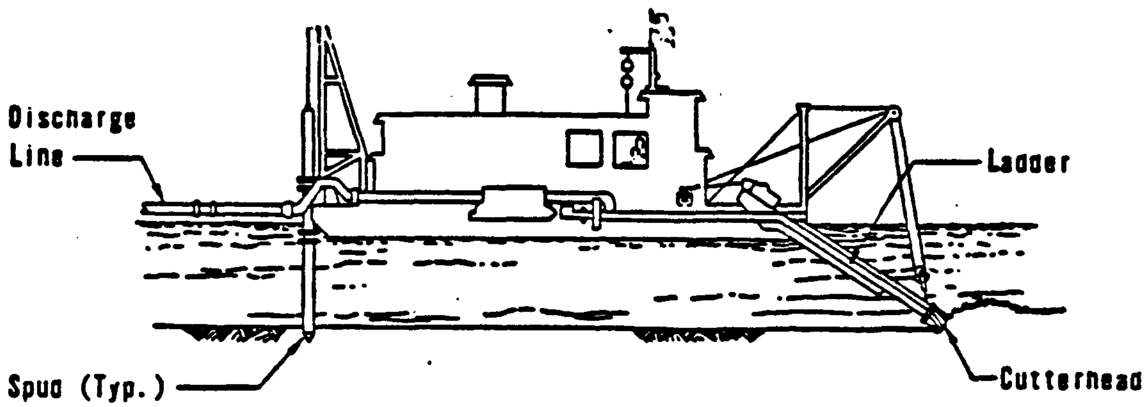


HARD RUBBER METHOD

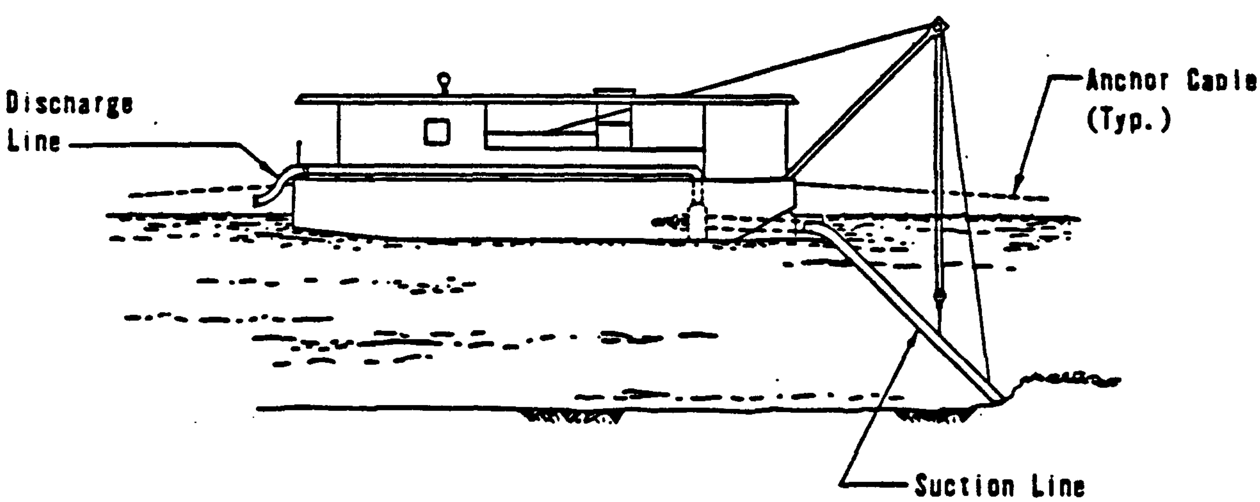
LIP SEALING METHODS

Figure 5: WATERTIGHT GRAB BUCKET

After Malcolm Pirnie, 1978
SOURCE: MITSUBISHI SEIKO CO., LTD.



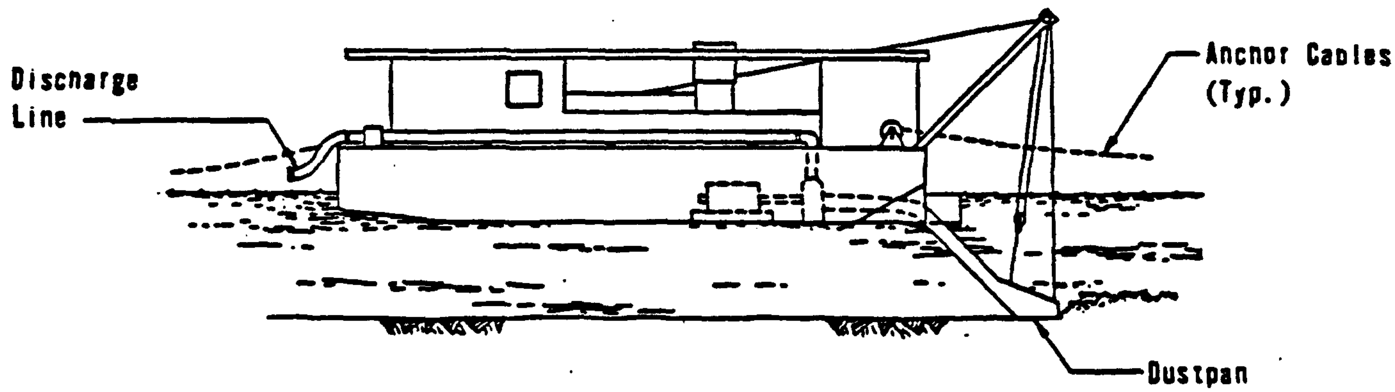
CUTTERHEAD SUCTION DREDGE



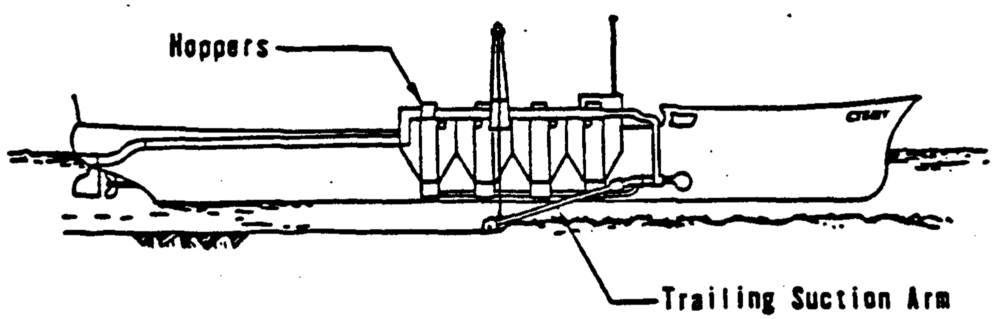
PLAIN SUCTION DREDGE

Figure 6: HYDRAULIC DREDGES

After Malcolm Pirnie, 1978



DUSTPAN DREDGE



HOPPER DREDGE

Figure 7: HYDRAULIC DREDGES

After Malcolm Pirnie, 1978

Intake

- a three way valve functions to create a vacuum in one of the chambers.
- when ready, the inlet valve opens... slurry enters, induced either by hydrostatic head pressure or vacuum.
- as the slurry reaches a certain level, the electronic sensoring device issues a command to the electronic controller for the three way valve to close.

Discharge

- at its turn, the three way valve is given a command to introduce pressurized air into the chamber.
- this pressurized air forces the slurry down, then up and through the "wye" discharge pipe.
- from the "wye" discharge, the slurry is conveyed through a pipeline to a disposal area.

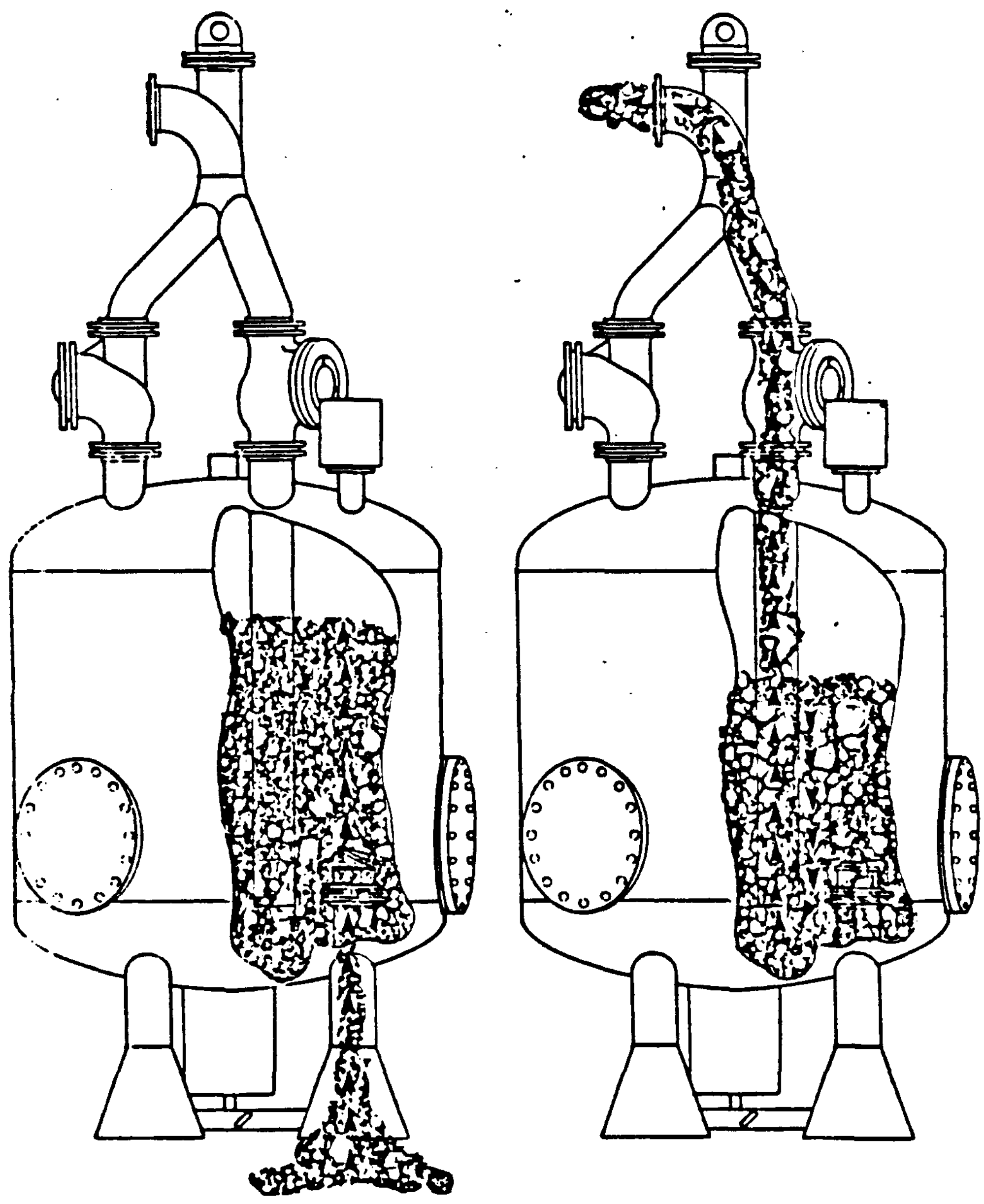
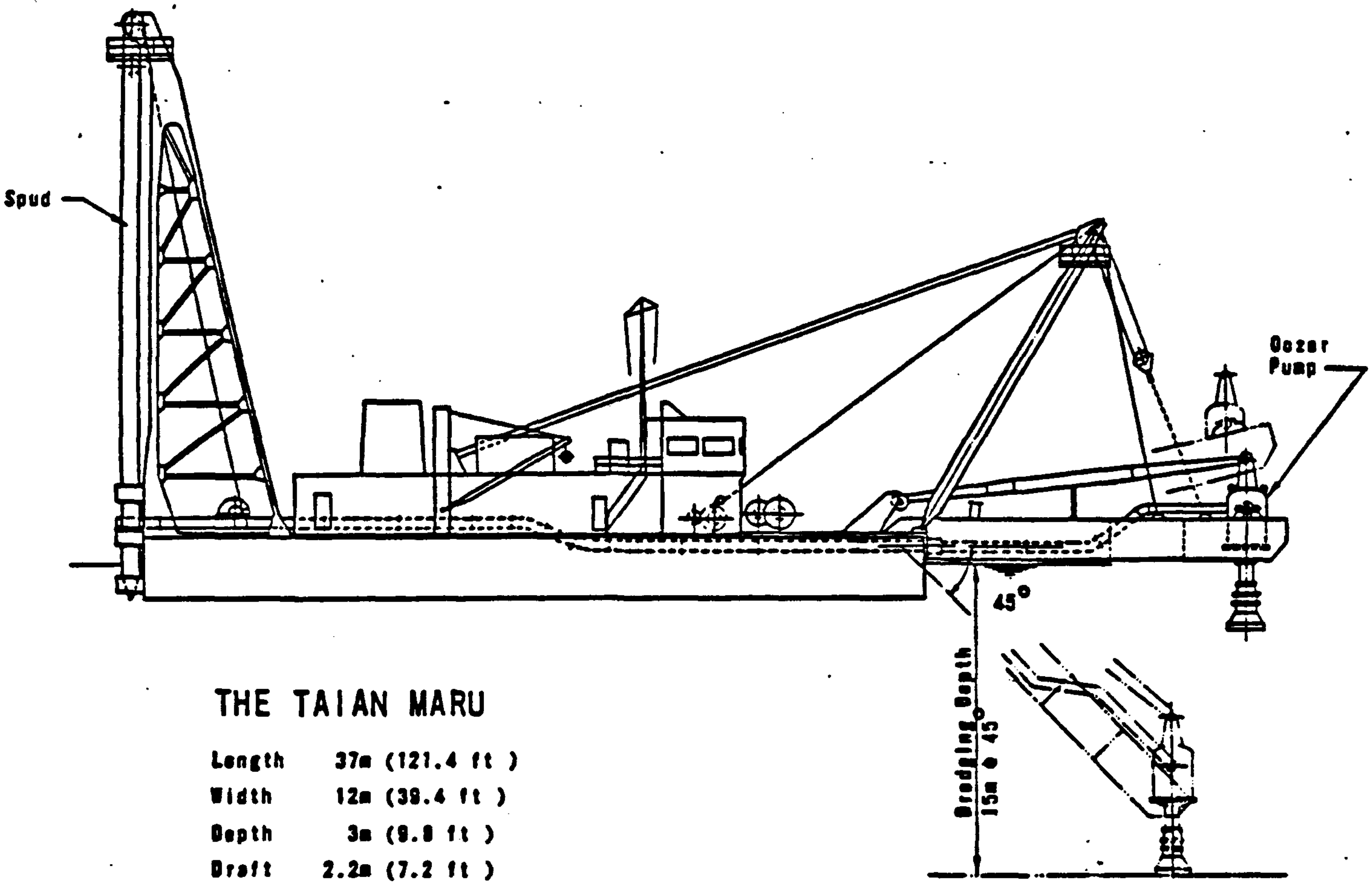


