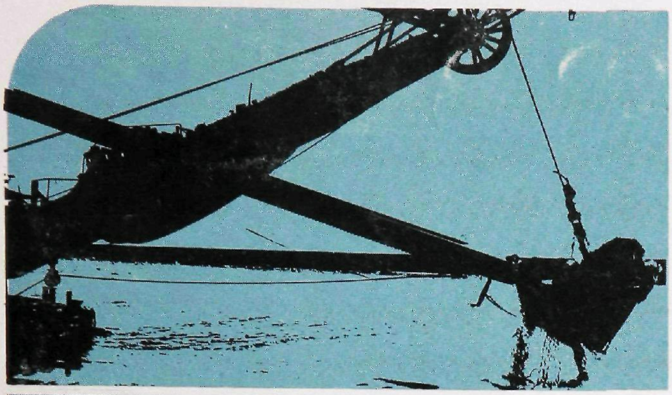

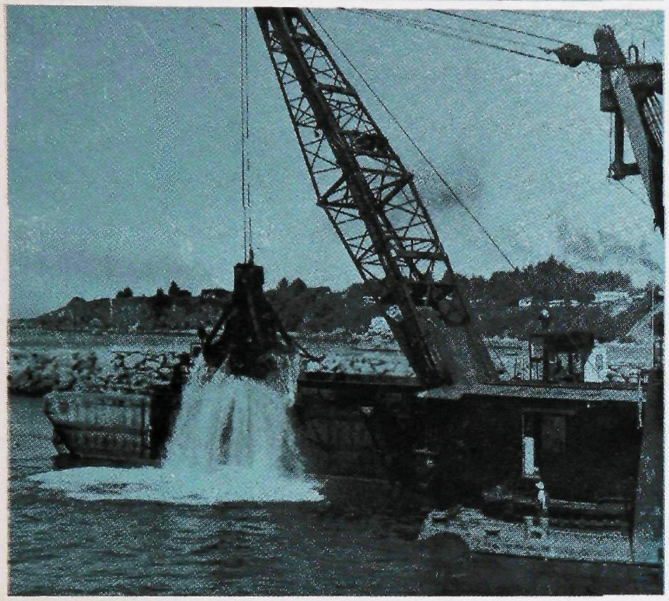

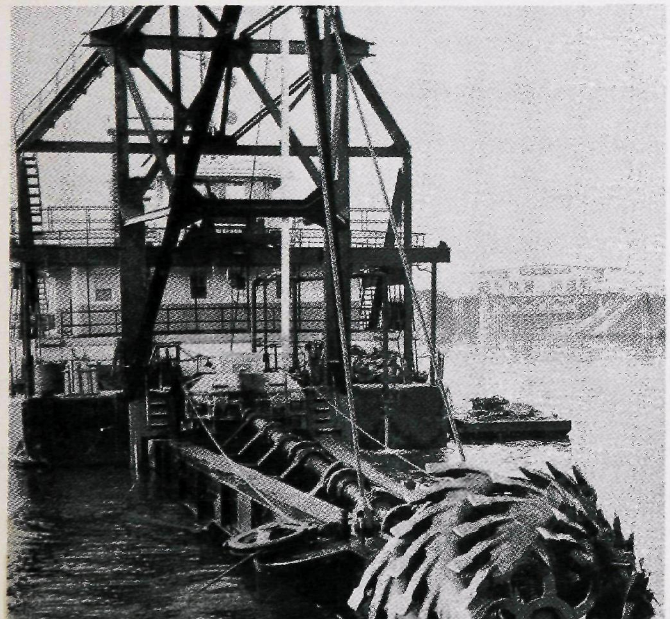

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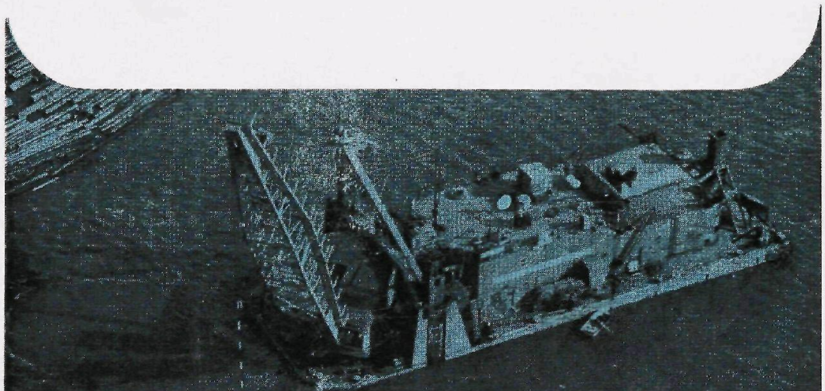
THE EFFECTS OF DREDGING ON WATER QUALITY IN THE NORTHWEST



ENVIRONMENTAL PROTECTION AGENCY
Region X

THE EFFECTS OF DREDGING ON WATER QUALITY IN THE NORTHWEST

Prepared
By
Gary O'Neal
Jack Sceva

Environmental Protection Agency
Office of Water Programs
Region X
Seattle, Washington

July 1971

CONTENTS

CONTENTS (Continued)

FIGURES

TABLES

INTRODUCTION

Problem

Dredging is one of the most extensive construction activities in the rivers and harbors of the Pacific Northwest. Maintenance dredging to insure adequate water depths in channels and dock areas is a continuing job. Development of new port and industrial areas often results in the dredging of fill material from nearby rivers or bays. Innumerable small-scale dredging jobs are carried out in log ponds, boat basins, etc.

Dredging removes and redeposits tremendous quantities of material. In Oregon, alone, estimates of the volume of material dredged range up to 30 million cubic yards per year. The material dredged (spoil) varies from clean river sand to organic sludge. Some of this material is deposited on land. A significant portion of the spoil, however, is dumped back into the water, or immediately adjacent to it. The possible adverse effects of this material on water quality and on the aquatic environment is of serious concern to the public and to the agencies charged with protecting the quality of the environment.

The Rivers and Harbors Act of 1899 specifies that plans for building bridges, dams, pipelines, piers, etc. in or across a navigable waterway must be approved by the Corps of Engineers by issuance of a permit. The same restriction applies for dredging in navigable waters.

In July, 1967, the Secretaries of the Department of the Army and Interior signed a Memorandum of Understanding which established a procedure for the environmental and fisheries agencies to review proposed project plans and comment on possible problems.[1/] This memorandum provides that consideration be given to the pollutional aspects of dredging operations, including spoil disposal, and measures to control adverse environmental effects. As a result of this agreement, all applications for dredging permits are submitted to Federal and State environmental and fisheries agencies for review. Any conditions or changes proposed by EPA or other agencies are considered by the Corps in issuing a permit.

Purpose

Soon after establishment of this review procedure, definite need was recognized for background data on river bottom materials, operating characteristics of dredging equipment, and spoil disposal practices. This study was planned and carried out to provide some of this information to aid in improving the adequacy of the permit review system.

1/ On December 2, 1970, the Presidential Order creating an independent Environmental Protection Agency took effect. The EPA incorporates many Federal programs concerning the environment, including water pollution control. The Federal Water Quality Administration in the Department of Interior was abolished and the water pollution control responsibilities and authorities of the Secretary of the Interior were transferred to the Administrator of EPA.

Authority

Section 5 of the Federal Water Pollution Control Act, as amended, authorizes the conduct of studies relating to the causes, control, and prevention of water pollution.

Objectives

The objectives of this project were to answer the following questions:

1. What are the methods used in dredging and spoil disposal?
2. What are the sediment characteristics in known or potential dredging areas in the Pacific Northwest?
3. What are the effects of dredging and spoil disposal on the aquatic environment?
4. What information should be available to evaluate a proposed dredging project and what should be monitored during a dredging surveillance program?
5. What prevention, control, or abatement measures may be used to reduce or eliminate any adverse environmental effects due to dredging?

Scope

The material and recommendations presented in this report are intended largely as a compilation of background information for use by those engaged in the regulation of dredging operations. Specific recommendations on individual water quality protection requirements are discussed only generally since they will vary considerably depending upon the location and type of dredging. Field activities were conducted in the coastal areas of Oregon and Washington and in the Columbia and Willamette Rivers. Active dredging projects were visited to gain insight into operating procedures. Field sampling was conducted to obtain bottom samples for chemical and physical characterization and to measure the effects of active dredging projects on water quality. Literature on environmental problems associated with dredging was also reviewed.

Acknowledgements

The Environmental Protection Agency received the assistance of many individuals and organizations in the conduct of this study. Those providing direct assistance were:

U.S. Department of the Army, Corps of Engineers
Portland District
Seattle District

Commission of Public Docks, Portland

West Tacoma Newsprint Corporation

Georgia Pacific Corporation

Foss Tug and Barge Company

Willamette Western Corporation

Their cooperation and assistance is gratefully acknowledged.

SUMMARY

Findings and Conclusions

1. The location of spoil disposal areas is often on a job-to-job or "emergency" basis to meet timing requirements desired by commercial and port interest. This is particularly true on privately financed projects. Conflicts in land use and competition for land is making the availability of acceptable sites for land disposal of spoil more and more difficult. Planning for spoil disposal is very limited and local in scope, and little effort has been expended in the development of long-term plans for such disposal.

2. The disturbance of bottom materials by pipeline and grapple dredging and the discharge of spoil materials can significantly reduce dissolved oxygen levels, cover or smother bottom organisms, and release toxic compounds in localized areas.

3. The chief visible effect from pipeline dredging is the turbidity plume created by the spoil disposal operation.

4. Spoil disposal from a pipeline dredge in Bellingham harbor produced very little visible surface effects; however, it created a submarine mudflow that moved outside the boundaries of the prescribed disposal area. Slurry samples from this mudflow had a dissolved oxygen level (DO) of 0.0 milligrams per liter (mg/l) and total solids (TS) of about 75,000 mg/l above background level.

5. The overflow from hopper dredges during dredging produces a turbidity plume that trails the ship.

6. Where observed, the emptying of hopper dredges created little visible effect on water quality.

7. Data in the literature indicate that hopper dredging in areas with polluted sediments can produce significant degradation in water quality; however, the current uses of hopper dredges to maintain harbor entrances and channels in the Pacific Northwest do not create significant adverse water quality effects.

8. Unloading barges with hydraulic jets can produce large turbidity plumes.

9. Spoil disposal by bottom-dump barges creates a less visible effect on water quality than the use of deck type barges.

10. The dredging and disposal of material in a partially confined area behind a dike or breakwater can be an effective method of restricting or retaining the movement of turbid water and insuring the retention of spoil material within a specified area.

11. The design and operation of diked areas for the land disposal of dredge spoil often provides an inadequate detention time for settling of the waste water prior to its discharge into the receiving water.

12. The settling rate of sediments from Pacific Northwest harbors is much more rapid in salt water than in fresh water.

13. The development of a healthy biological population is inhibited when the volatile solids content of bottom sediments is ten percent or higher.

Recommendations

1. All dredge spoils exceeding the limits expressed in Water Quality Office (WQO) guidelines entitled "Criteria for Polluted Dredge Spoil," should be disposed of on land.

> These criteria were adopted by the WQO in December 1970. A copy of the criteria is presented in Appendix A.

2. Zoning should be initiated in rivers, estuaries, bays, and nearshore continental shelf areas so as to define areas where dredging and/or the disposal of dredge spoil is prohibited.

> Zoning is needed to point out the specific areas that are in most need of protection from dredging operations. These include spawning areas and productive estuarine areas. Consideration should also be given to restricting the time of the year that acceptable areas are subject to dredging so as to minimize any threat to fish migrations, spawning cycles of shellfish, etc.

3. Local and regional planning for the development of long-term land disposal sites for dredge spoil should be initiated for all harbor areas in the Pacific Northwest.

> The planning for each area should be undertaken by personnel from State and Federal regulatory and resource agencies, the Corps of Engineers, local governments and planning agencies, port and dock commissions, and dredging contractors. The planning should result in the location and development of a site or sites to be utilized for land disposal of dredge spoil. When material from a given project required land disposal, or if no zoned water disposal area is available, all contractors will be required to use the designated disposal site.

4. Water quality standards criteria for dredge spoil and other guidelines and regulations as appropriate should be incorporated into water quality standards adopted by the States and EPA.

In many States, the existing approved standards make general statements regarding certain essential activities, such as dredging, which may result in temporaty standards violations. These statements indicate that short-term exemptions to the standards may be approved for activities of this type. More specific standards which relate to the characteristics of identified water bodies should be added.

5. Where zoning has determined that dredge spoil disposal into the shallow waters of rivers, bays and estuaries is the least environmentally degrading method, controls should be implemented to minimize the effects on water quality.

Methods of improving shallow water disposal practices include:

a. disposal inside porous diked enclosures;
b. disposal into basins surrounded by underwater dikes;
c. disposal into sumps;
d. location of the disposal point to maximize retention of spoil in a specified area;
e. use of deflecting berms to minimize current flow through a spoil area.

6. Land disposal of spoil in diked areas should be conducted to minimize the possible adverse effects on the aquatic environment.

Suggested improvements in the design of disposal ponds or lagoons include:

a. locating the inlet and outlet to prevent short circuiting;
b. installing adequate discharge controls;
c. providing a capacity and a detention time based on the settling characteristics.

7. Applicants for dredging permits should be required to provide data on the chemical and physical characteristics of the material to be dredged.

The WQO and/or State water pollution control agencies will specify the number of samples, recommended sampling method, and type of analyses. Analyses should be conducted at qualified laboratories using specific test procedures approved by the WQO.

8. The regulatory agencies should monitor selected projects to insure compliance with permit requirements, followed by enforcement action where necessary, and to evaluate the effectiveness of control measures.

> The monitoring would determine compliance with permit requirements. It would also provide additional background information for improving the permit review procedure.

DREDGING EQUIPMENT

Pipeline Dredges

General Description

A hydraulic pipeline dredge, commonly called a pipeline dredge, consists of a large centrifugal pump mounted on a specially designed barge. Bottom materials are brought up to the pump through a large suction pipe and are pumped from the dredge to the disposal area through a pipeline (Figure 1).

The suction pipe is lowered to the bottom on a large hinged ladder that extends forward from the front, or bow, of the barge (Figure 1). The dredging depth is controlled by cables that can raise or lower the ladder. The bottom of the suction pipe is generally equipped with a revolving cutter-head that breaks up the bottom materials so that they can be drawn into the suction pipe. The cutter-head is turned by a shaft that extends down the ladder from a power source on the barge. On some dredges the cutter-head is replaced by a water jet that breaks up or loosens the bottom sediments.