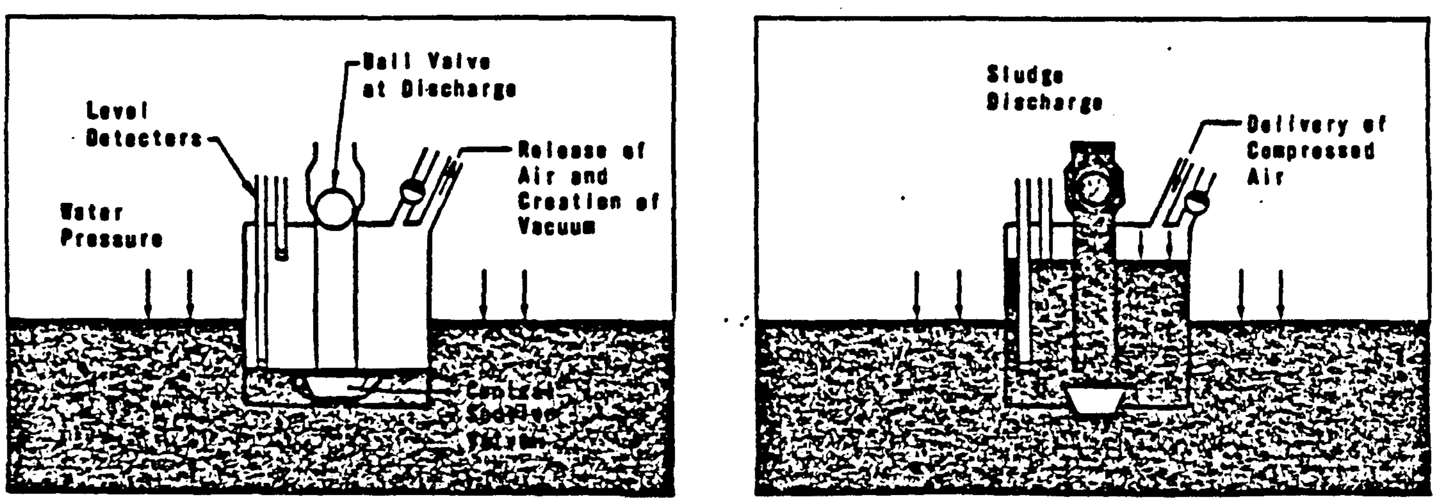
Figure 8: PNEUMATIC PUMP

After Amtec, 1981



THE TAIAN MARU

Length	37m (121.4 ft)
Width	12m (39.4 ft)
Depth	3m (9.8 ft)
Draft	2.2m (7.2 ft)



SUCTION

DISCHARGE

Figure 9: OOZER PUMP OPERATION

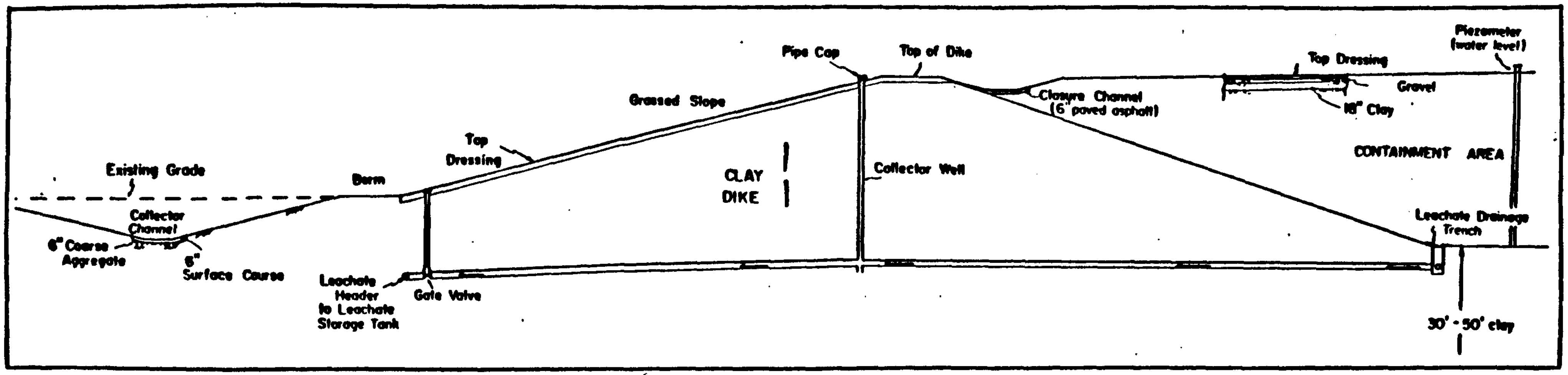
After Malcolm Pirnie, 1978

Geotechnical Engineers Inc.

Project 82990

August 13, 1982

SOURCE: TOYO CONSTRUCTION CO.



This diagram shows in detail surface water collection, ground water collection systems, and clay barriers which surround a typical secure land burial facility.

Figure 10: TYPICAL SECURE LAND BURIAL FACILITY FOR CONTAMINATED DREDGE SPOILS

After NY Department of Environmental Conservation (undated)

APPENDIX

LABORATORY TESING OF ACUSHNET RIVER ESTUARY SEDIMENTS

I. Bulk Analysis of Sediments

Fourteen sediment samples collected by ERCO on July 13, 1982 were analyzed for 9 metals (As, Cd, Cr, Cu, Pb, Hg, Ni, V, and Zn), oil and grease, and grain size distribution. Sediments were collected in the Acushnet River estuary at 7 of the 33 stations occupied by the Coast Guard in April 1982 (Figure 1). Descriptive information regarding station locations and sediment samples is summarized in Table 1. All sediment samples were collected using a push corer equipped with a polycarbonate liner. Two samples were collected at each station. One core was transferred to a 1-liter Teflon jar for compositing for the elutriate analysis, EP toxicity testing, and the solid-phase bioassay. The second core intended for bulk analysis was cut and capped in the field. All samples were stored at 4° C during sampling and transportation to the laboratory. At the laboratory, the upper and lower 10 cm of each undisturbed core was removed for bulk analysis.

For bulk analysis of the sediments, a homogenized subsample was removed and split into aliquots for each analysis. Analyses for oil and grease were performed according to methods outlined by the U.S. EPA (1979a). Grain size analysis utilized methods of Folk (1974). Samples for trace metal analyses were digested according to methods of the U.S. EPA (1977) and analyzed by atomic absorption spectrophotometry (U.S. EPA, 1979a).

Results of the bulk analyses are summarized in Table 2. In general, concentrations of metals, oil and grease, and PCBs were highest in the upper portion (0-10 cm) of the sediment cores. Concentration ranges of various constituents in the upper and lower portions of the cores were as follows:

As (ppm):	Upper; 5.3-23	Lower; 6.1-13
Cd (ppm):	Upper; 0.77-34	Lower; 0.13-7.5
Cr (ppm):	Upper; 32-830	Lower; 25-120
Cu (ppm):	Upper; 60-1,800	Lower; 5.3-910
Pb (ppm):	Upper; 70-1,400	Lower; 3.9-1,100
Hg (ppm):	Upper; <0.3-24	Lower; <0.3-1.9
Ni (ppm):	Upper; 12-123	Lower; 7.8-28
V (ppm):	Upper; 13-150	Lower; 24-38
Zn (ppm):	Upper; 170-4,400	Lower; 27-4,000

PCB (ppm):	Upper; 20-38,730	Lower; 2-150
Oil and grease (wt%):	Upper; 0.061-6.5	Lower 0.005-11.1
Gravel (wt%):	Upper; 0-1.89	Lower; 0-6.24
Sand (wt %):	Upper; 9.46-52.30	Lower; 1.73-54.75
Silt (wt %):	Upper; 30.45-69.39	Lower; 38.30-72.82
Clay (wt %):	Upper; 14.45-43.87	Lower; 18.51-30.88
Water (wt %):	Upper; 35.0-69.2	Lower; 42.0-59.3

Based on criteria established by the Massachusetts Division of Water Pollution Control (1978), sediments would be categorized as Category Three material on the basis of chemical composition and Type C material on the basis of physical characteristics.

Concentrations of total PCBs in the surface sediment are greater than 50 ppm at all stations sampled by ERCO indicating that disposal of this material is regulated by the Toxic Substances Control Act (TSCA), Public Law 94-469.

II. Elutriate Analysis of Sediments

The liquid (elutriate) phase of composite samples of bulk sediment from seven stations (Table 1) was prepared according to methods outlined by the U.S. EPA and Army COE (1977). Sediment samples were prepared by homogenizing the entire core from each of the 7 stations identified in Table 1. Sediment and seawater were mixed at room temperature (22 $\pm$ 2° C) in a 1:4 ratio by volume. Mixing was performed in 1,000-ml Erlenmeyer flasks by passing compressed air (treated in a deionized water bath) into the flasks for 30 min and manually stirring the slurry at 10-min intervals. The slurry was then allowed to settle for 1 hr. For analysis of metals, the supernatant was filtered through a 0.45-µm filter and acidified to a pH of <2.0 with concentrated Ultrex HCl. For analysis of PCBs and oil and grease, the supernatant was centrifuged to prevent adsorption of the organic compounds by the filter.

Analyses for metals were conducted by a variety of analytical methods. Mercury was determined by cold-vapor atomic absorption spectrophotometry (AAS) according to methods specified by the U.S. EPA (1979a). Arsenic was determined by hydride generation AAS according to methods described by Andreae (1977). Vanadium was determined by inductively coupled argon plasma emission spectroscopy according to methods of the U.S. EPA (1980a). Analyses for other metals (Cd, Cr, Cu, Pb, Ni, and Zn) were conducted by chelation/solvent extraction with APDC and MIBK (ammonium pyrollidine diothiocarbomate and methylisobutyl ketone) according to methods described by Jan and Young (1978). Instrumental analyses were conducted by flame or graphite furnace AAS. Analyses for oil and grease were conducted by solvent extraction and gravimetry according to methods of the U.S. EPA (1979a). Analyses for PCBs were performed according to methods of the U.S. EPA (1979b). Samples were extracted with methylene chloride and analyzed by gas chromatography with electron capture detection.

Results of elutriate analyses are presented in Table 3. Also shown in Table 3 are suggested water quality criteria (U.S. EPA, 1980c) for seven constituents (Cd, Cr, Cu, Hg, Ni, Zn, and PCBs) in saltwater environments. These criteria have been established for protection of saltwater aquatic life and are generally lower than equivalent criteria for freshwater environments. Comparisons of constituent concentrations in the sediment elutriates with these levels should represent a conservative estimate for determination of the relative potential environmental impact of soluble constituents released by dredging activities.

Concentrations of seven metals (As, Cd, Cr, Pb, Hg, V, and Zn) in the elutriates (without application of a dilution factor) were higher than in the Acushnet River water used for sample preparation. Conversely, Cu and Ni concentrations decreased in the elutriates relative to ambient levels. The maximum concentration levels suggested by the criteria (U.S. CPA, 1980c) were not exceeded for any element for which criteria exist, although the 24-hr average level was exceeded, in some cases, for Hg, Ni, and Zn (it should be noted that no dilution factor was applied to the elutriate concentrations). Ambient levels of Cu and Ni in the Acushnet River estuary exceeded the suggested criteria.

Concentration of total PCBs in the elutriates exceeded the ambient level in the Acushnet River water for all stations except Station 16. In addition, concentrations of total PCBs in the elutriate (without application of a dilution factor) exceeded both the 24-hr average and maximum

Table 3. Results of elutriate analysis of sediment samples

ERCO ID IC-82-	Sample Description	Concentration (µg/l) As	Cd	Cr	Cu	Pb	Hg	Ni	V	Zn	Oil and Grease	Total PCB[a]
2192	Station 9 - Composite	5.2	<0.10	<0.50	<1.0	1.6	0.43	12	5.2	29	5,000	11,000
2193	Station 11 - Composite	5.5	<0.10	3.6	1.3	4.2	<0.20	7.3	5.5	60	8,000	920
2194	Station 16 - Composite	21	<0.10	3.9	1.2	5.9	0.28	6.4	21	19	350	3.4
2195	Station 21 - Composite	7.5	0.18	0.60	1.7	300	<0.20	12	7.5	87	8,000	1,010
2196	Station 27 - Composite	3.6	0.25	18	1.1	13	0.43	7.4	3.6	21	3,300	3,360
2197	Station 29 - Composite	7.3	0.13	1.6	1.2	87	0.71	11	7.3	84	900	22
2198	Station 31 - Composite	35	<0.10	1.0	<1.0	18	0.64	9.1	35	<2.5	500	47
Acushnet River Water		<1.0	<0.10	2.9	6.2	1.8	<0.20	20	<10	6.2	370	6.1
Criterion[b]												
	- 24-hr	NA	4.5	18	4.0	NA	0.025	7.1	NA	58	NA	0.030
	- Maximum	NA	59	1,260	23	NA	3.7	140	NA	170	NA	10

[a]PBCs were quantified as Aroclor 1248 and Aroclor 1254.

[b]These criteria are based on recommendations of U.S. EPA (1980c) for protection of saltwater aquatic life.

NA - None available

concentration levels suggested by the water quality criteria. In the case of Station 9, the elutriate concentration exceeded the maximum concentration level of the criteria by a factor of greater than 1,000. Ambient levels of PCBs in the Acushnet River exceeded the 24-hr average concentration suggested by the criteria.

Table 4. Results of EP toxicity testing of composite sediment sample from the New Bedford Harbor

Constituent	Concentration (ppm) in sample 82-2199	Maximum Contamination Level (ppm)[a]
As	0.021	5.0
Ba	0.135	100
Cd	0.016	1.0
Cr	0.005	5.0
Pb	0.060	5.0
Hg	<0.050	0.2
Se	<0.002	1.0
Ag	<0.001	5.0
Endrin	<0.0001	0.02
Lindane	<0.0001	0.4
Methoxychlor	<0.001	10.0
Toxaphene	<0.001	0.5
2,4-D	<0.0004	10.0
2,4,5-TP Silvex	<0.0001	1.0

[a]EPA (1980b)

III. Analysis of Sediments for EP Toxicity

A single composite sample, comprised of equal amounts of sediment from seven stations (Table 1, was analyzed for the characteristic of EP toxicity according to procedures outlined in Appendix II (pp. 33127-33128) of the U.S. EPA (1980b).

A 100 g sample was combined with 16 times its weight of distilled, deionized water and maintained at a pH of 5.0 $\pm$ 0.2 for 24 hr by addition of 0.5N acetic acid. The sample was then filtered, diluted to volume, and analyzed for metals pesticides, and herbicides according to methods described by the U.S. EPA (1979a, 1979b).

Results of the EP toxicity test are presented in Table 4. Also presented are maximum contamination levels (MCLs) that have been established for eight metals, pesticides, and herbicides (the MCLs are 100 times the Interim Primary Drinking Water Standards [U.S. EPA, 1980b]). Results indicate that the composite sediment sample is EP non-toxic with respect to metals, pesticides and herbicides.

Nitex containers to prevent predation by grass shrimp). Organisms were maintained in uncontaminated media for a period of 2 days. During this time, fecal material was removed from aquaria. At the end of the 2-day period, all samples of organisms were split into approximately equal amounts. One of these subsamples was placed in a polyethylene clean bag and frozen for later analyses for metals. The second subsample was put in solvent-rinsed aluminum foil and frozen for analyses for organics.

Data produced by solid phase bioassays with grass shrimp, hard clams, and sandworms are presented in Table 5. Mean survival of organisms exposed for 10 days to the composite sediment sample was 19.0% (grass shrimp), 99.0% (hard clams), and 97.0% (sandworms).

Analysis of total (combined) survival data for the three species exposed for 10 days to control (culture) sediment and the solid phase of the composite sediment sample is presented in Table 6. Mean survival of control organisms was greater than 90%, thus allowing evaluation of data from tests with the composite sediment sample. These data indicate that total survival of organisms exposed to the solid phase of the composite sediment sample was significantly less than total survival of organisms exposed to control sediment (71.7% versus 96.7%).

IV. Results of Solid Phase Bioassay

The composite sediment sample was prepared for biological testing according to procedures described in Appendix B of the manual entitled Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters (U.S. EPA and U.S. Army COE, 1977). Bioassays with sediment were conducted according to guidelines presented in Appendix F of the EPA and COE manual for dredged material (U.S. EPA and U.S. Army COE, 1977).

Species tested in the solid phase bioassays were the grass shrimp (*Palaemonetes pugio*), hard clam (*Mercenaria mercenaria*), and sandworm (*Nereis virens*). Grass shrinp were collected in Osterville, Massachusetts. Hard clams and sandworms were acquired from commercial suppliers in, respectively, Long Island, New York, and Boston, Masschusetts. Animals were acclimated in artificial seawater for at least 3 days prior to initiation of testing. All species were tested in the same aquaria. Testing temperature was 20 $\pm$ 1° C. Water exchange (artificial seawater) was by the replacement, as compared to the flow-through, method. Control (culture) sediment employed in the tests was collected on July 14, 1982, from the subtidal zone off Manchester, Massachusetts. The sediment, which was collected by R. Boeri and C. Smith, ERCO, consisted primarily of sand.

At the conclusion of the solid-phase bioassays with grass shrimp, hard clams, and sandworms, all surviving organisms from each aquarium (replicate) were placed in an aquarium containing clean, sediment-free water and allowed to void their digestive systems (sand worms were confined in

Table 6. Analysis of total (combined) survival data for grass shrimp (*Palaemonetes pugio*), hard clams (*Mercenaria mercenaria*), and sandworms (*Nereis virens*) exposed for 10 days to control (culture) sediment and solid phase of composite sediment sample.

Step 1. Total Survival Data (From Table 5)

Treatment (t): Replicate (r)	Total Number of Survivors: Control (Culture) Sediment	Total Number of Survivors: Composite Sediment Sample
1	58	42
2	57	45
3	57	45
4	58	41
5	60	42
Mean ($\bar{x}$):	58.00 (96.7%)	43.00 (71.7%)

Step 2. Cochran's Test for Homogeneity of Variances of Survival Data

Treatment (t)	Survival: Mean ($\bar{x}$)	Survival: Variance (S^2)
Control (culture) sediment	58.00	1.50
Composite Sediment Sample	43.00	3.50

$$C_{(cal.)} = \frac{S^2(max)}{\Sigma S^2} = \frac{3.50}{5.00} = 0.70 \text{ ns.}$$

as compared to: $C_{(tab)} = 0.91$ for $\alpha = 0.05$, $k = 2$, and $v = 4$

Step 3. Parametric Unpaired "t" Test of Survival Data (Comtrol Sediment vs. Composite Sediment Sample)

$$t_{(cal)} = \frac{\bar{x}_1 - \bar{x}_2}{\frac{S_1^2 + S_2^2}{5}} = \frac{15.00}{1.00} = 15.00^*$$

as compared to: $t_{(tab)} = 1.86$ for $\alpha = 0.05$, one-tailed hypothesis, and df = 8

Table 5. Results of solid phase bioassays with grass shrimp (*Palaemonetes pugio*), hard clams (*Mercenaria mercenaria*), and sandworms (*Nereis virens*)[a]

Treatment (t):	Number of Survivors[b,c]							
	Control (Culture) Sediment				Composite Sediment Sample			
Replicate (r)	Grass Shrimp	Hard Clams	Sand-worms	Total	Grass Shrimp	Hard Clams	Sand-worms	Total
1	18	20	20	58	3	20	19	42
2	18	19	20	57	5	20	20	45
3	18	20	19	57	5	20	20	45
4	18	20	20	58	4	19	18	41
5	20	20	20	60	2	20	20	42
Mean ($\bar{x}$)	18.40	19.80	19.80	58.00	3.80	19.80	19.40	43.00
____(%)	(92.0)	(99.0)	(99.0)	(96.7)	(19.0)	(49.0)	(97.0)	(71.7)

[a]Bioassays (10-day tests) were conducted at 20± 1° C in 38-liter aquaria. Organisms were exposed to each replicate of a treatment in a single aquarium. Water in aquaria was exchanged by the replacement, as compared to the flow-through, method and was aerated. A 14-hour light and 10-hour dark photoperiod was maintained with cool-white fluorescent bulbs. Minimum values of dissolved oxygen and pH recorded during the bioassays were 5.4 mg/l and 7.1 respectively. Salinity was maintained at 30 ppt.

[b]Twenty (20) individuals of each species were initially exposed to each replicate of a treatment. Thus, a total of 60 animals was employed in each aquarium.

[c]In addition to monitoring survival of all species, burrowing behavior of sandworms was noted at 2-day intervals. No differences were observed among aquaria.

LABORATORY PROCEDURES FOR PREPARING THE COMPOSITE SEDIMENT SAMPLE[a]

Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure: Aquatic Toxicologist	Aquatic Toxicologist	Laboratory Director
1. Store control sediment (CS), and composite sediment sample (CSS) at 2-4° C in separate containers. Mix sediment in each container as thoroughly as possible.	CS 7/14/82	[signature]	[signature]	[signature]
		"	"	"
	7/13/82	"	"	"

Solid Phase Bioassays

Bioassays should be initiated by July 27, 1982 (2 weeks after July 13, 1982, date of sediment arrival).
Do not be concerned with sophisticated photoperiod.
Maintain dissolved oxygen in aquaria at >4 ppm.
Cover aquaria to prevent salinity changes.