The dredge pump is usually a large-capacity, single-stage centrifugal type that has sufficient clearance to pass anything that can move through the openings in the cutter head and enter the suction pipe. The pipeline, extending from the dredge to the shore or to an area of water disposal, floats on pontoons. To move coarse material through the pipe, a fluid velocity of at least 12 feet per second (fps) is necessary. Consequently, the larger the discharge pipe, the

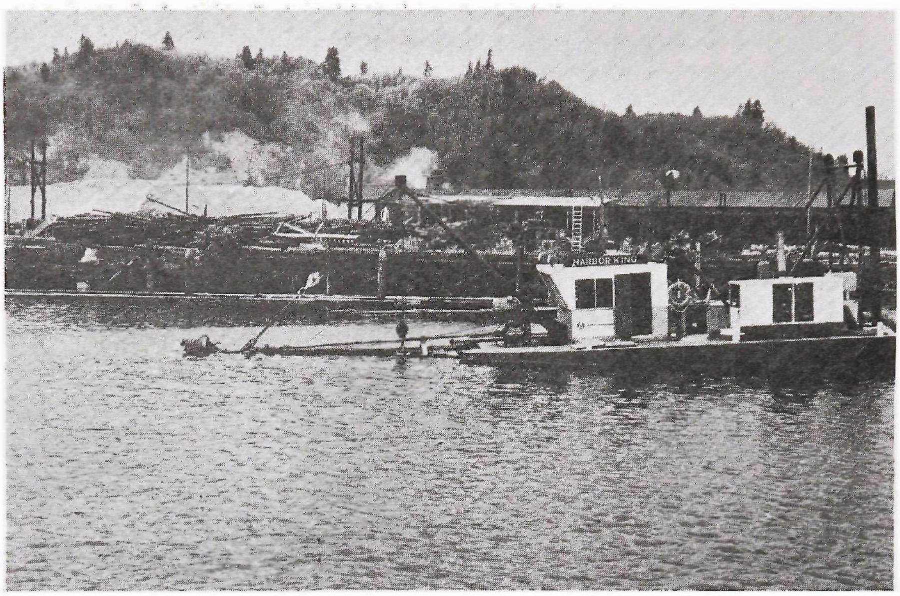


FIGURE 1 Small pipeline dredge. Cutter-head visible at left.

FIGURE 2 Bucket dredges employed in the construction of a yacht basin near Bellingham, Washington.

greater the pump capacity required. The fluid volume moving through a 24-inch pipeline at 12 fps is about 17,000 gallons per minute (gpm) or 37½ cubic feet per second (cfs); with a 28-inch pipeline the volume is 23,000 gpm or 51 cfs. The pipeline can reach several thousand feet from the dredge and can be extended for greater distances by using booster pumps to overcome friction head losses.

The dredge is held in position during dredging by anchors, swing lines, and spuds. Spuds are long heavy timbers that are hung from masts near each corner of the stern of the dredge. They pass through openings in the vessel and can be raised or lowered independently. When dropped alternately, they penetrate into the bottom sediments, and serve as a pivot for the dredge.

Pipeline dredges are measured by the diameter of the suction pipe. They range from small 4-inch sand pumpers to large 36-inch dredges.

Table 1 lists the pipeline dredges operating in the Pacific Northwest.

Mode of Operation

Pipeline dredges are generally towed to the dredging site. The pipeline is assembled and survey markers are established to orient the dredge. When in position, the spuds are dropped, and swing lines and anchors are put out. The anchors are on each side of the dredge; swing lines from these anchors can be tightened or loosened so as to swing the bow or suction end of the dredge back and forth in a small

TABLE 1

PIPELINE DREDGES OPERATING IN
THE PACIFIC NORTHWEST

Vessel Name	Owner	Size (Suction Pipe)
Beaver	Olympic Dredging Co.	8-inch
Grasshopper	Hayden Island Inc.	6-inch
H.W. McCurdy	Western Pacific Dredging Corp	24-inch
Hadco #1	Hadco Credging Co.	10-inch
Harbor King	Lewis Nicholson Inc.	10-inch
Hoquiam	Quigg Brothers-McDonald	12-inch
Husky	Manson-Osberg Co.	12-inch
Karen	Carmac Dredging	8-inch
Luckiamute	Corps of Engineers	14-inch
MacLeod	Hydromar Corp	26-inch
Malamute	Manson-Osberg Co.	16-inch
Melbourne	Quigg Brothers-McDonald	10-inch
Missouri	General Construction Co.	24-inch
Molly B	Hayden Island Inc.	12-inch
Multnomah	Corps of Engineers	24-inch
Natoma	Port of Astoria	20-inch
North Star	Pope & Talbot	10-inch
Olympia	Hydromar Corp.	24-inch
Oregon	Port of Portland	30-inch
Polhemus	Western-Pacific Dredging Corp.	16-inch
Portland	Marine Dredge & Equipment	16-inch
Q.T. No. 1	Quigg Brothers-McDonald	12-inch
Quillayute	Port of Camas-Washougal	10-inch
Riedel	Western-Pacific Dredging Corp.	16-inch
Robert Gray	Port of Grays Harbor	22-inch
Sand Hog	Western-Pacific Dredging Corp.	14-inch
Sandy	Milwaukie Sand and Gravel	10-inch
Sandra Lee	M.P. Materials Corp.	16-inch
Seacrest #1	Evergreen Tug & Barge Co.	4-inch
Skagit Bay	Marine Construction & Dredging	16-inch
Texas	General Construction Co.	10-inch
Unit No 1	Marine Dredge & Equipment	12-inch
Unit No 2	Marine Dredge & Equipment	14-inch
Washington	General Construction Co.	24-inch
Wahkiakum	Corps of Engineers	24-inch

arc. During dredging, only one spud is in place at a time. This permits the dredge to move forward as it swings back and forth by "walking" from one spud to the other.

When ready, the pump and cutter-head are started and the ladder lowered to the desired depth. Bottom sediments (about 15 percent) and water are pumped through the pipeline to the disposal area. Dredging can be an almost continuous operation except for occasional changes in anchor positions and additions of sections to the pipeline, however it is customary practice to break the pipeline or move the dredge from a navigation channel to permit passage of a vessel.

Advantages and Limitations

The chief advantage of a pipeline dredge is the large volume of material that can be moved in a short period of time. Other advantages include the ease of on-shore spoil disposal, the simultaneous dredging and disposal operation, and the flexibility to perform a variety of dredging operations.

The major limitation of pipeline dredges is that spoil areas must be relatively close to the dredging operation. Another problem is the inability to operate in open or rough water areas. The large volume of materials moved in a pipeline dredge causes a high degree of wear on the cutter-head, pump, and pipeline. Pipeline dredges are also troubled by buried logs, large boulders, and man-discarded wastes, such as cables that become entwined on the cutterhead and pump impeller. The anchoring cables and pipeline can present a temporary obstruction to navigation in confined channels.

Hopper Dredges

General Description

A hopper dredge is a self-propelled, ocean-going vessel designed for hydraulic dredging and transportation of the spoil to a dumping area. Their primary function is to maintain harbor entrances and channels where rough water would make other methods of dredging impractical.

On the Pacific Coast, these vessels range up to 350 feet in length and have hopper capacities up to 3,000 cubic yards. Since the Corps of Engineers is responsible for the maintenance of harbor entrances and channels, all hopper dredges operating in the Pacific Northwest are owned by the Corps of Engineers (Table 2).

TABLE 2

HOPPER DREDGES THAT OPERATE IN
THE PACIFIC NORTHWEST

Vessel Name	Owner	Hopper Capacity	Maximum Dredging Depth
Biddle	Corps of Engineers	3,060 cu. yds.	62 feet
Harding	Corps of Engineers	2,682 cu. yds.	62 feet
Davison	Corps of Engineers	720 cu. yds.	45 feet
Pacific	Corps of Engineers	500 cu. yds.	45 feet

Hopper dredges are equipped with one or two large centrifugal pumps similar to those employed on pipeline dredges. The suction pipes are hinged on each side of the ship with the intake, or suction, end towards the stern. They are lowered and raised by hoisting cables.

The suction pipes are equipped with a broad scraper, or shoe, that directs or feeds the bottom materials into the pipes as they are dragged along the bottom. Hopper dredges are not equipped with revolving cutter heads.

Mode of Operation

The dredge moves onto the dredging course, starts the pumps and lowers the suction pipes to the bottom, and continues moving along the course. The shoe on the bottom of the suction pipe scrapes a thin layer of bottom sediments that are drawn up and discharged into the hopper (Figure 3). The sediment tends to settle out in the hopper. The liquid overflow from the hoppers is discharged into the water (Figure 4). When the hoppers are full, the dredge moves to the disposal site. Large valves in the bottom of the hoppers are opened and the material is flushed out the bottom of the ship. Many trips over the same course are often required to attain the desired depth and width of a channel.

Advantages and Limitations

The chief advantage of a hopper dredge is its ability to operate in rough or open waters. It operates without anchors and causes little obstruction to navigation.

Its chief limitation is that it cannot operate continuously as a dredge because much of its time is spent moving between the dredging site and the disposal area.

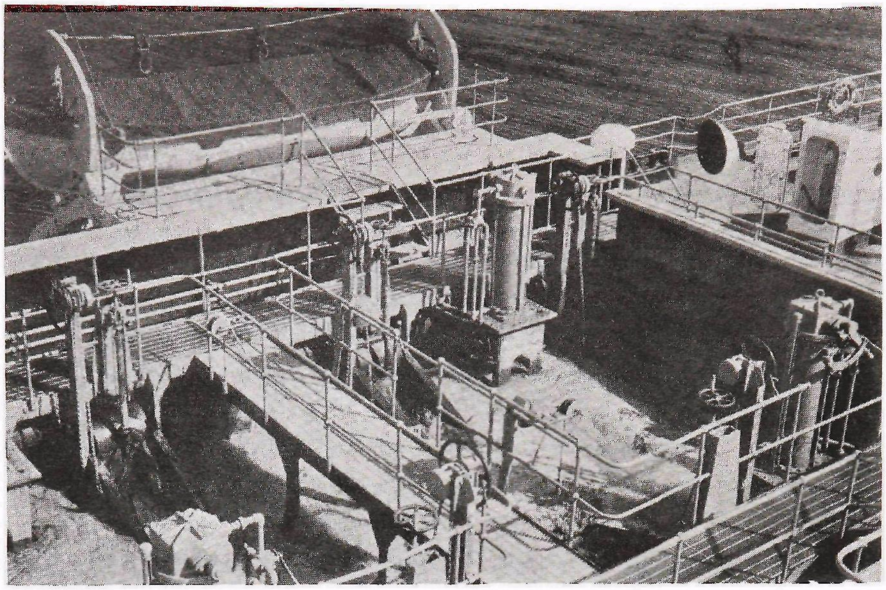


FIGURE 3 Filling of a hopper on the Corps of Engineers' dredge, "Harding."

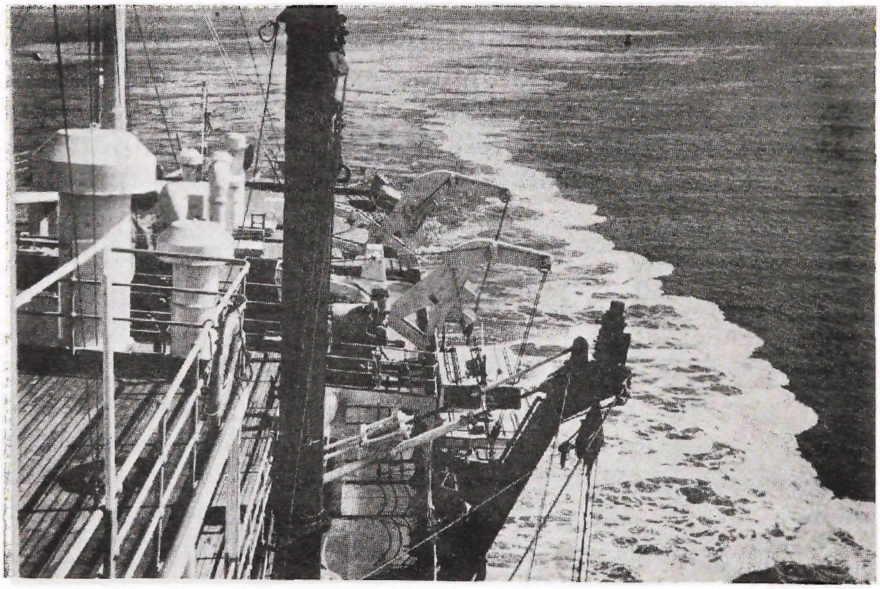


FIGURE 4 Foam and turbid water being discharged during hopper-filling operations.

Use in Pacific Northwest

The Corps of Engineers' hopper dredges have operated in Oregon in the Coquille, Umpqua, and Siuslaw Rivers; Coos Bay and Yaquina Bay; and the Columbia and Lower Willamette Rivers. In Washington they have operated in Grays Harbor and Willapa Harbor. The larger dredges are generally used at the mouth of the Columbia and Rogue Rivers and on the bars at Tillamook, Coos Bay.

Bucket Dredges

General Description

A bucket dredge is a float-mounted hoist that utilizes a bucket or grapple to remove the bottom materials. The essential components include a barge or float, hoisting machinery, a swinging boom, a bucket, and an anchoring system. Some dredges are also equipped with winches to shift barges to facilitate material disposal.

Buckets are of two general types, the clamshell and the orange peel. The clamshell bucket consists of two similar halves that are hinged at the top, similar to its namesake. The bucket can be opened or closed at any time by the dredge operator. The orange-peel bucket is similar to the clamshell, but generally has four sections that open and close. Buckets are designed for hard- or soft-digging materials. Hard-digging buckets are heavier and have a more powerful closing mechanism than soft-digging buckets. This added weight generally necessitates a reduction in bucket capacity.

Since bucket dredges are neither self-contained like the hopper dredges nor equipped with disposal pipelines like the pipeline dredges, they are dependent upon auxillary disposal equipment. This generally consists of barges and a supporting tug to move the barges to the disposal area.

Mode of Operation

The dredge and its support barges are towed to the dredge site and anchored in position. Positioning equipment may include spuds, similar to pipeline dredges, and wires, anchors, and winches to shift the dredge along the cut. Materials are brought to the surface in the bucket and dumped onto a disposal barge, or scow. When full, the barge is pulled to a disposal site. Usually two or more disposal barges are used so that the dredge can operate almost continuously.

Advantages and Limitations

One of the advantages of bucket dredges is their ability to operate in small or confined areas. This makes them useful in maintaining slips in harbor areas. These dredges are not limited to shallow dredging depths and are useful in deep water excavation. Their chief limitation is that they are relatively slow. They also require separate disposal equipment.

Use in Pacific Northwest

Bucket dredges are commonly used in harbor maintenance in the docking areas. In recent years they have had widespread use in the construction of small boat basins (Figures 2 and 6). They are also used in Puget Sound for deepwater excavations for pipelines and cables.

Other Dredge Types

Dipper dredges, similar in operation to power shovels, use a bucket and dipper arm. In general design they resemble a bucket dredge. Their chief advantage is their ability to lift or remove large boulders that cannot be handled by other types of dredges and their ability to excavate harder or more compact material.

Another type of dredge that was used extensively in placer mining prior to World War II is the ladder dredge. This dredge uses a ladder that extends from the barge down to the bottom. An endless chain carries a series of buckets down where they are filled by scraping along the bottom as they revolve around a large sheave at the lower end of the ladder. The dredged materials are usually discharged to a barge or back to the dredge pond by means of conveyor belts. Neither the dipper nor ladder dredges are known to be operating currently in the Pacific Northwest.