Procedure	Date of Implementation of Procedure	Aquatic Toxicologist	Aquatic Toxicologist	Laboratory Director
2. Remove CS from storage and wet sieve through 1-mm mesh. Use minimum volume of artificial sea water [ASW] of salinity 30 ppt for sieving purposes. Place nonliving material remaining on sieve in appropriate containers.	7/14	"	"	"
3. Mix CS and allow to settle for 6 hr.	7/14	"	"	"
4. Decant ASW and mix CS as thoroughly as possible.	7/14	"	"	"
5. Assign treatments (CS and CSS) and replicates (5 r per treatment) to aquaria.	7/14	"	"	"
6. Randomly position aquaria (10) in environmental chamber maintained at 20+1°C. 20$\pm$ 1°C.	7/14	"	"	"

[a]This document is a copy of the work sheet that was used during the evaluation. The document differs from the work sheet in that dates appear in typed form and certifications were added at a single time after the dates were typed.

V. LABORATORY PROCEDURES FOR CONDUCTING SOLID-PHASE BIOASSAY

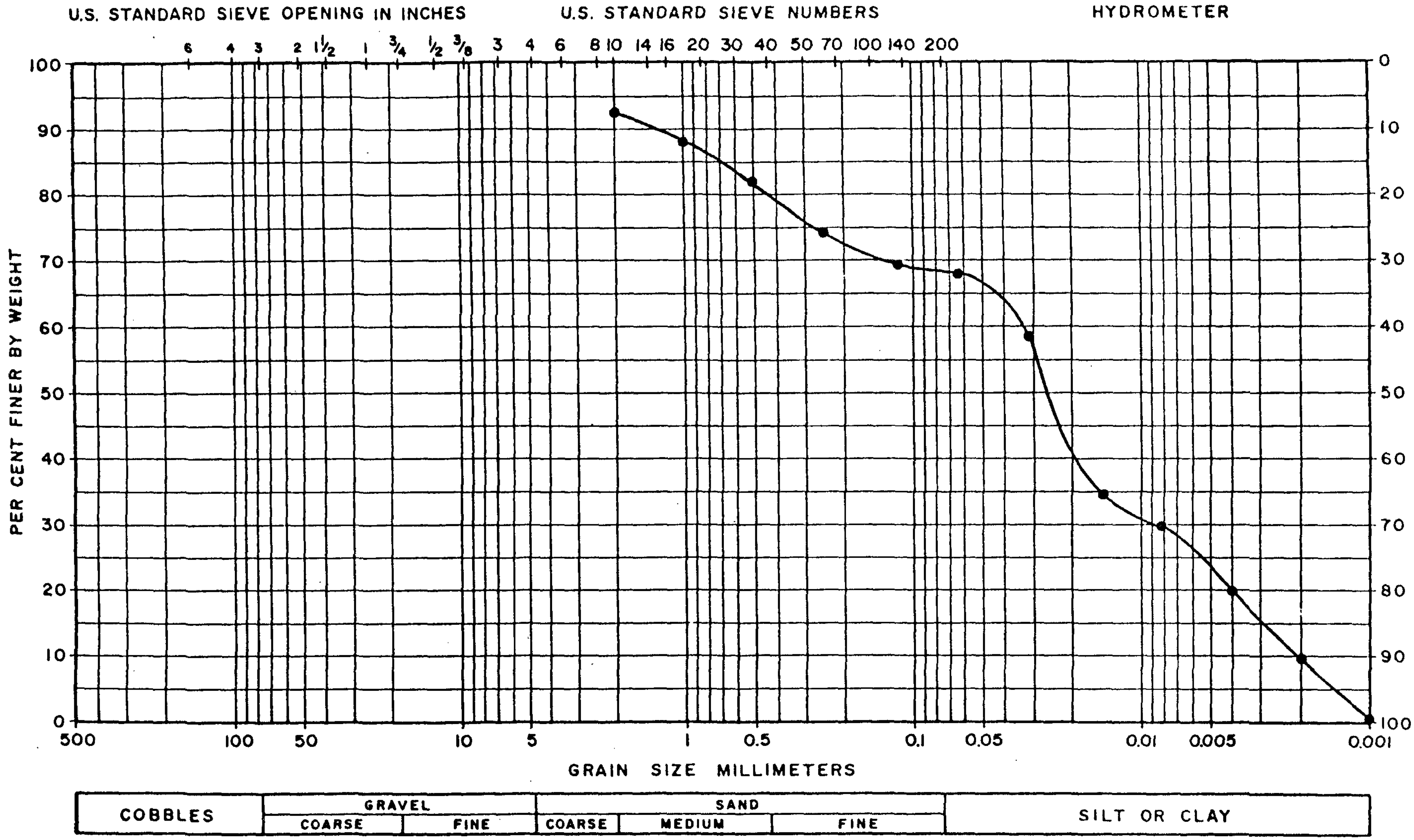
This section contains laboratory procedures for preparing the composite sediment sample and conducting the solid phase bioassay.

Laboratory Procedures (Continued)

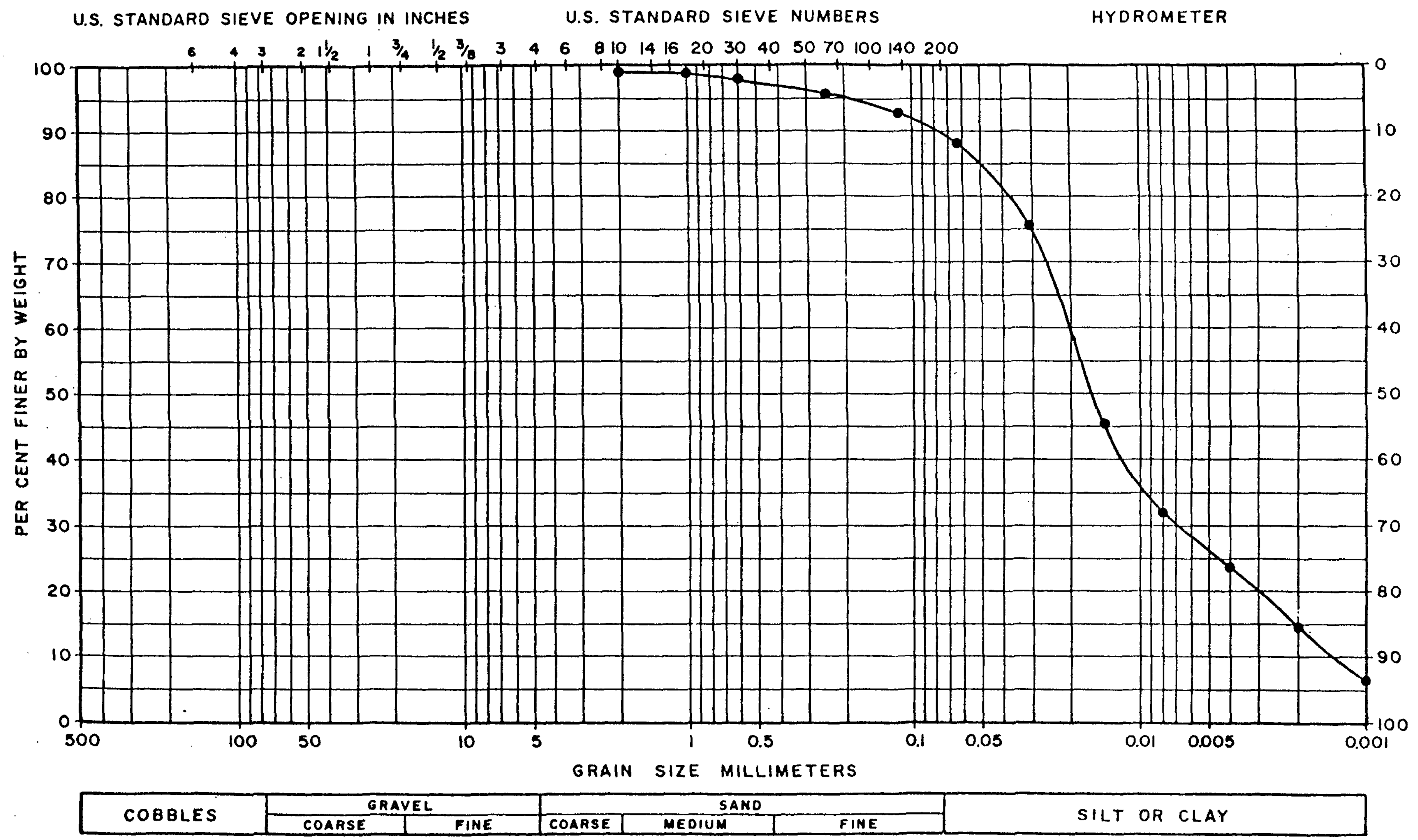
Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure		
		Aquatic Toxicologist	Aquatic Toxicologist	Laboratory Director
14. During acclimation period, remove appropriate volumes of CSS from storage and wet-sieve each sample through 1-mm mesh into containers. Use minimum volume of ASW for sieving purposes. Place nonliving material remaining on sieves in container.	7/16	"	"	"
15. Mix CSS and allow to settle for 6 hr.	7/16	"	"	"
16. Decant ASW and mix CSS as thoroughly as possible.	7/16	"	"	"
17. Place 15 mm of CSS in all but control aquaria. Employ basic strategy identified in Step 8.				
18. Remove remaining CS from storage. Warm to test temperature (20$\pm$1°C). Add 15 mm of CS to each control aquarium. Employ basic strategy identified in Step 8.	7/16	"	"	"
19. Replace 75% of ASW 1 hr after addition of CSS and final addition of CS.	7/16	"	"	"
20. Select 200 grass shrimp from holding tank and randomly distribute into 10 culture dishes.	7/16	"	"	"
21. Randomly distribute contents of 10 culture dishes into 10 aquaria.	7/16	"	"	"

Laboratory Procedures (Continued)

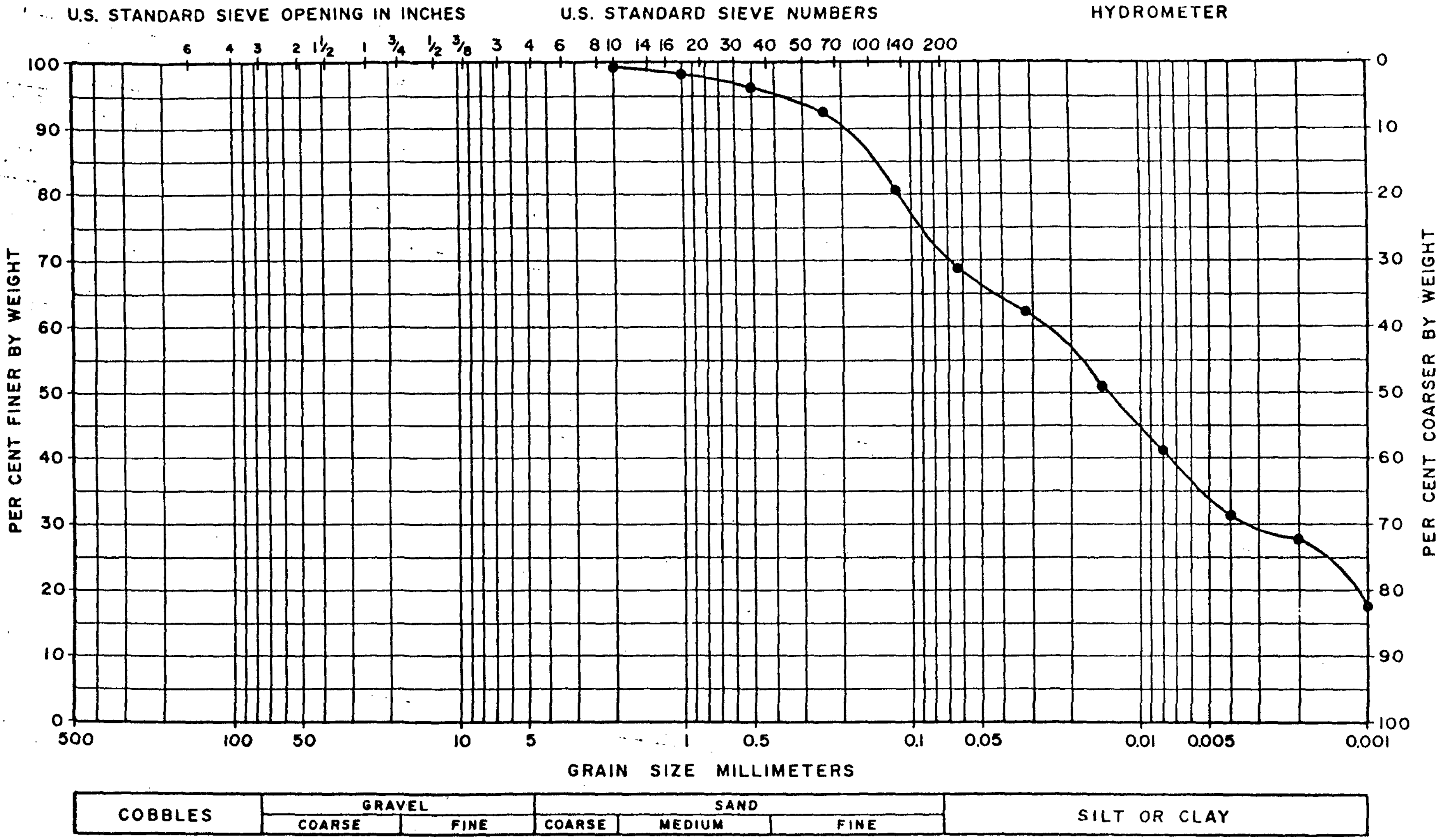
Procedure	Date of Implementation of Procedure	Certifications of Performance of Procedure		
		Aquatic Toxicologist	Aquatic Toxicologist	Laboratory Director
7. Partially fill aquaria with ASW.	7/14	"	"	"
8. Place 30 mm of CS in each aquarium. Fill 1st aquarium to ~10mm, then 2nd aquarium to ~10mm, ..., and finally last aquarium to ~10 mm. Repeat sequence until aquaria are filled to ~20 mm. Repeat sequence again until aquaria are filled to ~30 mm. This procedure will help to ensure that CS in all aquaria is homogeneous. Store remaining CS at 2-4°C for later use.	7/14	"	"	"
9. Replace ASW 1 hr after CS has been added to aquaria. Do not disturb sediment during replacement.	7/14	"	"	"
10. Select 200 hard clams from holding tanks and randomly distribute into 10 culture dishes. Follow same procedure for sandworms.	7/14	"	"	"
11. Randomly distribute contents of 10 culture dishes into 10 aquaria.	7/14	"	"	"
12. If necessary, replace 75% of AWS 24 hr after animals are introduced into aquaria.	Not necessary	"	"	"
13. Acclimate animals for 48 hr. During this time period, remove dead animals and replace with live animals.	7/14-7/16	"	"	"



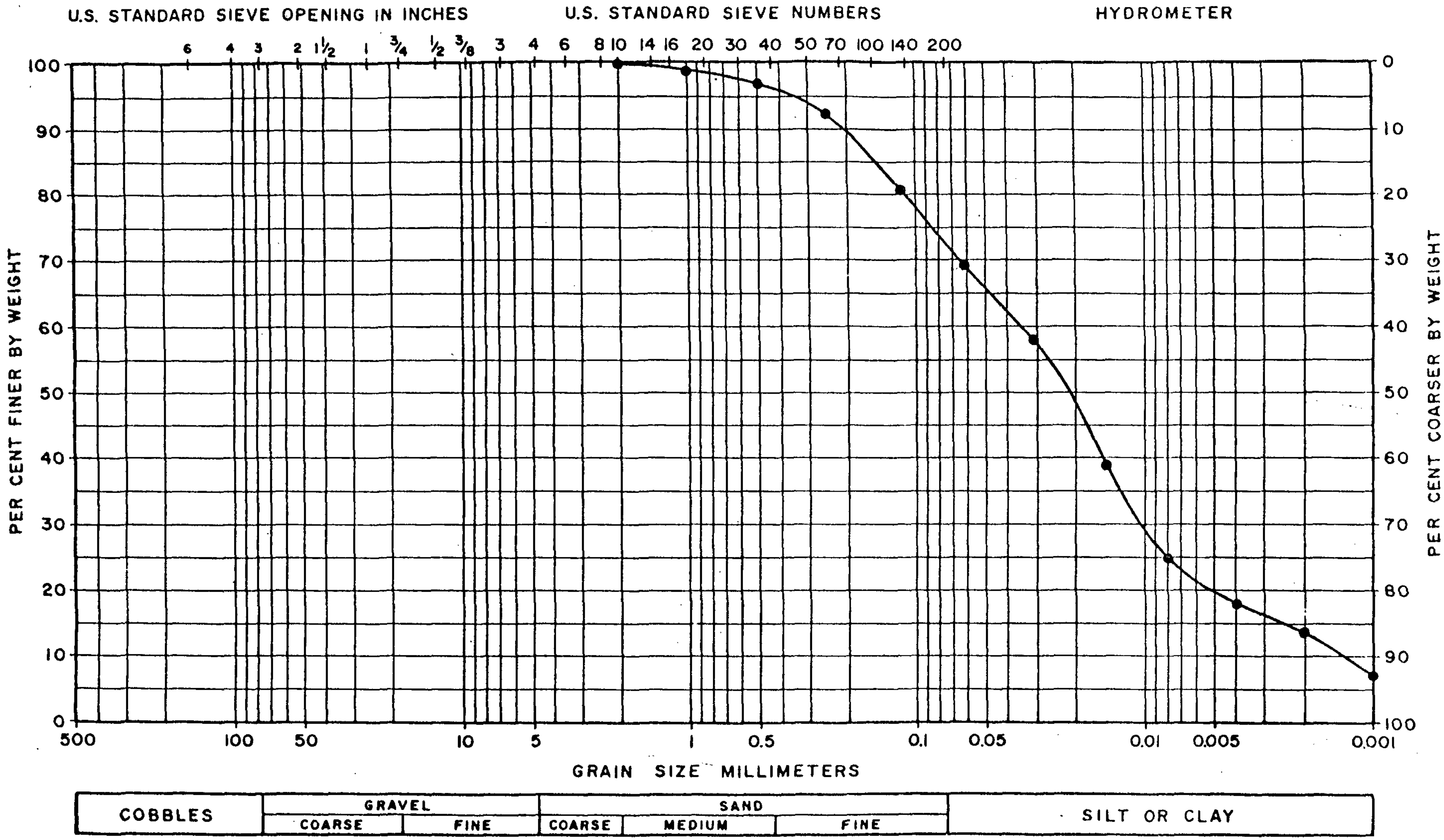
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 9 LOWER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 3



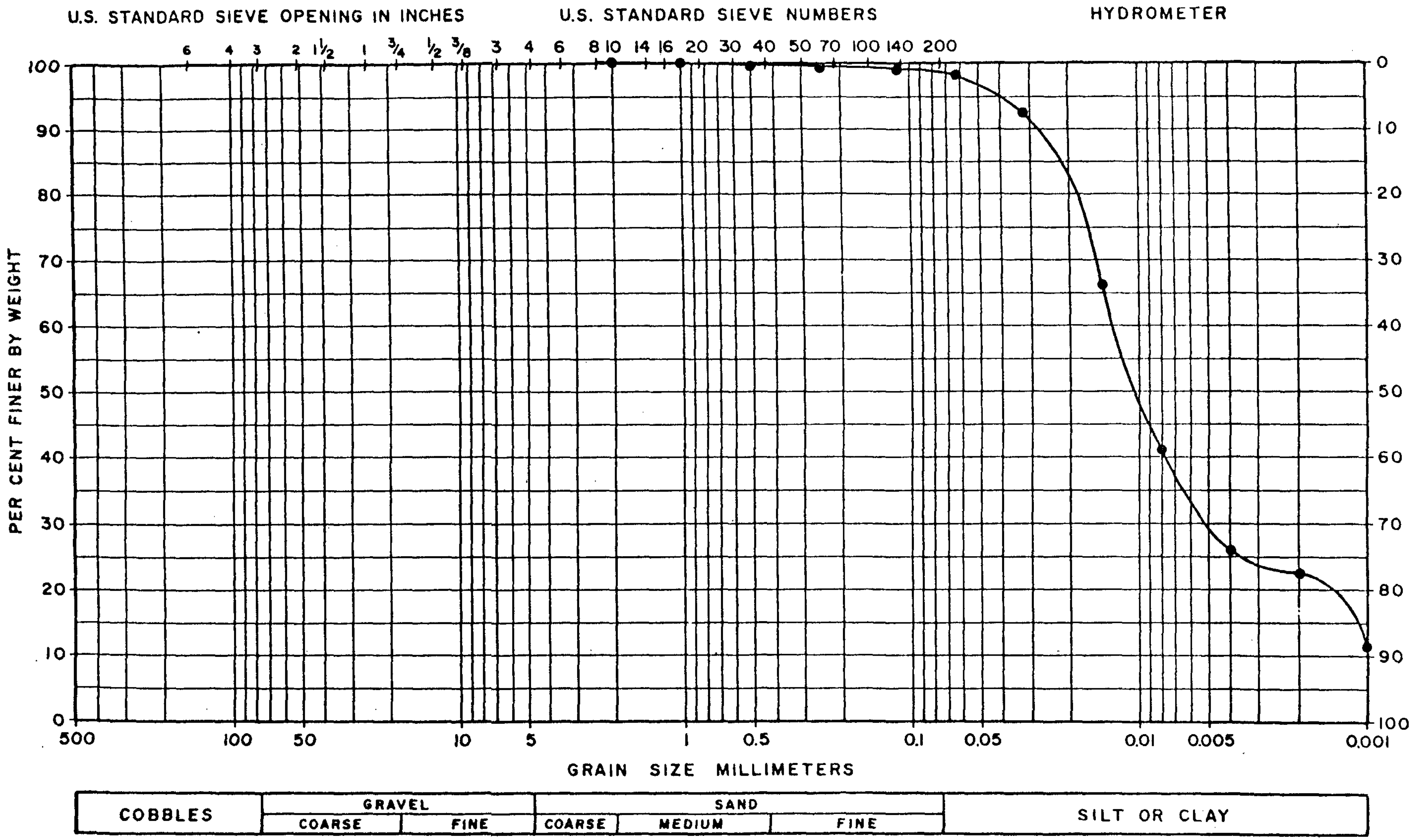
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 9 UPPER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 2