Barges

Barges used with bucket dredges in the Pacific Northwest are of two general types. These are the bottom-dump and the deck types. The bottom-dump barge is a hopper barge that is towed from the

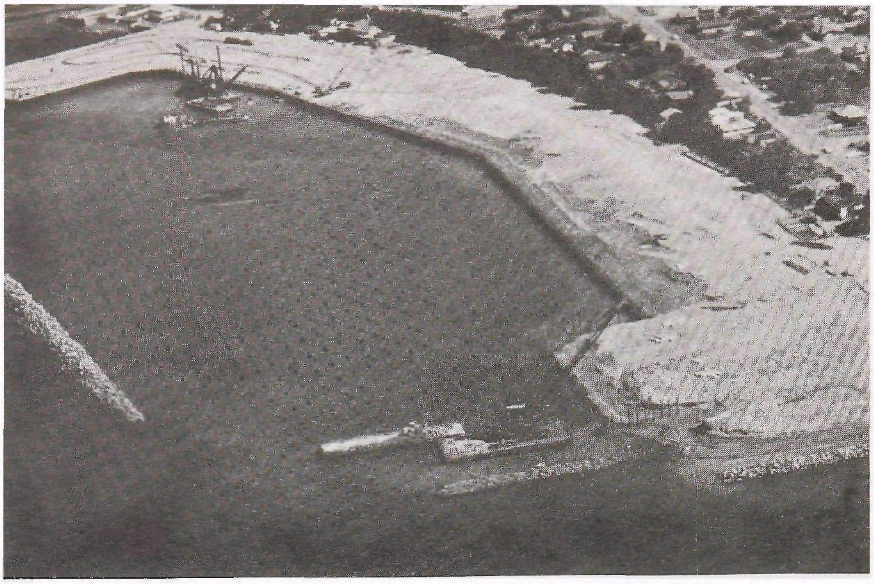


FIGURE 5 Bucket dredges employed in the construction of a yacht basin near Seattle. South entrance is in foreground.

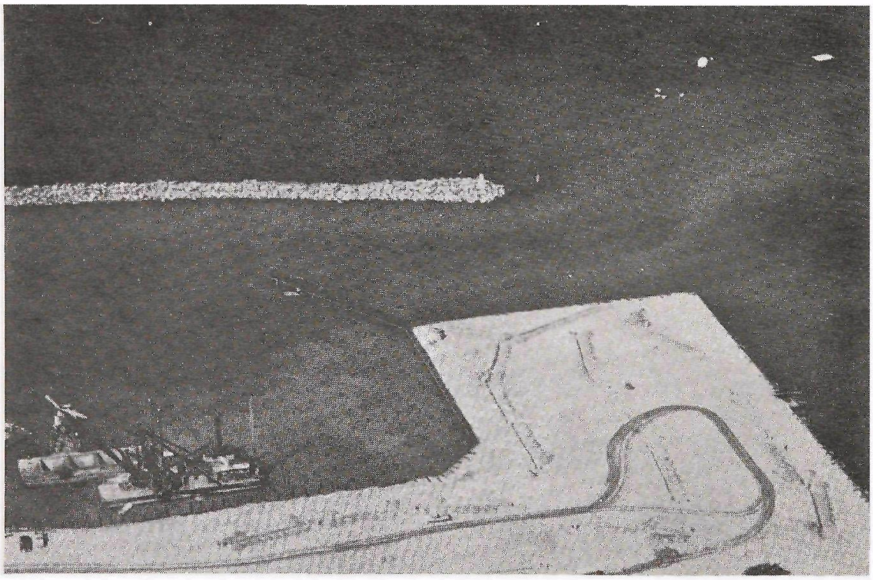


FIGURE 6 North entrance of yacht basin shown in Figure 5. Note most of the turbidity remains inside diked area.

dredging site to the disposal area. Gates or doors in the bottom of the barge are opened and the materials drop out the bottom. The emptying of a bottom-dump barge takes only a few minutes.

Deck type barges have flat decks on which the dredged materials are piled. After they are towed to the disposal area, the materials are pushed over the side with a small bulldozer, or washed overboard with a high pressure water jet. The unloading of a deck type barge takes considerable time when compared to bottom-dump barges.

In other areas of the country there are barges used which have a "pump-ashore" capability. They are used to transport spoil when it is disposed on land at a site beyond the range of a pipeline dredge. At the spoil site the barges are connected to a pipeline on shore, and the spoil is pumped into a suitable land disposal site. At the present no equipment of this type is available in the Pacific Northwest.

SPOIL DISPOSAL PRACTICES

Disposal in Water

Pipeline dredges may discharge spoil on either land or in water. In water disposal, the pipeline generally extends from the dredge to the disposal area. The spoil can be discharged above the water, where it is shot out the end of the pipe, or it can be discharged below the surface by using an elbow attached to the end of the pipe. Some dredging operations are for the purpose of building islands or land areas, and the material is discharged at a particular site until the spoil pile extends above the water surface. Since disposal is contemporaneous with dredging, disposal may extend almost continuously over periods of days, and sometimes weeks, at a particular site.

The greatest visible water quality effect from pipeline dredges occurs at the discharge end of the operation (Figures 7 and 8). A plume of turbid water usually radiates from the end of the pipe. On some river dredging projects, the plume of turbid water extends many miles downstream. There is little or no apparent effect at the dredging end of the operation because most of the material loosened by the cutter-head is sucked into the dredge.

In hopper dredges, the spoil is dropped out the bottom of the dredge in a disposal area. Several thousand yards of material may be dumped in a few minutes. The bottom area covered with spoil depends upon the type of material, the speed of the hopper dredge, and the current and depth of the water in the disposal area. Where

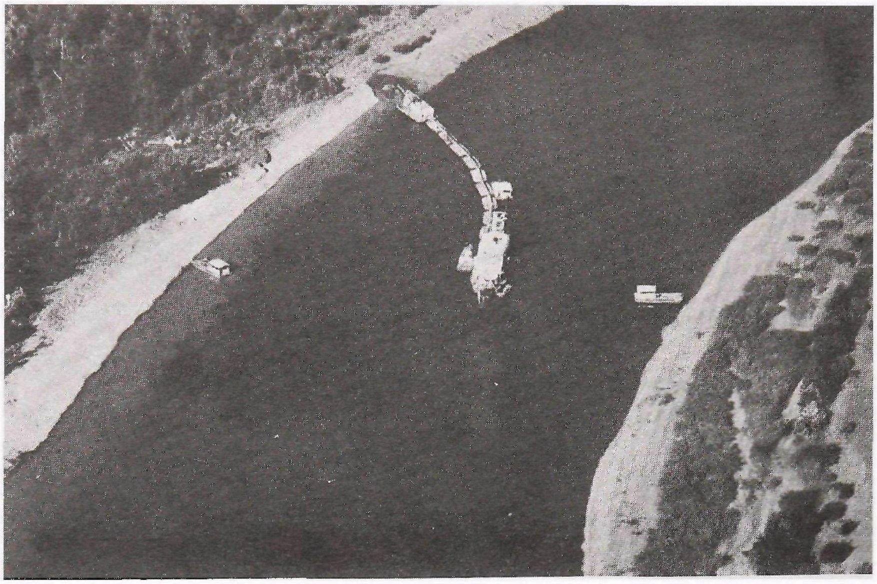


FIGURE 7 Maintenance dredging in the Willamette River. Note turbidity plume extending downstream from the shore-end of the pipeline.

FIGURE 8 Maintenance dredging in the Willamette River.

observed, the emptying of hopper dredges caused little visible effect at the surface.

During dredging, the overflow from the hoppers is discharged from the vessel. This waste water is generally very turbid and results in a plume of turbid water trailing behind the dredge.

The emptying of bottom-dump barges is very similar to the emptying of hopper dredges. The barges are generally stopped or are moving very slowly during disposal, and the spoil is dumped above a very small bottom area. The dispersal of the material depends upon the type of material and the currents and water depth in the disposal area.

The emptying of deck type barges, by pushing the material over the side, requires considerably more time than emptying bottom-dump barges. During this time the barge drifts and material is discharged over a larger area. The emptying of deck type barges with a hydraulic jet also takes considerable time, and creates a large plume of turbid water around the barge (Figures 9 and 10).

Disposal on Land

Except for the hopper dredge, most types of dredges can be used in the land disposal of spoil. With bucket dredges, land disposal is generally employed when the dredging site is immediately adjacent to land, as in canals, small boat basins, or boat slips. Land disposal from offshore areas is generally accomplished with a pipeline dredge.

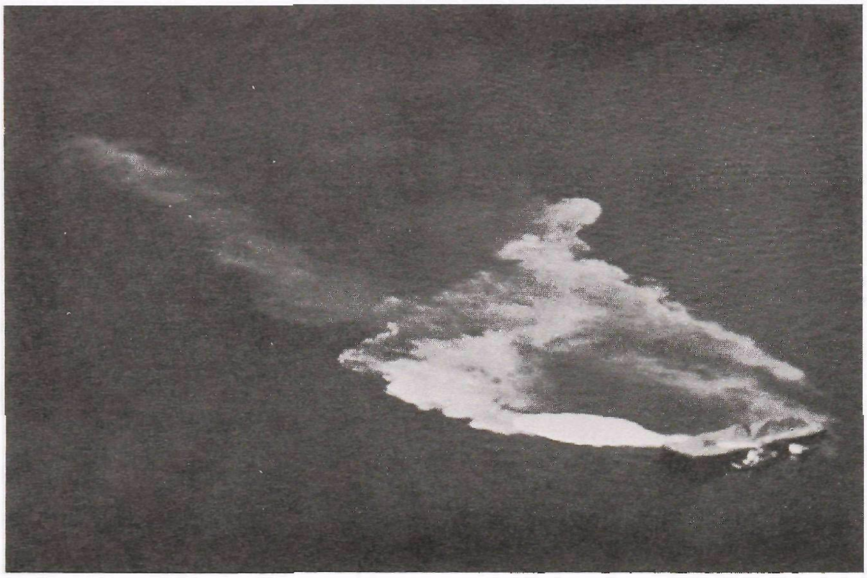


FIGURE 9 Barge being emptied in Puget Sound.

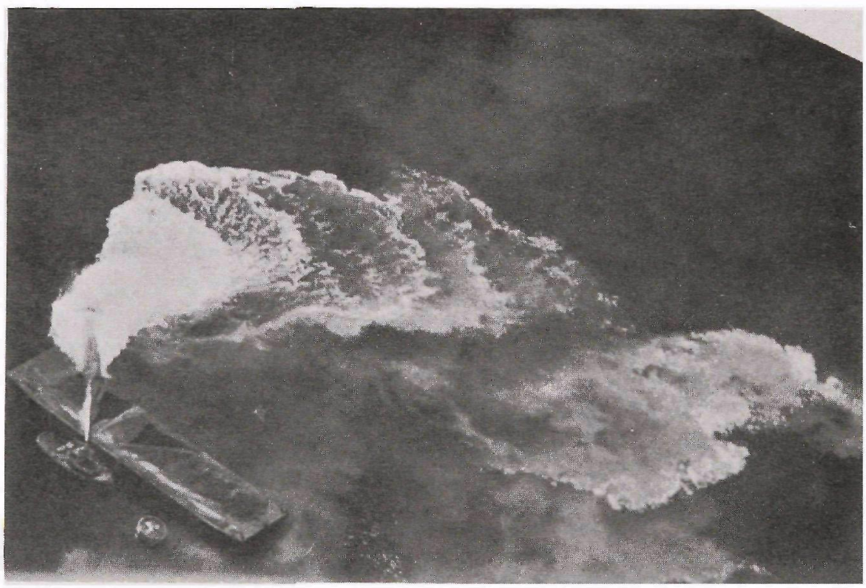


FIGURE 10 Close-up showing hydraulic jet from tug being used to wash material overboard.

Land disposal may be used for building beaches, land filling in low areas, filling for highway, airport and other types of construction, and as a source of construction material. In recent years land-disposal has been utilized for water quality control.

In land disposal from a pipeline dredge, the spoil is generally discharged into a diked area. The initial inflow receives some retention before the waste water overflows or is discharged into the receiving water. As the diked area becomes filled with material, the retention time in the diked area becomes less and the suspended material in the waste water overflow becomes greater. The overflow from land-disposal sites creates plumes of turbid water in the receiving river, lake or estuary. These plumes have been observed extending several miles from the discharge site. The discharge of liquid waste from land disposal operations may extend over a period of days, sometimes weeks, depending upon the size of the project and equipment employed.

Where observed, the dikes around disposal areas were constructed with materials excavated from inside the enclosure (Figure 11). To prevent erosion of the dike from overflow, a large diameter pipe extends through the dike and serves as a spillway (Figure 12). The spillway pipe may extend from the dike all the way to the receiving water. In some land disposal operations the spillway pipe is located on the same side of the pond as the spoil discharge pipe. This results in a shortcircuiting of the waste water from the discharge pipe to the spillway with little retention time in the diked area.

FIGURE 11 Spoil from a pipeline dredge being discharged to a settling pond at Terminal 4, Portland, Oregon.

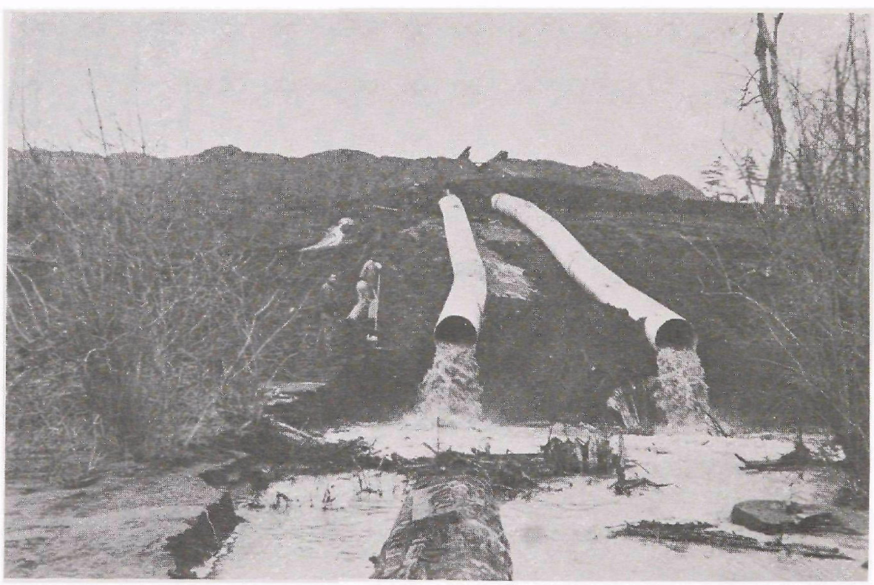


FIGURE 12 Overflow pipes from the settling pond. Return water is still very turbid.

The dredge spoil generally builds an alluvial fan that slopes away from the end of the discharge pipe. If the spoil is chiefly sand, compaction is very rapid and bulldozers can traverse the fill a few minutes after deposition. If the material is predominantly silt or clay, a long time may be required for dewatering and compaction. The utility of land areas filled with fine-grained or highly organic dredge spoil depends upon the compacting characteristics of the fill. Some dredge fills of highly organic materials are essentially unusable for long periods of time.

Double-Handling of Spoil

The methods of spoil dispersal previously discussed involve a single handling of the material. In many instances, this is not possible because of equipment limitations or the lack of spoil sites close to the dredging operation. In these situations, land disposal requires double-handling of the material. For a pipeline dredging operation, double-handling may involve initial dredging followed by water disposal into a pre-dredged sump. The dredge is then moved and the material is redredged and pumped onto a shore disposal site. In a barge disposal operation, the scows may be dumped in shallow water close to shore. A dragline or clamshell on shore, or another barge is used to re-excavate the material and place it on land.

There are many limitations associated with double-handling. It is considerably more expensive and time consuming than single-handling. More important, the potential for adversely affecting water quality is much greater. All double-handling techniques involve temporary deposition of the spoil in the water after initial dredging. The mixing received during the dredging, followed by this water disposal, permits silts, sulfides, dissolved and particulate organic matter, etc. to wash out of the spoil into the receiving water. This may result in high sulfide levels, turbidity, and depressed dissolved oxygen levels.

REVIEW OF LITERATURE ON ENVIRONMENTAL PROBLEMS ASSOCIATED WITH DREDGING

Types of Problems

There are many types of real or potential environmental problems which may be associated with dredging. The turbidity and suspended solids may reduce light penetration and in severe cases produce physiological damage in fish and other organisms. In sediments containing significant quantities of organics, agitation or resuspension may reduce oxygen levels due to the high initial oxygen demand. In addition, the exposure of unoxidized sludges adds to the oxygen demands placed on the waters from other sources. Sulfides and certain other components from industrial deposits may produce conditions toxic to biological life. Water disposal of spoil can create severe biological problems by smothering the benthic community and reducing the available habitat by filling.

There is much in the literature on the problems associated with turbidity, toxicity, low oxygen levels, etc. Very few studies, however, specifically relate these problems to dredging. The results of those studies that do relate to dredging will be discussed below. The results of the many studies of spoil disposal methods and water quality effects conducted in the Great Lakes area by the Water Quality Office, EPA, (formerly the Federal Water Quality Administration) and the Corps of Engineers will also be discussed.

Results of Individual Studies

Several studies have been conducted in Chesapeake Bay on dredging effects. Biological investigations were conducted on a dredging and spoil disposal operation near the upper end of the Bay.(1) The project involved disposal of over one million cubic yards of spoil, predominantly silt and clay, in water depths of 3 to 6 meters. The material was excavated with a pipeline dredge. The effects of spoil disposal operations on phytoplankton, zooplankton, fish eggs and larvae, benthos, and fishes were investigated. No acute effects were noted for organisms in any of the categories, except the benthos. Significant numbers of bottom animals were smothered over a fairly large area.

Another study associated with the same project investigated the distribution of the spoil within and around the disposal site.(2) Bottom profiles showed that, although the spoil was always discharged within the prescribed bounds of the spoil area, the material spread over an area five times larger than the spoil area. The maximum side slope on the spoil pile was 1:100 and the average was 1500:1. Turbidity was increased above background levels over an area of two square miles.

A third study in Chesapeake Bay examined the effects of depositing 1.3 million cubic yards of sand and silt.(3) Data showed the spoil had no significant adverse effect beyond the areas of the bottom actually covered with sediment. In both the dredging and the spoil disposal areas a rapid resettlement of biota occurred.

The distribution of sediment around a spoil area was also examined in Galveston Bay.(4) In this area the accepted spoil disposal technique is to build banks or spoil islands by deposition in shallow waters. In the particular project studied, 9 to 10 inches of sediment were deposited up to 0.5 miles from the discharge. Accumulations at a distance of 1.0 mile were negligible. Deposition was measured by spreading a layer of red gravel at the sampling stations and measuring the accumulation of material on top of this gravel by periodic core samples.

The effect of resuspension of sediments on dissolved oxygen was investigated in Arthur Kill, New Jersey.(5) Arthur Kill is a long, narrow tidal channel which separates Staten Island from mainland New Jersey. The area is heavily industrialized and numerous domestic and industrial wastes are discharged into the Kill. The bottom material generally consists of a black, soft, oily silt which smells of chemicals, oils, and hydrogen sulfide. Periodically, dredging operations are conducted to maintain the navigation channel. The material is excavated with a clam shell bucket and loaded into a hopper barge for ocean disposal. During two routine surveillance surveys when dredging was in progress, discolored water and depressed oxygen levels were observed. These reduced oxygen levels, which were attributed directly to resuspended bottom deposits, varied from 16 to 83 percent below the 6 to 8 milligrams per liter (mg/l) normally encountered during periods of dredging.

Extensive studies have been conducted in the vicinity of the ocean dumping ground off New York.(6) Separate bottom areas have been designated as dumping sites for municipal sewage sludges and industrial wastes, and for the dredge spoils. These dumping grounds have been used for many years. Data showed dissolved oxygen (DO) depressions in the bottom water above the spoil deposits of 2 to 3 mg/1 below bottom DO values in uncontaminated areas. The organic content of the sediments was high, with values to 11.5 percent on a dry weight basis. A large area over and around the dredge spoil area was essentially devoid of benthic organisms. This absence of macrofauna is attributed to three factors: (1) toxic effects or smothering of adults and juveniles; (2) the creation of a physical environment which adversely affects the normal development of eggs and larvae; and (3) avoidance reactions by adults of areas contaminated with spoil. Significant levels of heavy metals and pesticides were found, and the sediments have a distinctive petrochemical odor.

A mass mortality of stickleback and shiner appears to have been caused by the dredging of cedar bark deposits in a western Canada estuary.(7) There was an obvious odor of hydrogen sulfide during dredging and concentrations in the water were greatly in excess of the lethal levels for fish. Significant reductions in dissolved oxygen were also measured around the dredge.

Similar effects on the benthic biota were observed at a dumping ground in Bellingham Bay, Washington.(8) An area in central Bellingham Bay had been used for years as a dumping ground for organic sludges and debris removed from the inner navigation channel and a log ponding area. Bottom samples showed an area approximately one mile in diameter had volatile solids concentrations over 10 percent. Both the total number of organisms and the species diversity were severely reduced in this area.

Recent laboratory investigations have shown the detrimental effects on salmon of polluted sediments from the inner portion of Bellingham Bay.(9) Bioassays were used to determine the effects of various concentrations of sediments on sockeye smolt. Concentrations of inner harbor sediments (27 percent volatile solids) of 10 and 1 percent by volume caused 100 percent mortalities in less than 10 minutes. At the 0.1 percent concentration the fish were initially distressed, but recovered and were alive at the end of the 120-hour test. The studies indicated that hydrogen sulfide toxicity, rather than depressed oxygen levels, was the primary cause of death.

As part of this work, the reduction of dissolved oxygen and the amount of hydrogen sulfide (H_2S) released were determined for various concentrations of sediment. In a stirred mixture containing 2 percent by volume of inner harbor sediment, the dissolved oxygen was reduced from 9 to 5 mg/l in 30 minutes and was 2.5 to 3.0 mg/l after 90 minutes. The initial levels of H_2S for the same conditions were 4.0 to 4.5 mg/l. H_2S concentrations steadily decreased to zero after

60 minutes. Outer harbor sediments, with volatile solids of 5 percent, showed no measurable release of H_2S. There was, however, a significant reduction in dissolved oxygen. Stirred concentrations of 1 percent produced a drop in dissolved oxygen of 2 mg/l after 30 minutes, while concentrations of 5 percent reduced oxygen levels by more than 8 mg/l in 30 minutes.

The investigators concluded:

> The amount of mixing and dispersion which would occur during discharge of sediment from a barge is unknown; however, zones of high hydrogen sulfide, low dissolved oxygen and excessive turbidity may occur. Therefore, elimination of potential hazards to fish through adequate dilution during dumping would be necessary. Bioassay results indicated the concentration of inner harbor sediment should not exceed 0.1 percent. This concentration corresponds to the visible threshold of distress for salmon, exerts an insignificant oxygen demand, and creates a turbid condition which would clarify within approximately one hour. Thus, if requirements for eliminating stress and toxicity caused by hydrogen sulfide could be satisfied by dispersal and dilution, turbidity and oxygen demand would not be significant factors.(9)

Great Lakes Studies

Calumet River Pilot Project

The Calumet River Pilot Project involved land disposal of material from the Calumet River in a 91-acre site.(10) Material was excavated by clam-shell and transported by scows to a temporary disposal site. This temporary spoil area was a basin or "pocket" surrounded by a submerged dike. When sufficient material had accumulated, a hydraulic dredge was used to excavate the basin and pump the spoil to the permanent disposal site.

The following conclusions were based on the FWQA sampling program:

1. The operation of the clamshell produced no significant changes in water quality. The only parameter showing a significant increase was turbidity, which rose from 20 Jackson Turbidity Units (JTU) above the dredge to 39 JTU below.

2. The submerged dike in the temporary spoil area was effective in minimizing water quality degradation. Parameter values immediately outside the dike showed no significant increase above background.

3. The detention time in the final settling basin was insufficient to effectively reduce the turbidity and suspended solids to a degree which would have been possible with improved control of the drainage.

4. The final settling basin was not effective in improving the chemical quality of the drainage from the spoil.

Inland Steel Landfill Lagoon

In this project material was removed from the highly polluted Indiana Harbor Canal and disposed in an 80-acre lagoon along the shore of Lake Michigan.(11) The lagoon was 20 feet deep and was surrounded by an impervious dike. A gap 12 to 14 feet deep and 150 feet wide was provided for the entrance of loaded barges. The Water Quality Office monitored to determine the effectiveness of the sill in retaining contaminants within the lagoon.

Bottom samples taken outside the lagoon showed that little of the heavy organic material escaped. Water quality was noticeably degraded in the gap and a quarter mile from the entrance. The primary effects were increases in suspended solids, oil and grease, ammonia nitrogen, organic nitrogen, and total phosphorus.

During the project the Corps of Engineers attempted to use an air curtain across the gap to contain surface films and polluted materials. The results were inconclusive because the supply of compressed air was inadequate.

Green Bay Pilot Study

In this study 632,000 cubic yards of dredge spoil were used to fill a 380-acre diked basin and to construct a dike enclosing a 230-acre spoil area in the shallow waters of Green Bay Harbor.(12) The project used a temporary spoil site in the bay consisting of a 200 foot by 750 foot sump excavated to a depth of 25 feet below natural bay bottom. Material dredged from the Fox River channel by clamshell was transported by scow to this temporary site. It was then moved by hydraulic dredge to the 380-acre basin. Some channel areas were excavated directly by hydraulic dredge with spoil disposal in the large diked area.

The data collected show that only turbidity and suspended solids were effectively controlled by the 380-acre diked area. Turbidity in the outfall was usually less than 25 JTU. Chemical constituents such as phosphorus, ammonia and organic nitrogen, and chemical oxygen demand increased through the pond. In the temporary sump significant increases above background were noted for conductivity, alkalinity, turbidity, suspended solids, total phosphorus and total nitrogen. Turbidity levels in the channel near the sump went as high as 300 JTU compared to background levels of about 15 JTU.

Cleveland Harbor Dredging Effects Study, Interim Report

This study involves water and bottom sampling in the Cuyhoga River, the Cleveland Inner Harbor, and the dredge dump area located in Lake Erie outside the breakwater.(13) The dump area is well defined by increases in the chemical constituents of bottom sediments. (Volatile solids, chemical oxygen demand, oil, and grease showed definite peaks in the dumping areas with levels similar to those found in the river prior to dredging.) In addition, general background levels in areas surrounding the dumping ground were relatively high. The general background level outside the breakwater for oil and grease was 4 milligrams per kilogram (mg/kg), dry weight. Farther out, in the central areas of the lake, concentrations were less than 1 mg/kg.

Sampling in the dredging area indicated short-term adverse effects on water quality. Dissolved oxygen levels in the vicinity of hopper dredging were lowered as much as 25 percent. In the scow dumping area, depressions up to 35 percent in the oxygen level were measured. Suspended solids also increased substantially. Values for other water quality parameters were not significantly more than the already high background levels in the study area.

Cleveland Diked Dredging Disposal Area Investigation

The study evaluated two methods of spoil disposal into a completely diked basin in Cleveland harbor.(14) The dike, which was constructed from 286,000 tons of limestone and dolomite, was designed to act as a filter. The storage volume inside the dikes was approximately 300,000 cubic yards. A slip was constructed adjacent to the enclosure for use both as an unloading point and as an intermediate storage site for spoil.

The first method of spoil disposal tested was the direct removal of material from scows and transfer into the basin by simultaneous jetting and pumping. Forty-one scow loads totaling 45,500 cubic yards were transferred in this manner. The average pumping time per scow was slightly over two hours. A 5:1 ratio of water to sediment was necessary to permit pumping. In the second method of disposal the spoil was dumped into the adjacent slip by bottom dump scows. A hydraulic dredge completed the transfer into the basin. The volume of material handled in this manner was the same as that for the first method.

Water quality sampling showed no significant effect on the lake from seepage through the dike. The data indicated over 95 percent retention of all constituents measured. In the case of disposal method two, adverse effects were found in the vicinity of the slip. These changes were attributed to discharge from the slip, rather than seepage through the dike. Turbidity plumes up to 1400 feet long were observed. These were thought to be caused by prop wash from the tugboats. Depressed oxygen levels were also measured 300 to 400 feet from the slip after spoil dumping. Chemical constituents in the bottom sediments increased near the mouth of the slip.

A portable water treatment plant was evaluated as a means of further treating the supernatant from the disposal area. Treatment procedures tested included: (1) coagulation, filtration, and disinfection; (2) coagulation only; (3) coagulation and filtration; and (4) filtration only. The combination of coagulation, filtration, and disinfection was most effective in reducing turbidity, chemical oxygen demand, and nutrients.

Pilot Study of Rouge River Dredging

The purpose of this study was to determine the degree and extent of pollution caused by dredging in the Rouge River in Detroit and by spoil disposal on Grassy Island in the Detroit River.(15) A hopper dredge was used and the spoil was pumped ashore into the holding basin. Sediments in the project area were grossly polluted with volatile solids varying from 11 to 35 percent (dry weight basis). Grease and oil concentrations were in the range of 10 to 40 grams per kilogram (g/kg).

The dredging caused significant increases in suspended solids, volatile suspended solids, chemical and biochemical oxygen demand, total phosphorus, and iron in the immediate area of the dredge.

Overflow from the hopper bins caused the most severe pollution. After passage of the dredge the dissolved oxygen levels decreased with time as long as the stirred-up material remained suspended. In the Detroit River near the spoil area, no significant changes in water quality could be attributed to the spoil disposal.

Great Sodus Bay Dredging Study

This project involved hopper dredging in a navigation channel in Great Sodus Bay, with spoil disposal in Lake Ontario.(16) The material excavated was lightly polluted with volatile solids from 0.5 to 3.0 percent. Sampling was conducted in both the dredging and spoil disposal areas. The results indicate no significant change in the benthic biology or the water quality characteristics in the project area. One conclusion was that the load on a spoil area cannot necessarily be determined by sampling in the excavated area. During the hopper dredging work in Great Sodus Bay, much of the turbidity-producing fraction and the dissolved and volatile material was lost through the overflow. It was then dispersed by lake currents, or deposited in areas adjacent to the channel, and did not reach the spoil area.

SEDIMENT CHARACTERISTICS IN NORTHWEST HARBORS

Need for Sediment Characterization

Little information is available on the physical and chemical characteristics of materials dredged in the Pacific Northwest. When a dredging project is proposed, the Federal and State resources agencies review the proposal for possible adverse effects on the environment. Basic to such a review is accurate data on the nature of the material involved in the work. These data are lacking, and evaluations of proposed projects are frequently based on someone's guess as to whether the material is "good" or "bad". There is an immediate need for standard chemical and physical data to assist in these reviews.

To fully utilize any data on bottom materials which may be obtained, a framework of data must be established which shows the characteristics of polluted and unpolluted sediments. In the sections that follow the results of a bottom sampling program designed to establish such a framework are discussed. The types of chemical and physical analyses needed to characterize the pollution potential of the material are emphasized.