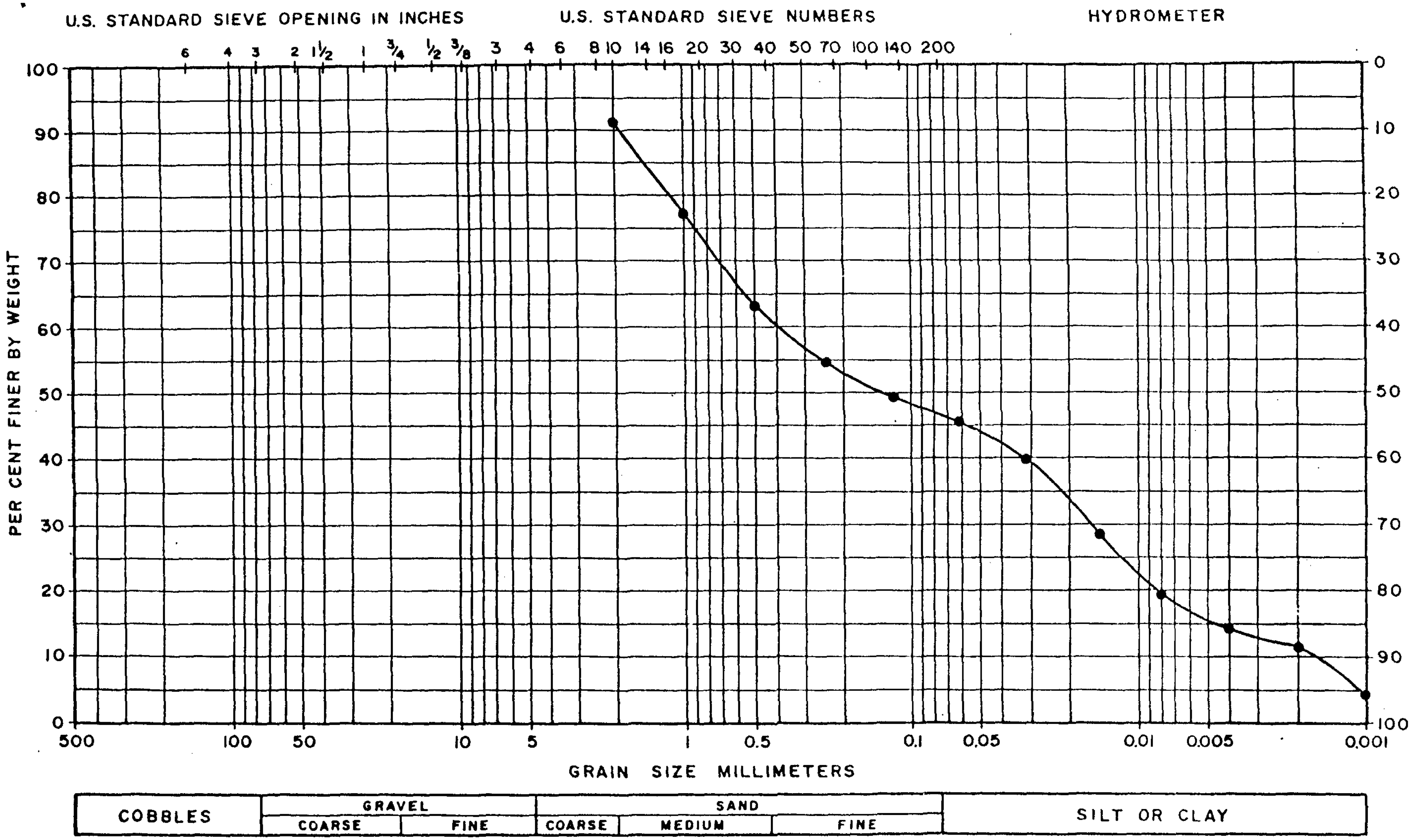
New England Governor's Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 11 LOWER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 5



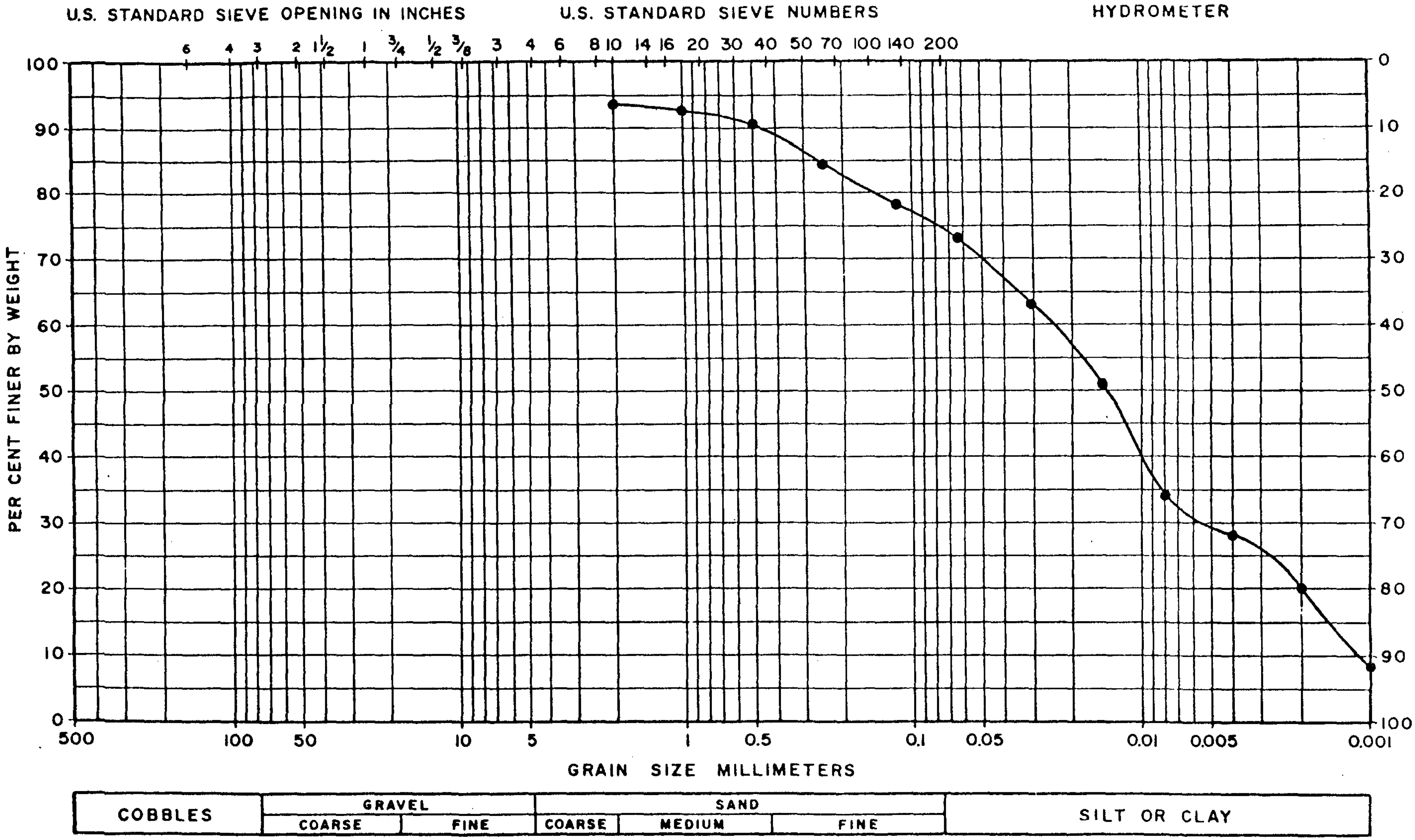
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 11 UPPER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 4



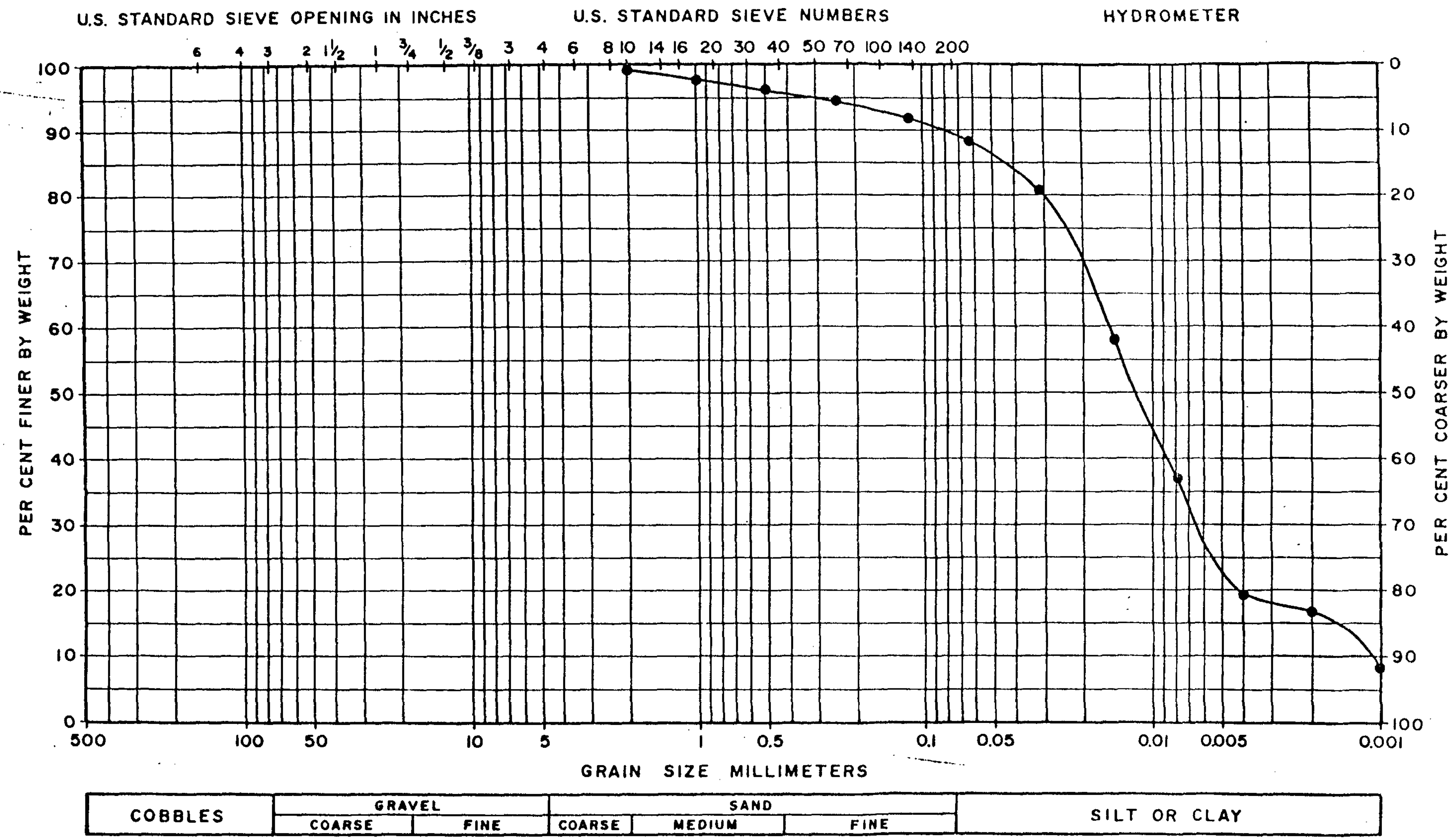
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 16 LOWER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 7



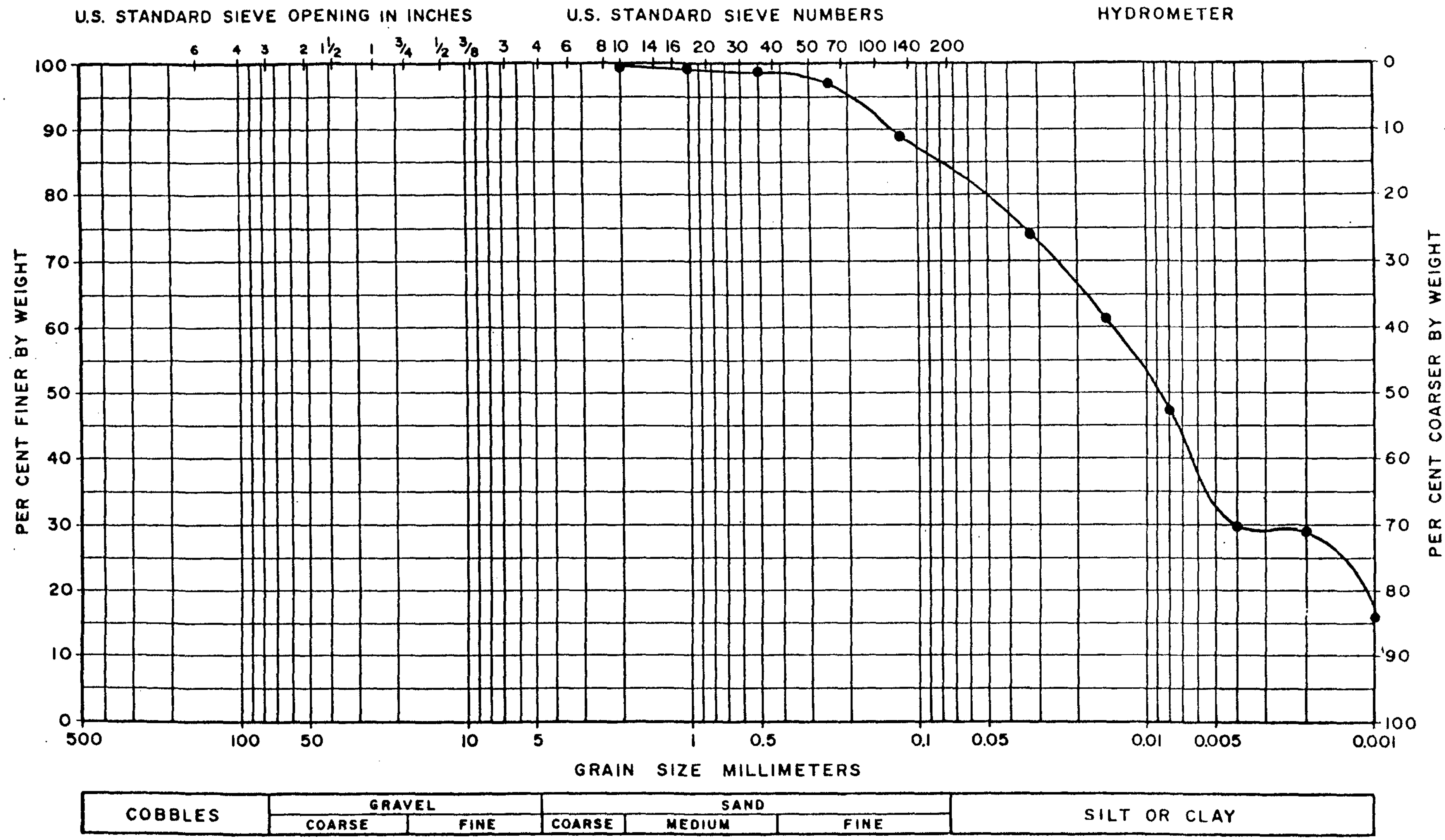
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 16 UPPER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 6