Sampling and Analyses

Selection of Sampling Locations

Sixty-five bottom samples were collected from twelve different river and harbor areas. Appendix B contains maps showing the detailed location of the points. The samples were taken either in conjunction with active dredging projects or in areas commonly dredged. Areas were selected to provide a diversity of bottom types. Most samples were taken in salt water areas. Table 3 lists the areas sampled and the number of samples collected.

TABLE 3

BOTTOM SAMPLING AREAS AND NUMBER OF SAMPLES

Area	Number of Samples
Bellingham, Wash.	19
Anacortes, Wash.	2
Everett, Wash.	4
Seattle, Wash	8
Tacoma Harbor, Wash.	6
Chambers Creek Estuary, Wash.	3
Olympia, Wash.	3
Hoquiam-Aberdeen, Wash.	3
Astoria, Oregon	3
Portland, Oregon	6
Yaquina Bay, Oregon	3
Coos Bay, Oregon	5
	65

Sampling Techniques

Ideally, the material collected in potential dredging areas should be representative of the full depth of the proposed excavation. Some type of powered coring device is the best method for obtaining this representative sample. Weighted core samplers will work, but the length of core obtained with equipment suitable for use from a small boat is usually less than two feet. Another problem associated with the smaller coring devices is the small volume of sample obtained. Numerous cores are necessary to provide enough sample for chemical and physical analyses.

The bottom sampler used in this study was a van Veen dredge[2/]. This grab-type sampler takes material from the top 4 to 6 inches of the bottom. This is an obvious disadvantage when the excavation may be many feet deep. Compared to the coring devices available, however, it is simple to use and collects a much larger sample. Since the primary purpose of the sediment sampling program in this study was to obtain a variety of bottom materials, and not to characterize any one area in great detail, the dredge sampler was deemed satisfactory. In the study of a specific area to develop information relative to a proposed dredging project, a minimum approach would require using the dredge sampler to take samples for chemical analyses and a pipe or long tube corer to obtain at least some qualitative information on the deeper deposits.

Types of Analyses

The following chemical analyses were conducted on all the bottom samples: total volatile solids, chemical oxygen demand (COD), kjeldahl nitrogen, total phosphorus, and grease and oil. In addition, initial oxygen demand (IDOD), oxidation-reduction potential, and sulfides were

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2/ Use of product name is for identification only and does not constitute endorsement by the Environmental Protection Agency.

determined for the majority of the samples. The analyses for initial oxygen demand and total sulfides were conducted using the methods specified in the 12th Edition of Standard Methods.(17) All the other analyses mentioned were run according to methods specified by the Environmental Protection Agency.(18)

Forty-nine of the bottom samples were characterized physically by complete grain size analyses. Turbidity settling tests were conducted on 33 of the samples. To conduct these tests, a solution of tap water containing 15 percent by volume of sediment was thoroughly blended in a mechanical mixer and then allowed to settle in a glass cylinder. At various time intervals a small sample was withdrawn and analyzed for turbidity using a Hach Model Turbidimeter.

A detailed presentation of all the data for the sediment samples is too voluminous for inclusion in the body of the report. This data appears in Appendix B. Included in this appendix are maps showing the sampling location and a tabulation of the analytical results for each sample. These data are summarized in the following section.

Summary of Analytical Data

Chemical Data

The chemical data vary widely, both among samples from different geographical areas and among samples from the same general area. The mean and range for the primary chemical analyses are shown in Table 4. These averages give some insight into the characteristics of a "typical" bottom material from Northwest harbor areas. To gain some feeling for the significance of these characteristics, samples having the lowest and highest volatile solids content were compared. For this comparison, samples with a volatile solids content of five percent or less were assumed to be relatively unpolluted. Eleven samples fell within this range. To represent highly polluted conditions, 21 samples with volatile solids content of 10 percent or greater were chosen. The mean and range of the chemical analyses on these two groups of samples are shown in Table 5.

TABLE 4

MEAN AND RANGE OF SELECTED CHEMICAL PARAMETERS DETERMINED FOR BOTTOM SEDIMENTS

Parameter	Units	No. of Analyses	Mean	Range
Total volatile solids	%	63	10.9	0.7-49.3
Chemical oxygen demand	g/kg	59	101	3-395
Kjehldal nitrogen	g/kg	55	1.75	0.01-6.80
Total phosphorus	g/kg	62	0.96	0.24-2.55
Grease and oil	g/kg	43	3.62	0.10-32.1
Initial oxygen demand	g/kg	45	1.47	0.08-5.16
Sulfides[a/]	g/kg	37	1.05	.01-3.77
Oxidation-reduction potential	MV	52	-.07	-0.22 to +0.41

a/ Values are conservative due to preservation method used.

The data show significant differences between the two groups for all the parameters listed. Comparing the data from a proposed dredging site with these extremes and with the average sediment characteristics in Table 4 provides a valuable indication of the degree of contamination in the sediments.

TABLE 5

CHEMICAL COMPARISON OF HIGHLY POLLUTED AND RELATIVELY UNPOLLUTED BOTTOM SAMPLES

		Lightly Polluted		Heavily Polluted	
Parameter	Units	Mean	Range	Mean	Range
Total volatile solids	%	2.9	0.7-5.0	19.6	10.2-49.3
Chemical oxygen demand	g/kg	21	3-48	177	39-395
Kjehldal nitrogen	g/kg	0.55	0.01-1.31	2.64	0.58-6.80
Total phosphorus	g/kg	0.58	0.24-0.95	1.06	0.59-2.55
Grease and oil	g/kg	0.56	0.11-1.31	7.15	1.38-32.1
Initial oxygen demand	g/kg	0.50	0.08-1.24	2.07	0.28-4.65
Oxygen uptake	g/kg				
Sulfides [a]	g/kg	0.14	0.03-0.51	1.70	0.10-3.77
Oxidation-reduction potential	MV	+0.05	(-0.18)-(+0.41)	-.13	+.11 to -.22

a/ Values are conservative due to preservation method used.

Physical Data

As with the chemical data, the results of the grain size analyses showed materials ranging from pure sand to almost completely silt and clay. The average sample had a distribution of 43 percent sand and 57 percent silt and clay (passing a 200-mesh sieve). A frequency distribution of the silt and clay fraction is shown in Table 6, further indicating the variability encountered. The data showed no correlation between levels of organics and the percent silt and clay.

TABLE 6

FREQUENCY DISTRIBUTION OF SILT-CLAY FRACTION

Percent Silt & Clay	No. of Samples	Percent of Samples
0-10	6	14.5
11-20	1	2.5
21-30	2	4.9
31-40	2	4.9
41-50	4	9.8
51-60	4	9.8
61-70	4	9.8
71-80	7	17.0
81-90	8	19.5
91-100	3	7.3

Turbidity settling tests were conducted on several samples using both fresh and salt water. The average turbidity of the samples tested after four hours settling in fresh water was 1240 JTU. After the same period in ocean water the average turbidity was 74 JTU, a reduction of 94 percent over the fresh water value. Figure 13 shows

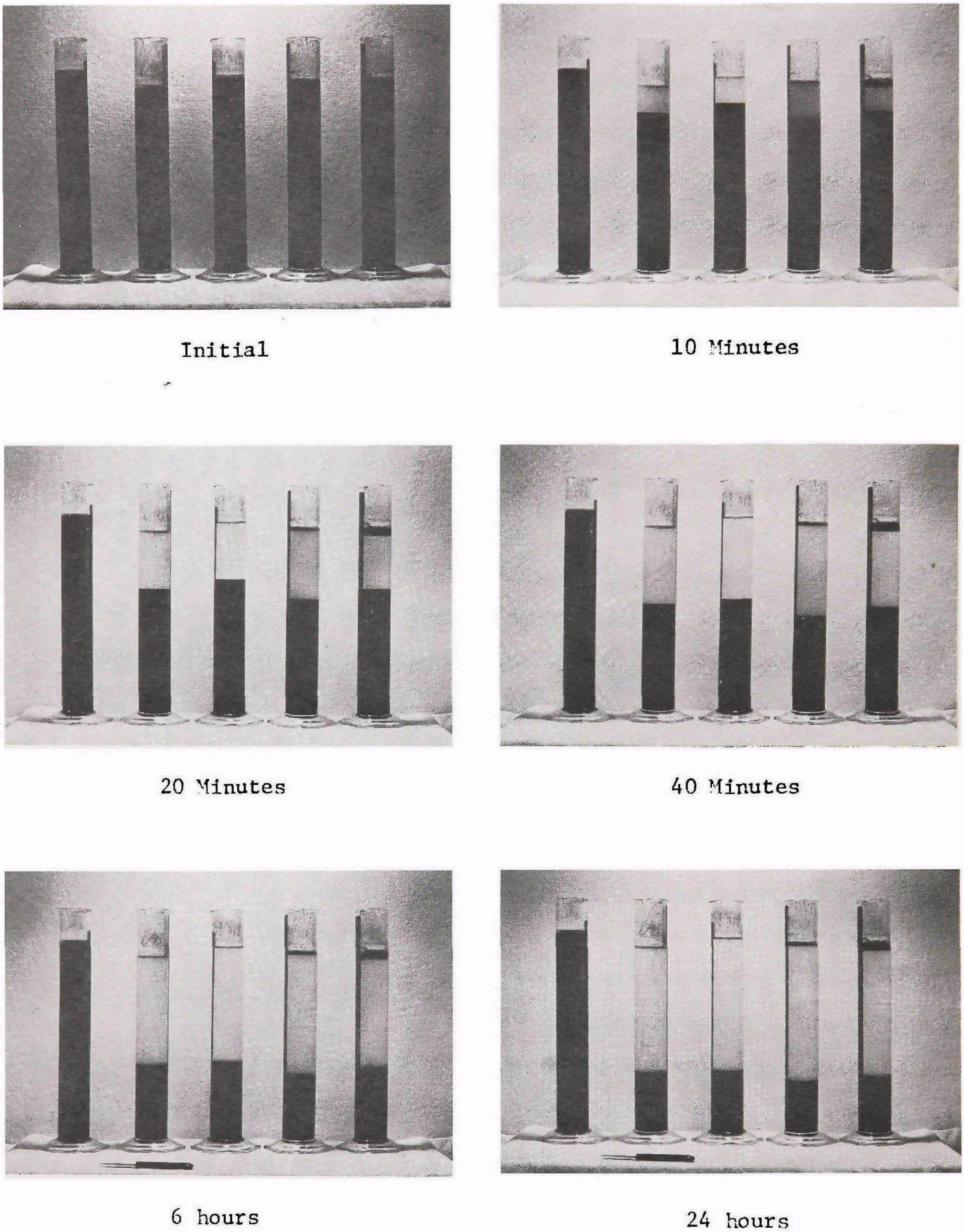

FIGURE 13 Settling test of Portland Harbor sediments in (left to right) freshwater, one-third saltwater, one-half saltwater, two-thirds saltwater, and saltwater.

the effect of the salt water in reducing the turbidity. These tests showed that settlement in salt water is essentially complete after 3-4 hours. Additional tests indicated that as little as 10 percent salt water is effective in greatly increasing the settling rate.

In conducting these and other settling tests, an attempt was made to correlate initial turbidities with the grain-size distribution. In general the finer materials had higher initial turbidities, but the variability was such that no accurate predictions on turbidity levels are possible.

FIELD STUDIES OF NORTHWEST DREDGING PROJECTS

General Approach

The object of these studies was to make field observations of equipment and operating practices for various types of dredging projects. Sampling was conducted in conjunction with these observations, to measure changes in physical and chemical characteristics of the bottom materials and water in the project area. These surveys were usually short. Field efforts were delayed in many cases by frequent dredging stoppages due to equipment breakdowns, blocked lines, etc.

Six dredging projects were sampled. Visual observations, alone, were made at several locations. The results of these surveys and observation trips are discussed below.

Discussion of Specific Studies

Terminal 4, Portland Harbor

This project involved removal of approximately 98,000 cubic yards of material from Pier 4, Terminal 4, with land disposal in an adjacent area. The excavation involved about equal portions of recent infill from the river and new excavation. The disposal area was located on a bench about 20 feet above river level. Excavated material was pumped into a 500-by-600-foot basin surrounded by dikes 10 feet high (Figure 11). The outlet works and the discharge from the dredge were located in adjacent corners of the basin.

Overflow from the basin was discharged through two 36-inch culvert pipes, which carried the overflow partially down the bank and onto a sand bar approximately 150 feet from the edge of the river. From this point, the discharge flowed directly through a shallow channel in the sand bar and into the Willamette River. Figure 12 shows the outlet from the basin.

A sample of bottom material from the dredged area was not collected. Analyses of a sample from an adjacent slip, however, indicated a physical composition of 62 percent silt and clay and a volatile solids content of 7.2 percent.

The evaluation of the land disposal operation emphasized turbidity levels and biochemical oxygen demand (BOD) in the basin discharge and the possible influence on the river. Additional analyses were run, however. The average influent and effluent characteristics of the basin are shown in Table 7.

TABLE 7

AVERAGE CHARACTERISTICS OF BASIN INFLUENT AND EFFLUENT AT TERMINAL 4

Item	Influent	Effluent
Turbidity, JTU	--	1600
Centrifuged BOD, mg/1[a]	3.6	4.8
Centrifuged COD, mg/1[a]	17	32
Total phosphorus, mg/1	74	3.8
Ammonia nitrogen, mg/1	3.2	0.7
Kjehldal nitrogen, mg/1	45	7.5

a/ Sample was centrifuged and supernatant was analyzed.

The discharge was also sampled at the point where it ran into the river. Additional samples were taken in the river 100 yards upstream and downstream from the discharge. Turbidities in the discharge averaged 1200 JTU. Values upstream and downstream averaged 22 JTU at the surface. The only obvious effect was a large amount of very stable foam produced by the turbulence in the discharge. Some of this foam persisted for several hours.

Several points of interest were noted concerning the construction and operation of the disposal site. The dredge was capable of pumping into the basin at a rate of about 18,000 gallons per minute, or 5300 cubic yards per hour. The volume of the basin, for a depth of nine feet, was 100,000 cubic yards. The maximum theoretical detention time is therefore 19 hours. In reality, the detention times were much less. To prevent excessive pressures on the dikes, the water depths above the bottom were maintained at three to six feet. This cut the detention time to ten hours. The placement of the inlet and outlet in adjacent corners of the basin caused short-circuiting and further reduced detention time. Filling the basin lowered the detention time even more, until, near the end of the project, it approached zero.

Turbidity Sampling, Portland Harbor

Two attempts were made to evaluate the effects of hydraulic dredging on turbidity and dissolved oxygen in Portland Harbor. On the first of these surveys the pipeline dredge Oregon was operating in mid-channel opposite Terminal 1. The cutterhead was at a depth of 50 to 60 feet. The current was very slow. Three sampling stations were located across the channel, both upstream and downstream 400 feet from the dredge. Turbidity profiles were determined for each of the stations. The levels above and below the dredge showed no difference, with turbidities falling in the range of 12 to 18 JTU. There were no apparent visual effects.

The spoil from this project was pumped to the east side of the river into an area being filled for future development. The water ran across the fill for several hundred feet before draining into the river. Samples were taken 100 feet downstream from this inflow at points 25 and 175 feet from shore. Two samples were collected at each point: one near the surface and one near the bottom. The two offshore samples and the surface sample from the inshore station had background level turbidities of 12 to 16 JTU. The nearshore bottom sample had a turbidity of 35 JTU, a two- to three-fold increase over background. Obvious discoloration was apparent only in the immediate vicinity of the inflow.

The second survey involved the pipeline dredge McCurdy, which was excavating in the Willamette River opposite Terminal 4. The sampling program was similar to the first survey, except there were two rows of three sampling stations each, downstream from the dredge in addition to the three stations upstream from the dredge. Samples were analyzed for turbidity and dissolved oxygen. There was no significant difference between values upstream and downstream from the dredge.

Depot Slough, Toledo, Oregon

Depot Slough is a narrow channel which winds through the industrial area of Toledo before discharging into the Yaquina River. At the time of the study there was very little inflow at the upper end of the slough. This particular project involved maintenance dredging in the lower end of the slough to a depth of ten feet with a pipeline dredge (Figure 1). Spoil was pumped into a large diked basin. The discharge from this basin flowed through a shallow marshy area, then ran back into the slough near the upper end of the work area.

Two bottom samples were taken in the project area, one near the mouth of the slough and one towards the upper end of the work area. Both indicated high organic levels, with volatile solids content of 13.7 and 21.8 percent. The sample near the mouth was 89 percent silt and clay; the upper sample was 56 percent silt and clay and contained a large quantity of wood chips.

Prior to start of the work water samples were taken to determine background water quality conditions. Turbidity levels were uniform at 6 JTU, and sulfides varied from 1.5 mg/l near the mouth of the slough to 3.4 mg/l at the upper end of the project area. During active dredging, samples were taken near the surface and the bottom of the water column at five locations. These samples were analyzed for turbidity, dissolved oxygen, and sulfides. Turbidity values were slightly higher than during the background survey. Those at the surface averaged 6 JTU and the depth samples averaged 11 JTU.

Dissolved oxygen levels were between 7.3 and 8.5 mg/1. Sulfides were less than 3.0 mg/1. There were no significant differences between samples taken close to the dredge and those taken farther away.

The effluent from the five-acre holding pond contained noticeable turbidity. At the point of discharge into the slough there was an obvious increase in turbidity for 20 to 30 feet offshore and 100 feet downstream. Turbidity levels in the effluent averaged 28 JTU.

Santiam River Dredging Project

This project involved maintenance dredging by the Corps of Engineers at the junction of the Santiam and Willamette Rivers with a pipeline dredge (Figure 8). At the time of the study, the dredge was operating in the Santiam River a few hundred feet upstream from the junction with the Willamette. The dredge was excavating coarse sand and gravel and depositing it for bank protection along the south side of the river.

An aerial reconnaisance of the project site was made to determine the extent of the turbidity effects and to locate possible sampling sites. From the air it was possible to see a narrow thread of turbidity extending downstream from the cutterhead. This was visible until it became mixed with the more turbid water in the Willamette. At the spoil pile, the turbid water hung in an eddy behind the pile and trailed off in a narrow plume against the south bank.

Following the aerial survey the site was visited by boat, and samples were collected for turbidity analyses. General background turbidity in the Santiam River was 2 to 3 JTU. Samples taken 200 feet downstream from the dredge and in the visible turbidity thread still indicated 3 JTU. Due to the fast current and turbulence, this line of turbidity was very patchy, and it was extremely difficult to obtain a representative sample. Maximum values in the plume were probably in the range of 5 to 10 JTU. In the plume below the spoil pile, the samples had turbidities of 15 to 18 JTU 100 feet downstream, decreasing to 6 to 7 JTU 400 feet downstream. The plume was very narrow, less than 40 feet wide in most places.

Chambers Creek Estuary

The Chambers Creek estuary is in Puget Sound a few miles south of Tacoma. The estuary is very small and drains almost completely during low tides. It is used extensively for log-rafting and receives the wastes from the West Tacoma Newsprint mill. Bottom deposits in the estuary are grossly polluted, having organic contents approaching 50 percent.

The dredging project in the estuary involved removal of 20,000 cubic yards of sand, silt, and organic sludges from the log-handling area immediately in front of the mill. The dredging permit specified removal by clamshell and bottom dump barge, with disposal in 480 feet of water at a specified latitude and longitude.

It was originally planned to measure water quality both in the dredging area and during the spoil disposal. Circumstances, however, prevented completion of either of these objectives. Water quality in the estuary was so variable, due to pollution and tidal effects, that significant effects of dredging could not be determined. Adequate water quality sampling during spoil disposal was precluded by sampling equipment malfunctions and the fact that all spoil disposal operations were carried out at night.

Despite the difficulties, a very interesting observation was made concerning the adequacy of the dredging permit system. When the newsprint mill requested a permit for their annual dredging, the State and Federal environmental agencies imposed numerous conditions for approval. The type of equipment, the time of year, and the point of disposal were all specified. These conditions were accepted by the mill and the permit was issued.

During a visit to the project a small clamshell dredge was observed working in a corner of the estuary used as a log pond by a small sawmill. This operation had no connection with the newsprint mill. Scrap lumber, steel strands from log bundles, wood chips, sawdust, etc. were removed and piled on a flat-top barge. Late that night the barge was towed 1000 to 2000 feet off the mouth of the estuary and the material was pushed overboard by a small tractor. The water at this point is approximately 100 feet deep. This was in direct contrast to the deep water site specified in the permit for the West Tacoma Newsprint Mill. A later check with the Corps of Engineers, Seattle District, indicated no permit had been applied for in connection with this work. It is obvious that a proper monitoring program is necessary, not only to assure compliance with permits, but also to apply enforcement procedures as a deterrent to those who would attempt such potentially damaging operations without a permit.

Bellingham Bay Dredging Project

The 1969 maintenance dredging of the Whatcom Waterway at Bellingham, Washington provided an opportunity to monitor the marine disposal of spoil from a pipeline dredge. The dredging area and the disposal areas are shown on Figure 14.

Prior to dredging, a series of bottom samples were collected in and around the disposal area. The location of the sampling stations and the chemical analyses are in Appendix B. The bottom material was principally silt and clay containing 7 to 10 percent volatile solids.

Water samples from near the water surface and near the bottom were collected at six stations in and adjacent to the disposal area. The end of the pipeline was equipped with an elbow and all spoil was discharged beneath the water surface. The sampling results indicated little or no change in the quality of the water near the surface. An aerial inspection of the disposal operation also failed to show any apparent effect from the dredging operation.

The analysis of the near-bottom water showed a marked increase in water turbidity within a large area around the end of the pipeline. A sample collected at Station 4, 1000 feet southwest of the discharge point, showed the bottom to be overlain with more than 2 feet of a thin slurry of spoil. The dissolved oxygen in this slurry was zero.

The discovery of this mud slurry at Station 4 resulted in the collection of water quality samples at five additional stations. The locations of these stations, designated P1 through P5, are shown on Figure 14. The data from the turbidity profiles taken at these points are presented in Table 8. Samples from Station P1, about 400 feet from the end of the pipeline, showed the bottom to be covered with about 7 feet of slurry. At Station P2 there was about 4 feet of slurry, and at Station P3, 1400 feet from the end of the pipeline, there was over a foot of slurry.

The mud slurry outside the disposal area indicates that fine-grained materials discharged from a pipeline dredge can build up beneath the disposal site and move laterally as a submarine mudflow. At this particular site, the slurry moved down a gentle bottom slope. It undoubtedly smothered all the bottom organisms that it covered.

Detailed monitoring of the marine disposal of fine-grained materials from a pipeline dredge would provide useful information as to the rate of movement and the thickness and extent of man-created submarine mudflows. It is possible that some of these mudflows could travel long distances from the disposal site. If true, information on the bottom gradients would be important in evaluating spoil disposal areas for pipeline dredges.

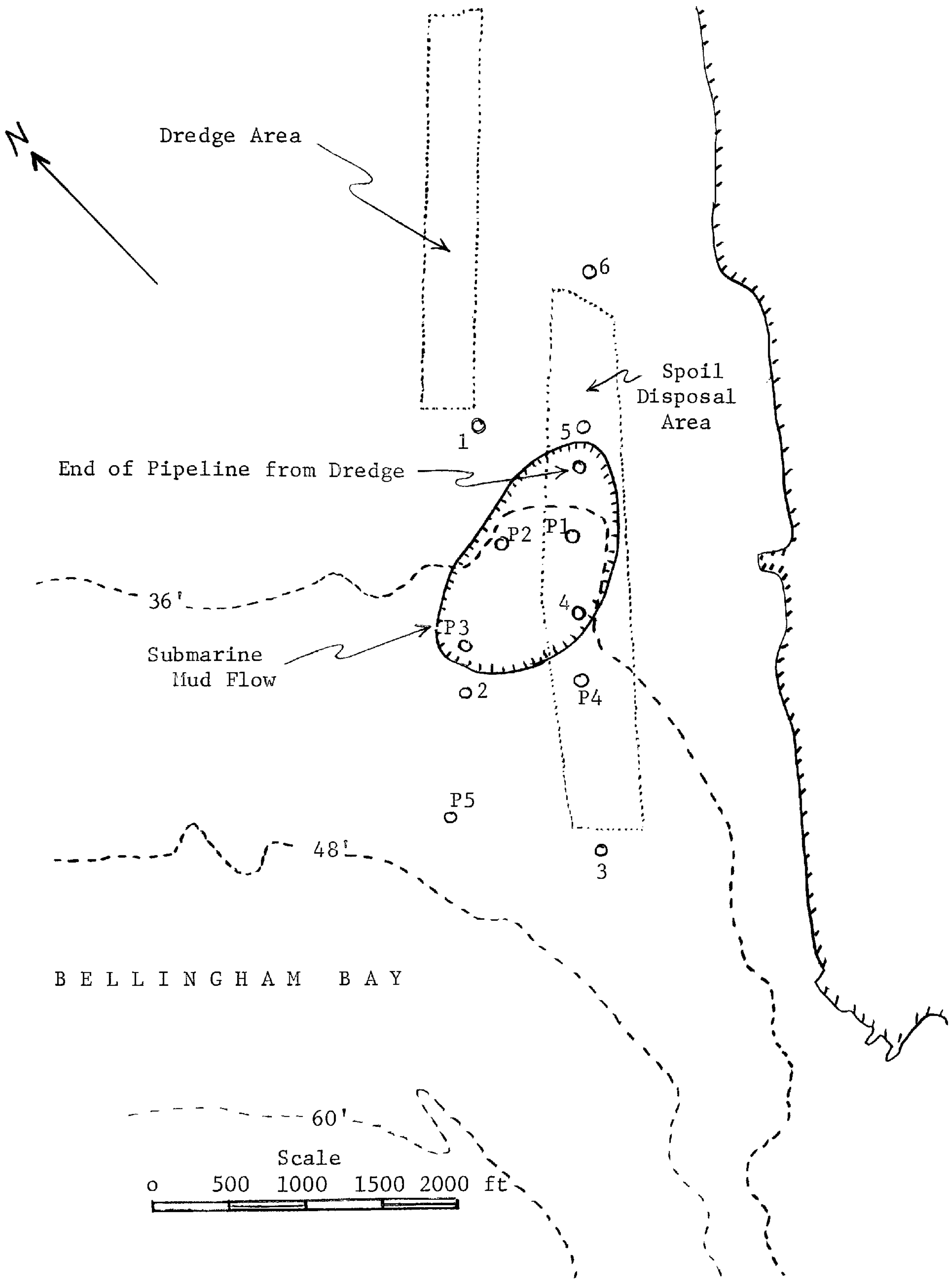

Figure 14: Dredging Operation Monitored at Bellingham Bay, Washington

TABLE 8

TURBIDITY PROFILES - BELLINGHAM BAY

Station	Depth (feet)	Turbidity (JTU)
P1	1	5
	6	5
	12	4
	18	4
	24	4
	30	68
	36	Opaque Slurry
	40	Opaque Slurry
	43	Bottom
P2	1	8
	6	9
	12	5
	18	4
	24	3
	30	10
	36	50
	42	Opaque Slurry
	45	Opaque Slurry
	46	Bottom
P3	24	4
	30	6
	36	12
	42	3
	46	Opaque Slurry
	47	Bottom
P4	24	6
	30	4
	36	30
	42	29
	44	75
	45	Bottom
P5	24	4
	30	2
	36	8
	42	16
	48	18
	49	Bottom

DISCUSSION

This report has covered a spectrum of techniques and problems associated with dredging activities. In this section, the major conclusions and recommendations to be derived from this information will be discussed under four separate headings: water quality problems, dredging techniques, the permit system, and planning.

Water Quality Problems

There is not a great mass of information available which shows that dredging activities generally create gross water quality degradation, fish kills, etc. There is sufficient data from numerous areas, however, to show the existence of, and the potential for, significant water quality degradation and adverse effects on the benthic biological community. In the Pacific Northwest, the release of turbidity producing and toxic materials, and the depression of dissolved oxygen levels are the primary water quality problems associated with dredging. The studies on the Rouge River (15) and in Arthur Kill (5) dramatically illustrate that the dredging of polluted sediments can reduce dissolved oxygen. The laboratory studies by Servizi (9) on Bellingham Bay muds and the Water Quality Office sediment data show a strong potential for high oxygen demands and significant concentrations of sulfides. Turbidity created by dredging and spoil disposal has been shown to persist and spread considerable distances, particularly in rivers.

As evidenced by some of the Great Lakes investigations and by studies of active dredging projects in the Northwest, it is sometimes difficult to measure and evaluate water quality degradation in the field. This is primarily due to the limitations of sampling techniques and the nature of dredging operations. The fact that it cannot be readily measured does not mean, however, that significant, short-term water quality degradation is not occurring. Sufficient evidence is available to warrant a close examination of all dredging activities, particularly those involving spoil disposal in water.

The effects of dredging and spoil disposal on the benthic environment are more apparent and more documentation is available. The smothering effects are obvious. Numerous studies indicate that areas covered by spoil are generally repopulated rather rapidly. This is only true, however, for relatively unpolluted sediments. Studies in Puget Sound, the New York Bight, etc. have shown that marine areas receiving polluted dredge spoil are either devoid of biological life or maintain only a limited population. In addition, the organic materials present can create a serious depletion of oxygen resources in the overlying water. During spoil disposal, submarine mudflows, as observed in Bellingham Bay and Chesepeake Bay, can spread the effects of polluted spoil over a much wider area than the designated disposal area. Significant degradation of the benthic community occurs when the volatile solids content of sediments approaches or exceeds 10 percent. To avoid this degradation and the associated water quality problems, material having a volatile content of 10 percent or greater should, in all cases, be disposed of on land in properly constructed and operated sites.

Dredging Techniques

As a rule, there are only minimal water quality problems associated with dredging alone. Most of the problems arise in the spoil disposal operations. These problems can be caused by several factors, such as "bad" material, improper location of spoil site, and poor timing. It is in the conduct of spoil disposal operations that major improvements are possible relative to water quality.

Until recently, spoil disposal in the Northwest was conducted on the basis of convenience. When the material was not used for land fill, the closest spoil disposal site was generally chosen, and the easiest method was used. In many instances these were not compatible with water quality control. In the last two to three years the situation has changed. State and Federal resource and regulatory agencies have imposed controls and restrictions on many dredging operations. Dredging contractors, port authorities, and others have followed the imposed conditions, but only because they are official requirements. Those planning and conducting dredging operations have shown little inclination to adopt new equipment or methodology to minimize water quality problems. Project proposals are still received which utilize the same spoil disposal methods and locations which have been used for years and which reflect little awareness of improved techniques.