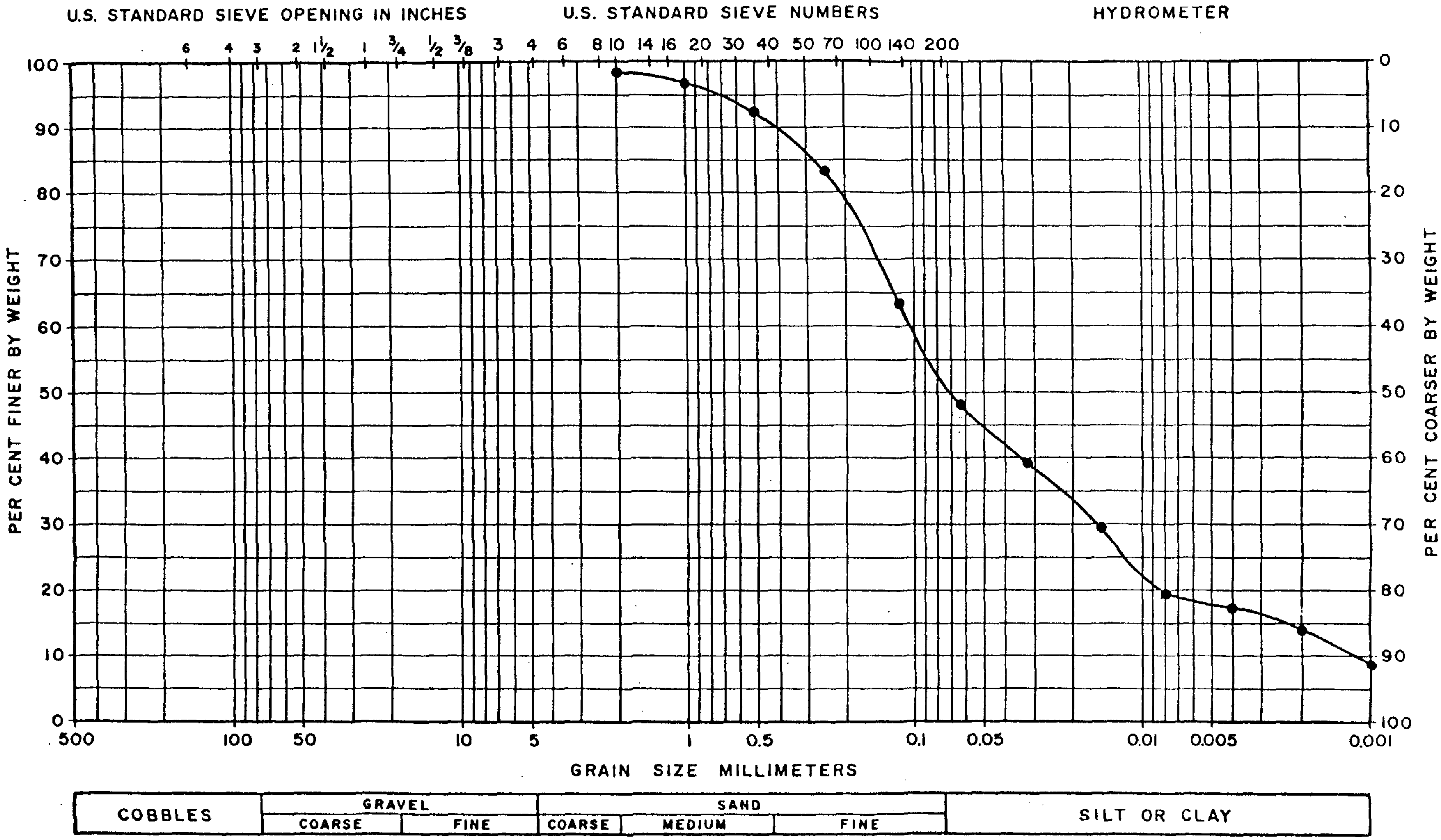
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 21 LOWER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 9



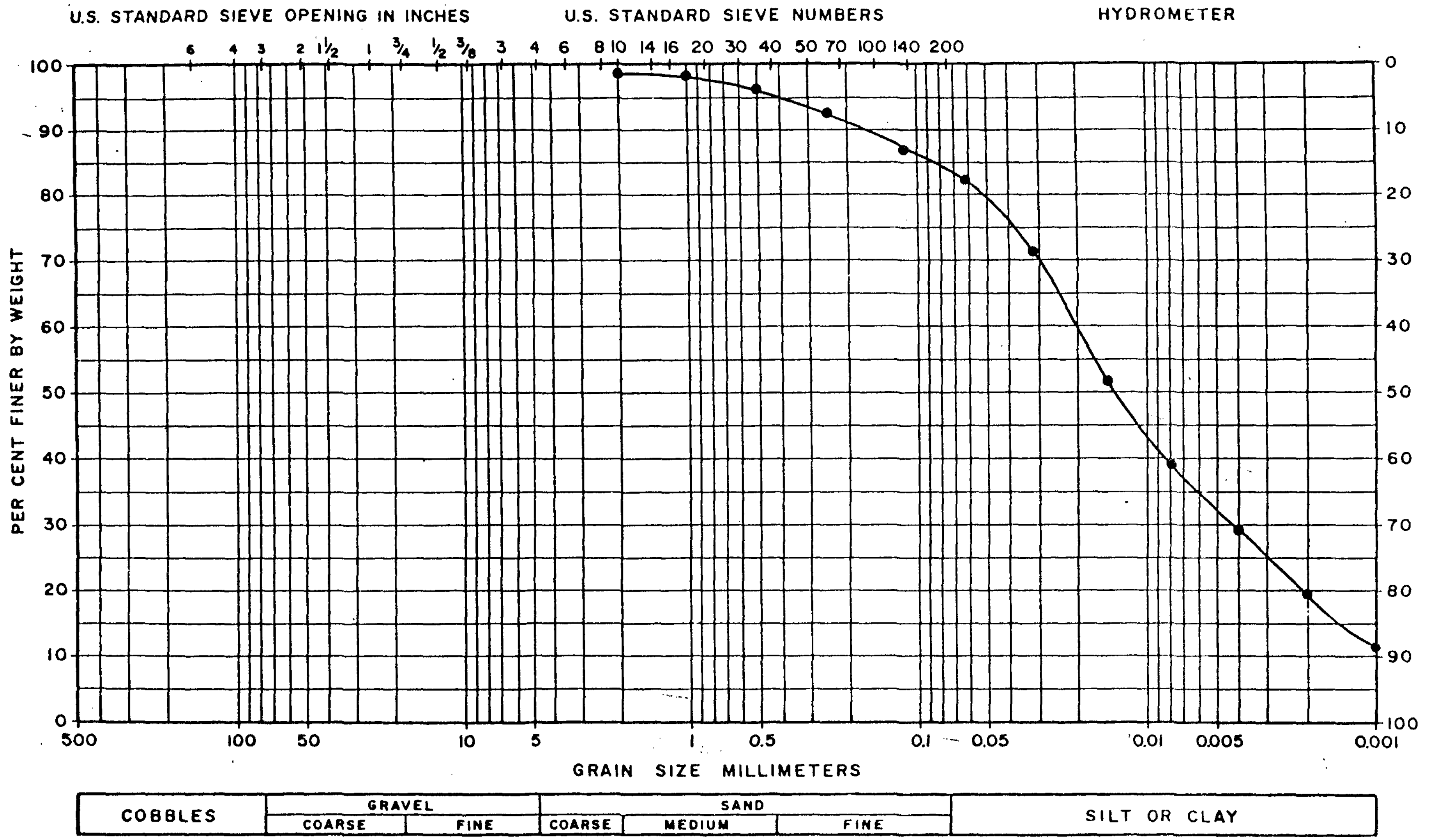
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 21 UPPER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 8



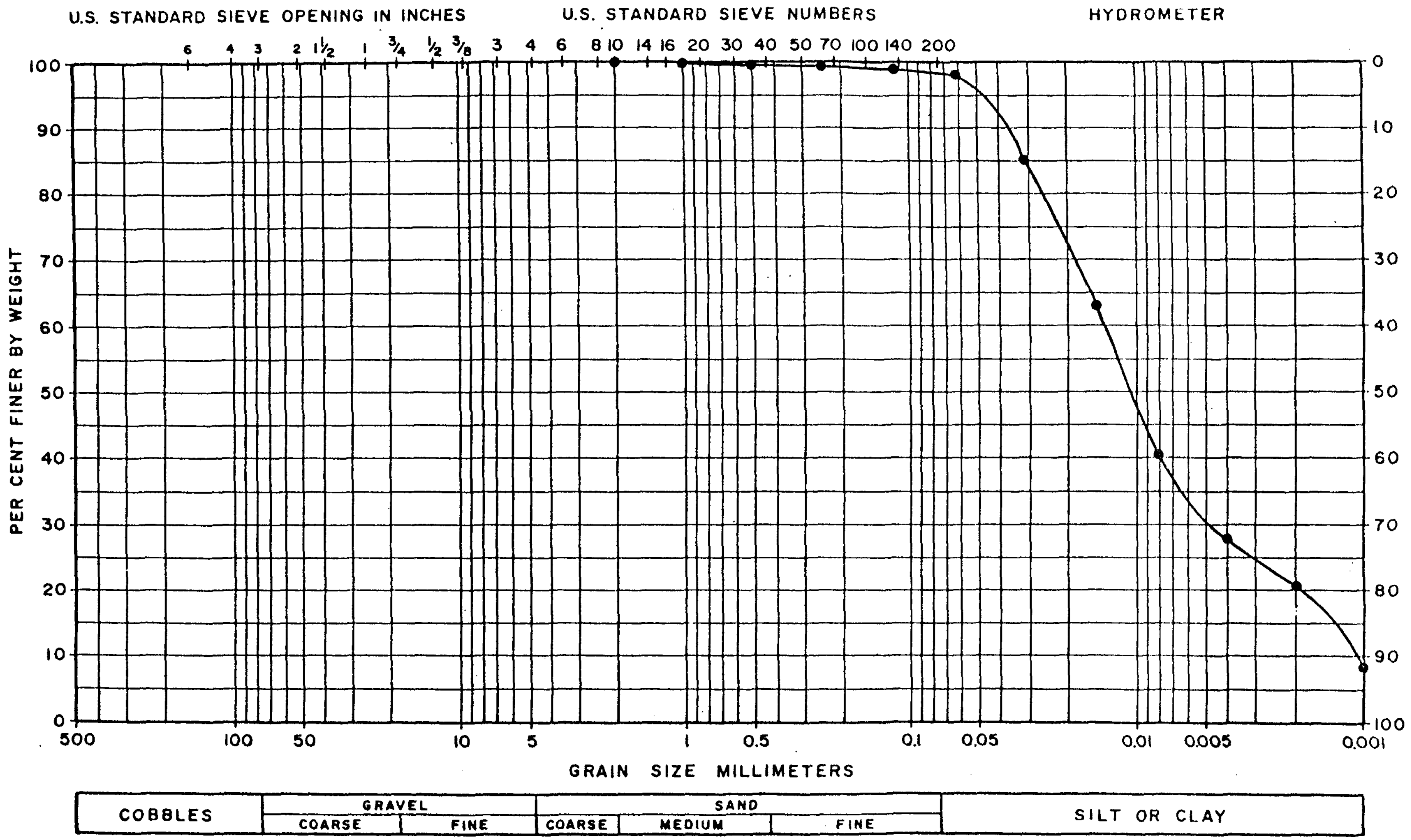
New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 27 LOWER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 11