There are many techniques which can be used to minimize water quality problems associated with dredging. Selection of the spoil site is very important and will be discussed in a following section. Basic chemical and physical analyses can be conducted to characterize the material to be dredged. Pump-ashore barges can provide land disposal for polluted materials excavated by clamshell dredge. Barge disposal of spoil can be conducted so as to adequately disperse the spoil and minimize smothering and water quality degradation. Underwater dikes can keep spoil within a specified area. Basins used for land disposal can be constructed and operated to minimize short-circuiting and to maximize solids retention. When double handling is required, diked areas can be utilized rather than the middle of a river or estuary.

These and other techniques are necessary to control pollution from dredging. The regulatory agencies are responsible for instituting controls and enforcing them. Those in charge of planning dredging operations also have a responsibility, to take the initiative in utilizing pollution-control techniques in projects under their control.

Dredging Permit System

Any dredging activity proposed for a navigable water must receive a permit from the Corps of Engineers. The Corps refers the applications to the regulatory fisheries and resource agencies for comments on environmental effects. The requirements and restrictions imposed for environmental protection are incorporated directly into the final permit.

This system works reasonably well as far as it goes. The problems arise in the areas of surveillance and enforcement. Many smaller, but potentially damaging, projects are conducted with no permit at all. Those projects with permits are rarely inspected to check conformance with permit requirements. There is a definite need for an expanded education program to promote the use of the permit system and for increased enforcement to insure compliance with the permit as issued.

The Corps of Engineers generally has only limited staff in each district responsible for handling all the navigation permits. There are no resources to cover any significant project monitoring. This should be changed. The State and Federal water pollution control agencies, and the Corps should provide the resources to insure that the requirement for a permit and the environmental protection measures in permits are enforced and that water quality standards are not violated. The Corps should provide similar controls and inspections for their own dredging activities.

Planning

There is an acute need for long-term planning of spoil disposal for all navigable waters in the Northwest. Presently, only a minimum amount of planning is done in the major harbor areas. Most harbors have plans for industrial developments and other activites which will require fill material. No one, however, is planning for the long-term spoil disposal problem, either for the material presently used in fills or for the material unsuitable for construction fills. Each proposed dredging project presents a "crisis" situation, and the spoil disposal does not follow a development plan which considers environmental effects.

To overcome this lack of planning, a coordinating group should be formed for dredging activities in each major geographic area (i.e. Lower Columbia River, Coos Bay). Contractors, port development agencies, the Corps of Engineers, resource agencies, regulatory agencies, and local planning groups, should be among the interests represented. This group should determine the long-term spoil disposal requirements and develop a plan to adequately handle this material, using techniques to minimize environmental effects. One goal of such a plan would be to develop properly designed and operated disposal sites available to all contractors.

Deep water disposal also requires planning. Large volumes of dredged material are not polluted and do not have the physical characteristics suitable for fill material. This material can be discharged back into the water if proper conditions of timing, location, and method are met. Ideally, the material should be dispersed to minimize turbidity, and to ensure the absence of dissolved oxygen depression and toxicity. Planning is necessary to define the locations and seasonal timing restriction. The resource and regulatory agencies should take the lead in formulating these plans, based on the requirements of the biological systems which exist in the areas. The result should be a specific statement documenting suitable disposal sites and the precise conditions under which each site may be used.

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APPENDIX A

CRITERIA FOR DETERMINING ACCEPTABILITY OF DREDGED SPOIL DISPOSAL TO THE NATION'S WATERS

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CRITERIA FOR DETERMINING ACCEPTABILITY OF DREDGED SPOIL DISPOSAL TO THE NATION'S WATERS

Use of Criteria

These criteria were developed as guidelines for FWQA evaluation of proposals and applications to dredge sediments from fresh and saline waters.

Criteria

The decision whether to oppose plans for disposal of dredged spoil in U.S. waters must be made on a case-by-case basis after considering all appropriate factors; including the following:

(a) Volume of dredged material.
(b) Existing and potential quality and use of the water in the disposal area.
(c) Other conditions at the disposal site such as depth and currents.
(d) Time of year of disposal (in relation to fish migration and spawning, etc.).
(e) Method of disposal and alternatives.
(f) Physical, chemical, and biological characteristics of the dredged material.
(g) Likely recurrence and total number of disposal requests in a receiving water area.
(h) Predicted long and short term effects on receiving water quality.

When concentrations, in sediments, of one or more of the following pollution parameters exceed the limits expressed below, the sediment will be considered polluted in all cases and, therefore, unacceptable for open water disposal.

Sediments in Fresh and Marine Waters	Conc. % (dry wt. basis)
*Volatile Solids	6.0
Chemical Oxygen Demand (C.O.D.)	5.0
Total Kjeldahl Nitrogen	0.10
Oil-Grease	0.15
Mercury	0.001
Lead	0.005
Zinc	0.005

*When analyzing sediments dredged from marine waters, the following correlation between volatile solids and C.O.D. should be made:

$$T.V.S.\ \%\ (dry) = 1.32 + 0.98(C.O.D.\%)$$

If the results show a significant deviation from this equation, additional samples should be analyzed to insure reliable measurements.

The volatile solids and C.O.D. analyses should be made first. If the maximum limits are exceeded the sample can be characterized as polluted and the additional parameters would not have to be investigated.

Dredged sediment having concentrations of constituents less than the limits stated above will not be automatically considered acceptable for disposal. A judgment must be made on a case-by-case basis after considering the factors listed in (a) through (h) above.

In addition to the analyses required to determine compliance with the stated numerical criteria, the following additional tests are recommended where appropriate and pertinent:

Total Phosphorus
Total Organic Carbon (T.O.C.)
Immediate Oxygen Demand (I.O.D.)
Settleability
Sulfides
Trace Metals (iron, cadmium, copper. chromium, arsenic, & nickel)
Pesticides
Bioassay

The first four analyses would be considered desirable in almost all instances. They may be added to the mandatory list when sufficient experience with their interpretation is gained. For example, as experiences is gained, the T.O.C. test may prove to be a valid substitute for the volatile solids and C.O.D. analyses. Tests for trace metals and pesticides should be made where significant concentrations of these materials are expected from known waste discharges.

All analyses and techniques for sample collection, preservation and preparation shall be in accord with a current FWQA analytical manual on sediments.

APPENDIX B

CHARACTERISTICS OF SEDIMENT SAMPLES FROM HARBOR AREAS IN OREGON AND WASHINGTON

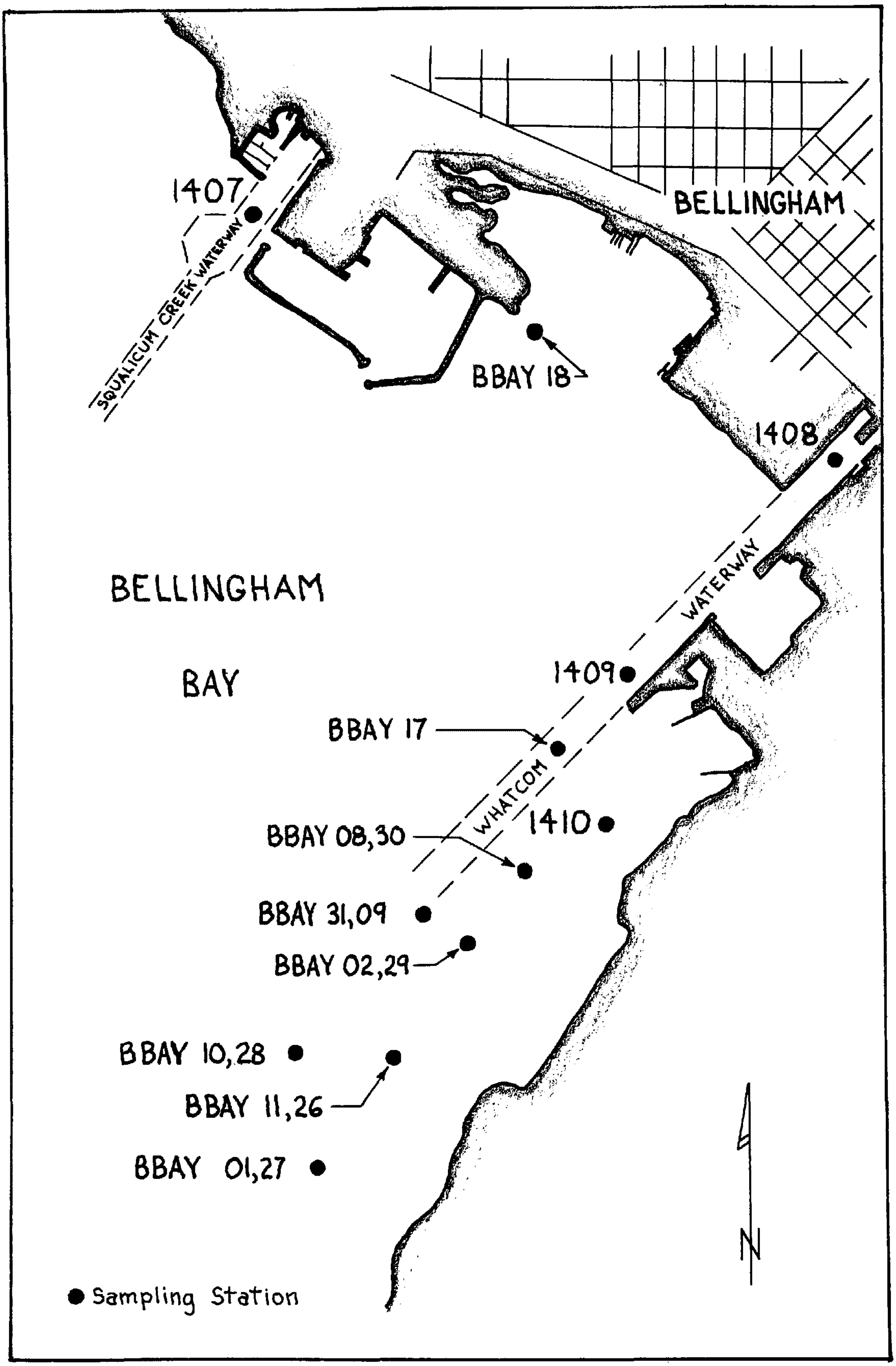

FIGURE B-1. Bellingham Bay, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. 1407

Station Location: Bellingham Bay in Squalicum Creek Waterway

Latitude: 48° 45' 30" N   Longitude: 122° 30' 40" W

Sampling Date: 1-14-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	4
Sand	5%		
Silt and Clay (-200 mesh)	95%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.4
Chemical Oxygen Demand (COD)	g/kg	80
Initial Oxygen Demand (IDOD)	g/kg	1.17
Oxidation-Reduction Potential	millivolts	-0.16
Sulfides	g/kg	
Total Phosphorus	g/kg	1.16
Kjeldahl Nitrogen	g/kg	1.83
Grease and Oil	g/kg	2.43

BOTTOM SAMPLE NO. 1408

Station Location: Bellingham Bay, Washington. Inner Reach of Whatcom Creek Waterway

Latitude: 48° 45' 05" N Longitude: 122° 44' 12" W

Sampling Date: 1-15-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___% Coefficient of Uniformity ______

Sand ___%

Silt and Clay (-200 mesh) ___%

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	49.3
Chemical Oxygen Demand (COD)	g/kg	390
Initial Oxygen Demand (IDOD)	g/kg	1.04
Oxidation-Reduction Potential	millivolts	-0.16
Sulfides	g/kg	
Total Phosphorus	g/kg	1.08
Kjeldahl Nitrogen	g/kg	6.80
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	32.1

BOTTOM SAMPLE NO. 1409

Station Location: Bellingham Bay, Washington. Outer Reach of Whatcom Creek Waterway

Latitude: 48° 44' 42" N Longitude: 122° 29' 41" W

Sampling Date: 1-15-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	4
Sand	14%		
Silt and Clay)_200 mesh)	86%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	10.5
Chemical Oxygen Demand (COD)	g/kg	125
Initial Oxygen Demand (IDOD)	g/kg	0.34
Oxidation-Reduction Potential	millivolts	-0.12
Sulfides	g/kg	
Total Phosphorus	g/kg	0.93
Kjeldahl Nitrogen	g/kg	2.65
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	2.82

BOTTOM SAMPLE NO. 1410

Station Location: Bellingham Bay, Washington. Adjacent to abandoned railroad ferry dock.

Latitude: 48^{o} 44' 32" N   Longitude: 122^{o} 29' 41" W

Sampling date: 1-15-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	8
Sand	26%		
Silt and Clay (_200 mesh)	74%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	6.6
Chemical Oxygen Demand (COD)	g/kg	87
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.08
Sulfides	g/kg	
Total Phosphorus	g/kg	0.69
Kjeldahl Nitrogen	g/kg	1.35
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.76

BOTTOM SAMPLE NO. BBAY-01

Station Location: Bellingham Bay near South Bellingham

Latitude: 48° 43' 53" N

Longitude: 122° 30' 28" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (_200 mesh) ____%

Coefficient of Uniformity ________

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	8.7
Chemical Oxygen Demand (COD)	g/kg	54
Initial Oxygen Demand (IDOD)	g/kg	1.17
Oxidation-Reduction Potential	millivolts	-0.07
Sulfides	g/kg	0.61
Total Phosphorus	g/kg	1.16
Kjeldahl Nitrogen	g/kg	1.81
Grease and Oil	g/kg	1.00

BOTTOM SAMPLE NO. BBAY-02

Station Location: Bellingham Bay northeast of Starr Rock Buoy

Latitude: 48^{o} 44' 16" N   Longitude: 122^{o} 30' 05" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%   Coefficient of Uniformity ________

Sand ___%

Silt and Clay (_200 mesh) ___%

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.7
Chemical Oxygen Demand (COD)	g/kg	64
Initial Oxygen Demand (IDOD)	g/kg	1.50
Oxidation-Reduction Potential	millivolts	-0.11
Sulfides	g/kg	0.93
Total Phosphorus	g/kg	1.13
Kjeldahl Nitrogen	g/kg	1.82
Grease and Oil	g/kg	1.51

BOTTOM SAMPLE NO. BBAY-08

Station Location: Bellingham Bay near Outer Reach

Latitude: 48° 44' 23" N

Longitude: 122° 29' 57" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	___%	Coefficient of Uniformity	______
Sand	___%		
Silt and Clay (-200 mesh)	___%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.7
Chemical Oxygen Demand (COD)	g/kg	
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	2.24
Total Phosphorus	g/kg	1.15
Kjeldahl Nitrogen	g/kg	1.94
Grease and Oil	g/kg	3.55

BOTTOM SAMPLE NO. BBAY-09

Station Location: Bellingham Bay near South end of Outer Reach

Latitude: 48° 44' 18" N   Longitude: 122° 30' 12" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.5
Chemical Oxygen Demand (COD)	g/kg	
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	1.42
Total Phosphorus	g/kg	1.11
Kjeldahl Nitrogen	g/kg	1.68
Grease and Oil	g/kg	2.12

BOTTOM SAMPLE NO. BBAY-10

Station Location: Bellingham Bay near South Bellingham

Latitude: 48° 44' 06" N   Longitude: 122° 30' 33" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.8
Chemical Oxygen Demand (COD)	g/kg	
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	0.16
Total Phosphorus	g/kg	1.27
Kjeldahl Nitrogen	g/kg	1.64
Grease and Oil	g/kg	0.49

BOTTOM SAMPLE NO. BBAY-11

Station Location: Bellingham Bay near Starr Rock Buoy

Latitude: 48° 44' 04" N   Longitude: 122° 30' 17" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.7
Chemical Oxygen Demand (COD)	g/kg	
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	0.40
Total Phosphorus	g/kg	1.15
Kjeldahl Nitrogen	g/kg	1.74
Grease and Oil	g/kg	1.00

BOTTOM SAMPLE NO. BBAY-17

Station Location: Bellingham Bay in Outer Reach

Latitude: 48° 44' 33" N   Longitude: 122° 29' 56" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.5
Chemical Oxygen Demand (COD)	g/kg	78
Initial Oxygen Demand (IDOD)	g/kg	3.66
Oxidation-Reduction Potential	millivolts	-0.15
Sulfides	g/kg	2.23
Total Phosphorus	g/kg	0.97
Kjeldahl Nitrogen	g/kg	1.94
Grease and Oil	g/kg	6.56

BOTTOM SAMPLE NO. BBAY-18

Station Location: Bellingham Bay near boat basin.