New England Governor's Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 27 UPPER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 10



New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 29 UPPER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 12



New England Governors' Conf. Boston, Massachusetts	New Bedford Harbor Investigation New Bedford, Massachusetts	GRAIN SIZE CURVE STATION 29 LOWER 10 CM
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 82990	July 30, 1982 Fig. 13

Table 1. Summary of sampling informaiton for sediment samples collected in the Acushnet River estuary on July 13, 1982

Station Location[a]	Date	Time (local)	Water Depth (m)	Sampling Equipment	Core Length (cm)	Sample Processing and Preservation Methods	Sample Identification
9	7/13/82	1355	1	Push corer	36	Composite in Teflon jar; store at 4° C	NB-9 (Composite)-82-2192
9	7/13/82	1400	1	Push corer	48	Cap core tube; store at 4° C	NB-9 (0-10 cm)-82-2178; NB-9 (38-48 cm)-82-2179
11	7/13/82	1405	1.2	Push corer	36	Composite in Teflon jar; store at 4° C	NB-11 (Composite)-82-2193
11	7/13/82	1410	1.2	Push corer	36	Cap core tube; store at 4° C	NB-11 (0-10 cm)-82-2180; NB-11 (26-36 cm)-82-2181
16	7/13/82	1520	1.7	Push corer	27	Composite in Teflon jar; store at 4° C	NB-16 (Composite)-82-2194
16	7/13/82	1525	1.7	Push corer	43	Cap core tube; store at 4° C	NB-16 (0-10cm)-82-2182; NB-16 (33-43 cm)-82-2183
21	7/13/82	1420	1	Push corer	36	Composite in Teflon jar; store at 4° C	NB-21 (Composite)-82-2195
21	7/13/82	1425	1	Push corer	39	Cap core tube; store at 4° C	NB-21 (0-10cm)-82-2184; NB-21 (29-39 cm)-82-2185
27	7/13/82	1445	1.5	Push corer	38	Composite in Teflon jar; store at 4° C	NB-27 (Composite)-82-2196
27	7/13/82	1450	1.5	Push corer	44	Cap core tube; store at 4° C	NB-27 (0-10 cm)-82-2186; NB-27 (34-44 cm)-82-2187
29	7/13/82	1500	1	Push corer	79	Composite in Teflon jar; store at 4° C	NB-29 (Composite)-82-2197
29	7/13/82	1505	1	Push corer	94	Cap core tube; store at 4° C	NB-29 (0-10 cm)-82-2188; NB-29 (84-94 cm)-82-2189
31	7/13/82	1435	0.6	Push corer	33	Composite in Teflon jar; store at 4° C	NB-31 (Composite)-82-2198
31	7/13/82	1440	0.6	Push corer	31	Cap core tube; store at 4° C	NB-31 (0-10 cm)-82-2190; NB-31 (21-31 cm)-82-2191

[a]All stations were located using navigational markers placed by the Coast Guard, Providence, Rhode Island.

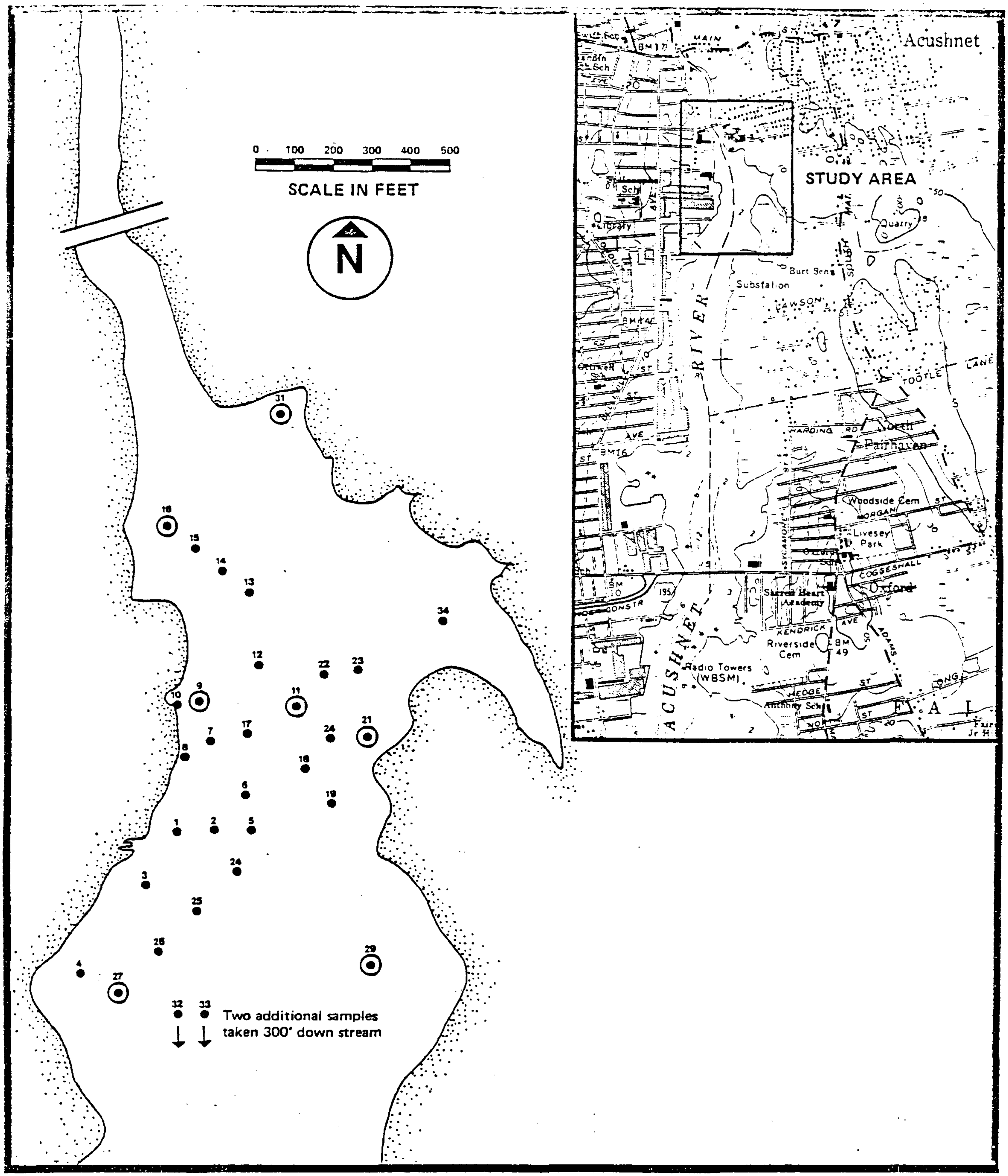


Figure 1. Location of sampling stations in Acushnet River. Stations denoted as ● were occupied by U.S. Coast Guard in April, 1982. Stations denoted as ⊙ were reoccupied by ERCO on July 13, 1982.

Table 2. Results of bulk analysis of sediment samples

ERCO ID IC-82-	Sample Description	Concentration (ppm, dry weight)[a] As	Cd	Cr	Cu	Pb	Hg	Ni	V	Zn	PCB[b]
2178	Station 9 - 0-10 cm	16	20	740	1,700	930	1.3	113	150	3,600	16,700; 38,370
2179	Station 9 - 38-48 cm	13 (13)	6.9 (7.5)	87 (120)	820 (910)	1,000 (1,100)	1.9 (1.8)	23 (23)	33 (32)	3,700 (4,000)	No sample
2180	Station 11 - 0-10 cm	13	34	716	840	560	1.1	82	100	1,800	1,200; 320
2181	Station 11 - 26-36 cm	7.9	0.71	36	110	150	0.09	8.9	28	200	28
2182	Station 16 - 0-10 cm	5.3	0.77	32	60	70	<0.3	12	16	170	190; 20
2183	Station 16 - 33-43 cm	7.4	0.13	25	5.3	3.9	<0.3	7.8	24	28	2
2184	Station 21 - 0-10 cm	23	33	680	580	310	<0.3	97	133	1,000	750; 1,290
2185	Station 21 - 29-39 cm	9.4	0.78	40	27	25	<0.3	11	31	69	150
2186	Station 27 - 0-10 cm	9.3	17	440	730	420	0.57	76	64	1,200	1,980; 66,500
2187	Station 27 - 34-44 cm	9.9	0.68	38	20	420	<0.3	12	38	51	27
2188	Station 29 - 0-10 cm	13	21	830	1,200	130	1.0	123	13	1,400	1,130; 430
2189	Station 29 - 84-94 cm	8.1	0.24	28	6.4	3.7	<0.3	8.7	16	31	9
2190	Station 31 - 0-10 cm	22	15	520	1,800	1,400	24	68	98	4,400	2,900; 1,860
2191	Station 31 - 21-31 cm	7.6 (6.1)	6.0 (4.9)	83 (62)	540 (420)	1,000 (780)	1.6 (1.0)	28 (20)	27 (19)	3,800 (2,700)	2
Concentration Ranges for Classification by Chemical Composition[c]											
Category One		<10	<5	<100	<200	<100	<0.5	<50	<75	<200	<0.5
Category Two		10-20	5-10	100-300	200-400	100-200	0.5-1.5	50-100	75-125	200-400	0.5-1.0
Category Three		>20	>10	>300	>400	>200	>1.5	>100	>125	>400	>1.0

[a]Duplicate analyses shown in parentheses.

[b]Data for PCB concentrations were obtained from the U.S. Coast Guard, Providence, Rhode Island; concentrations in the upper portion of the core were determined at the 0-1" and 5-1/2" to 6-1/2" depths in the core, respectively.

[c]Massachusetts Division of Water Pollution Control (1978).

[d]Combined silt-clay percentage.

Table 2. (CONT.)

ERCO ID IC-82-	Sample Description	Grain size (wt %) Gravel	Sand	Silt	Clay	Water Content (%)	Oil and Grease (wt%)	Classification[c]
2178	Station 9 - 0-10 cm	0	11.70	64.49	23.81	69.2	6.5	3c
2179	Station 9 - 38-48 cm	6.24	26.02	48.16	19.58	59.3	11.1	
2180	Station 11 - 0-10 cm	0	31.52	50.99	17.49	55.6	1.68	3c
2181	Station 11 - 26-36 cm	0	31.12	38.00	30.88	54.9	0.23	
2182	Station 16 - 0-10 cm	1.89	52.30	31.36	14.45	35.0	0.061	3c
2183	Station 16 - 33-43 cm	0	1.73	72.82	25.45	42.0	0.005	
2184	Station 21 - 0-10 cm	0	11.76	69.39	18185	52.0	1.41	3c
2185	Station 21 - 29-39 cm	4.23	54.75	46.29	27.73	55.8	0.03	
2186	Station 27 - 0-10 cm	0	52.12	30.45	17.43	54.7	2.97	3c
2187	Station 27 - 34-44 cm	0	10.66	59.63	29.71	56.9	0.02	
2188	Station 29 - 0-10 cm	1.63	15.76	53.93	28.68	66.7	1.83	3c
2189	Station 29 - 84-94 cm	0	2.04	70.43	27.53	46.3	0.01	
2190	Station 31 - 0-10 cm	1.52	9.46	45.15	43.87	66.9	3.47	3c
2191	Station 31 - 21-31 cm	1.17	36.06	44.23	18.51	58.2	1.24	
Concentration Ranges for Classification by Physical Characteristics[c]								
Type A		--	--	- - <60[d] - -		<40	<0.5	
Type B		--	--	- - 60-90[d] - -		40-600	0.5-1.0	
Type C		--	--	- - >90[d] - -		>60	>1.0	