Latitude: 48° 45' 17" N   Longitude: 122° 29' 54" W

Sampling Date: 6-18-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	___%	Coefficient of Uniformity	____
Sand	___%		
Silt and Clay (-200 mesh)	___%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	3.2
Chemical Oxygen Demand (COD)	g/kg	15
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	+0.32
Sulfides	g/kg	0.03
Total Phosphorus	g/kg	0.64
Kjeldahl Nitrogen	g/kg	0.59
Grease and Oil	g/kg	0.14

BOTTOM SAMPLE NO. BBAY-26

Station Location: Bellingham Bay near Starr Rock Buoy

Latitude: 48° 44' 04" N   Longitude: 122° 30' 17" W

Sampling Date: 7-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	___%	Coefficient of Uniformity	______
Sand	___%		
Silt and Clay (-200 mesh)	___%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.5
Chemical Oxygen Demand (COD)	g/kg	91
Initial Oxygen Demand (IDOD)	g/kg	1.62
Oxidation-Reduction Potential	millivolts	+0.01
Sulfides	g/kg	0.35
Total Phosphorus	g/kg	0.82
Kjeldahl Nitrogen	g/kg	
Grease and Oil	g/kg	1.11

BOTTOM SAMPLE NO. BBAY-27

Station Location: Bellingham Harbor near South Bellingham

Latitude: 48° 43' 53" N

Longitude: 122° 30' 28" W

Sampling Date: 7-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	8.1
Chemical Oxygen Demand (COD)	g/kg	86
Initial Oxygen Demand (IDOD)	g/kg	1.62
Oxidation-Reduction Potential	millivolts	-0.09
Sulfides	g/kg	0.04
Total Phosphorus	g/kg	1.10
Kjeldahl Nitrogen	g/kg	
Grease and Oil	g/kg	1.46

BOTTOM SAMPLE NO. BBAY-28

Station Location: Bellingham Harbor near South Bellingham

Latitude: 48° 44' 06" N

Longitude: 122° 30' 33" W

Sampling Date: 7-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	8.8
Chemical Oxygen Demand (COD)	g/kg	67
Initial Oxygen Demand (IDOD)	g/kg	1.55
Oxidation-Reduction Potential	millivolts	-0.09
Sulfides	g/kg	0.35
Total Phosphorus	g/kg	1.08
Kjeldahl Nitrogen	g/kg	
Grease and Oil	g/kg	1.48

BOTTOM SAMPLE NO. BBAY-29

Station Location: Bellingham Bay northeast of Starr Rock Buoy

Latitude: 48° 44' 16" N   Longitude: 122° 30' 05" W

Sampling Date: 7-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.1
Chemical Oxygen Demand (COD)	g/kg	79
Initial Oxygen Demand (IDOD)	g/kg	1.83
Oxidation-Reduction Potential	millivolts	+0.01
Sulfides	g/kg	<0.01
Total Phosphorus	g/kg	1.00
Kjeldahl Nitrogen	g/kg	
Grease and Oil	g/kg	1.49

BOTTOM SAMPLE NO. BBAY-30

Station Location: Bellingham Bay near Outer Reach.

Latitude: 48° 44' 23" N

Longitude: 122° 29' 57" W

Sampling Date: 7-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	8.7
Chemical Oxygen Demand (COD)	g/kg	105
Initial Oxygen Demand (IDOD)	g/kg	2.86
Oxidation-Reduction Potential	millivolts	-0.16
Sulfides	g/kg	0.91
Total Phosphorus	g/kg	1.07
Kjeldahl Nitrogen	g/kg	
Grease and Oil	g/kg	4.33

BOTTOM SAMPLE NO. BBAY-31

Station Location: Bellingham Bay near South End of Outer REach

Latitude: 48° 44' 18" N   Longitude: 122° 30' 12" W

Sampling Date: 7-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	8.2
Chemical Oxygen Demand (COD)	g/kg	63
Initial Oxygen Demand (IDOD)	g/kg	2.66
Oxidation-Reduction Potential	millivolts	-0.13
Sulfides	g/kg	2.56
Total Phosphorus	g/kg	0.95
Kjeldahl Nitrogen	g/kg	
Grease and Oil	g/kg	4.02

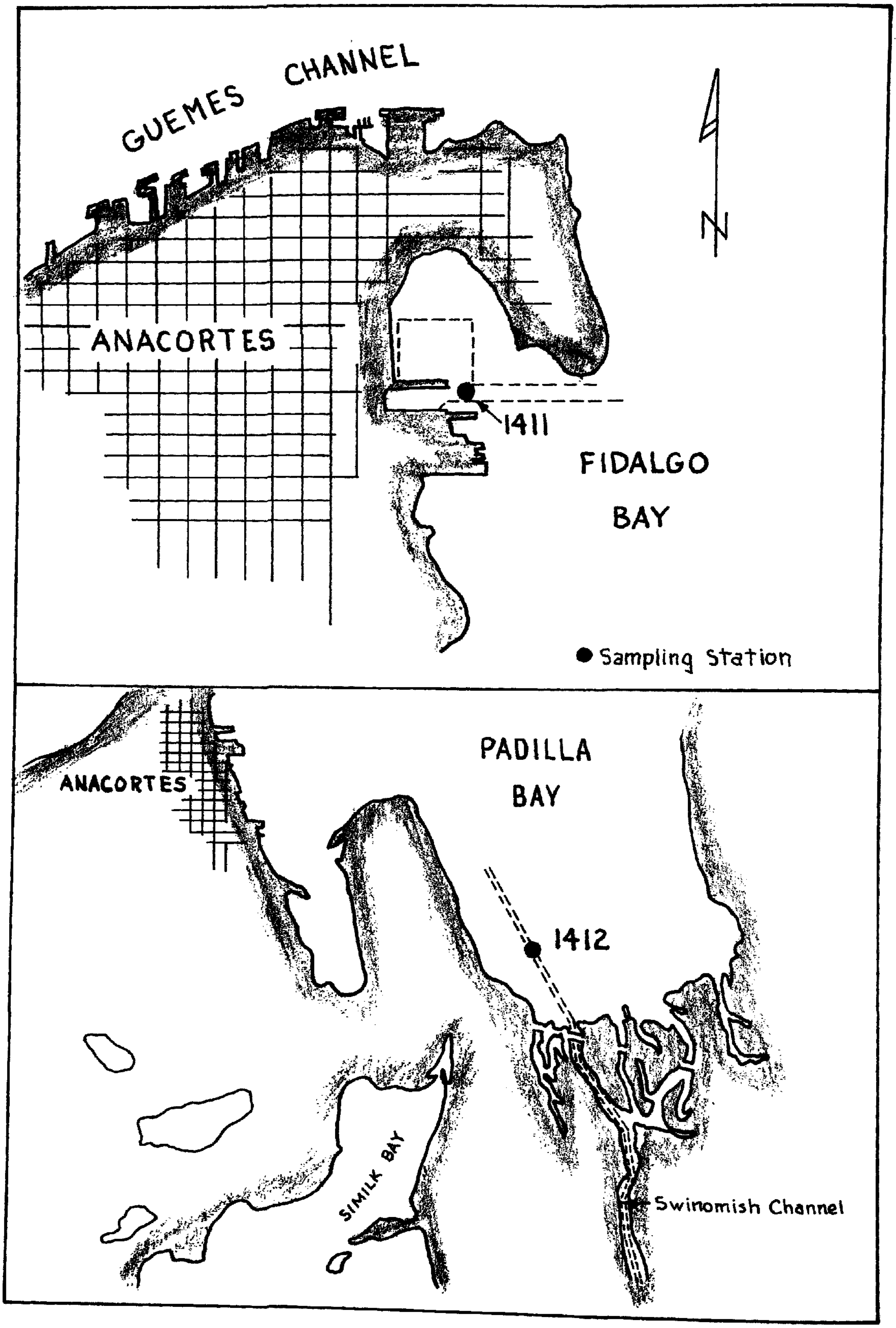

FIGURE B-2. Anacortes Area, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. 1411

Station Location: Anacortes Harbor, Washington. Harbor entrance at breakwater.

Latitude: 48° 30' 43" N

Longitude: 122° 31' 48" W

Sampling Date: 1-15-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	5
Sand	24%		
Silt and Clay (-200 mesh)	76%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	19.2
Chemical Oxygen Demand (COD)	g/kg	214
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.17
Sulfides	g/kg	
Total Phosphorus	g/kg	0.84
Kjeldahl Nitrogen	g/kg	3.83
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	3.84

BOTTOM SAMPLE NO. 1412

Station Location: Anacortes Area, Washington. Swinomish Channel at Piling, N. 18.

Latitude: 48° 28' 42" N

Longitude: 122° 31' 48" W

Sampling Date: 1-15-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	2
Sand	96%		
Silt and Clay (-200 mesh)	4%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	1.7
Chemical Oxygen Demand (COD)	g/kg	7
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	
Total Phosphorus	g/kg	0.41
Kjeldahl Nitrogen	g/kg	0.16
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.10

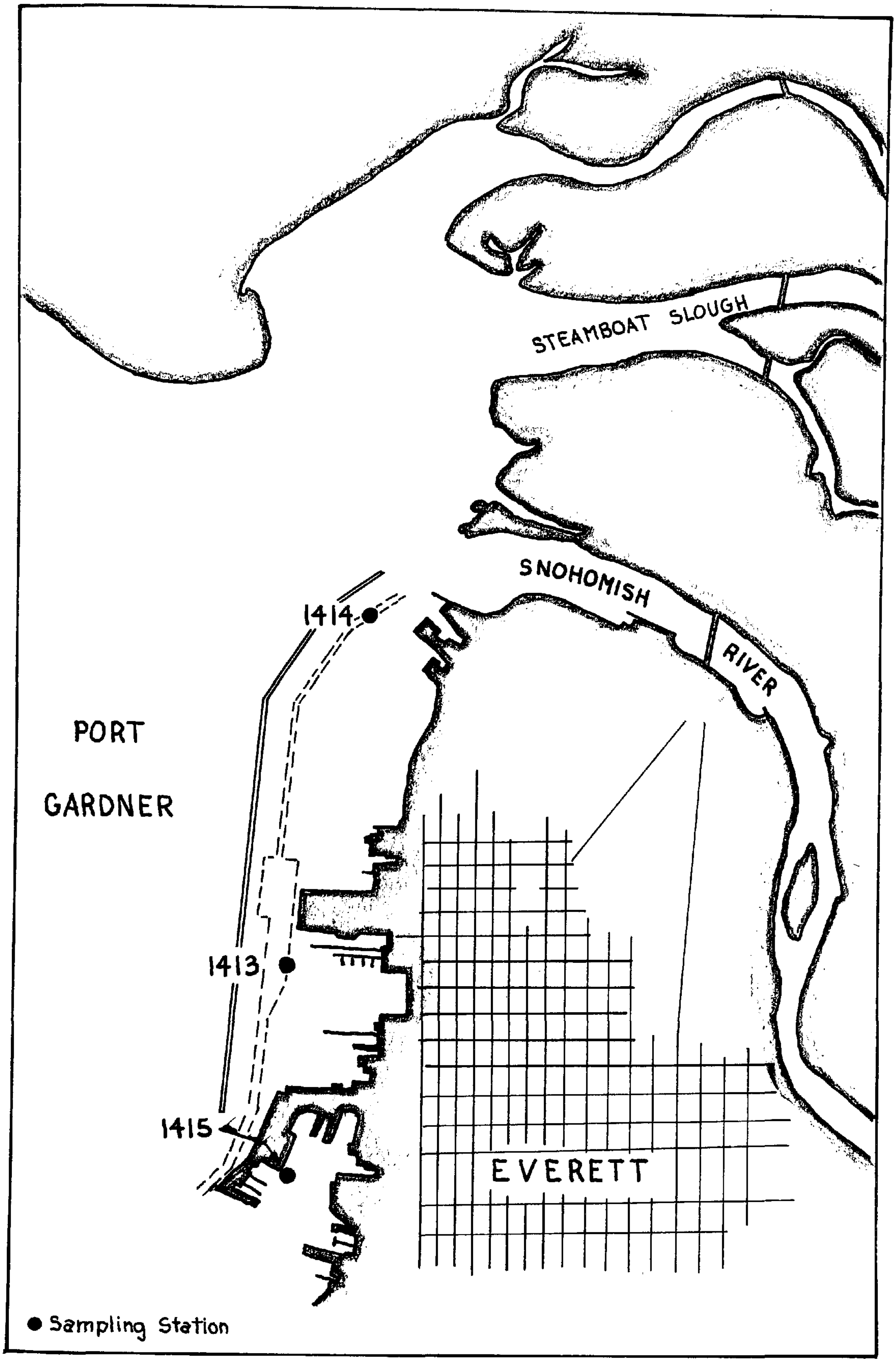

FIGURE B-3. Everett Harbor, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. 1413

Station Location: Everett Harbor, Washington. Main Channel at small boat harbor.

Latitude: 47° 59' 52" N Longitude: 122° 13' 21" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Shells (+6 mesh)	7%	Coefficient of Uniformity	7
Sand	68%		
Silt and Clay (-200 mesh)	25%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	5.6
Chemical Oxygen Demand (COD)	g/kg	59
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.09
Sulfides	g/kg	
Total Phosphorus	g/kg	0.46
Kjeldahl Nitrogen	g/kg	0.51
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.30

BOTTOM SAMPLE NO. 1414

Station Location: Everett Harbor, Washington. North end of Channel near Snohomish River.

Latitude: 48° 01' 01" N

Longitude: 122° 12' 55" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	5%
Sand	89%
Silt and Clay (-200 mesh)	6%

Coefficient of Uniformity: 4

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	2.5
Chemical Oxygen Demand (COD)	g/kg	4.0
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	+0.3
Sulfides	g/kg	
Total Phosphorus	g/kg	0.36
Kjeldahl Nitrogen	g/kg	0.13
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.11

BOTTOM SAMPLE NO. 1415

Station Location: Everett Harbor, Washington. Port Gardiner Harbor Near Port of Everett Dock.

Latitude: 47° 59' 01" N   Longitude: 122° 13' 17" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	5%	Coefficient of Uniformity	6
Sand	28%		
Silt and Clay (-200 mesh)	67$		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	17.8
Chemical Oxygen Demand (COD)	g/kg	163
Initial Oxygen Demand (IDOD)	g/kg	0.28
Oxidation-Reduction Potential	millivolts	-0.19
Sulfides	g/kg	
Total Phosphorus	g/kg	0.63
Kjeldahl Nitrogen	g/kg	2.02
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	3.43

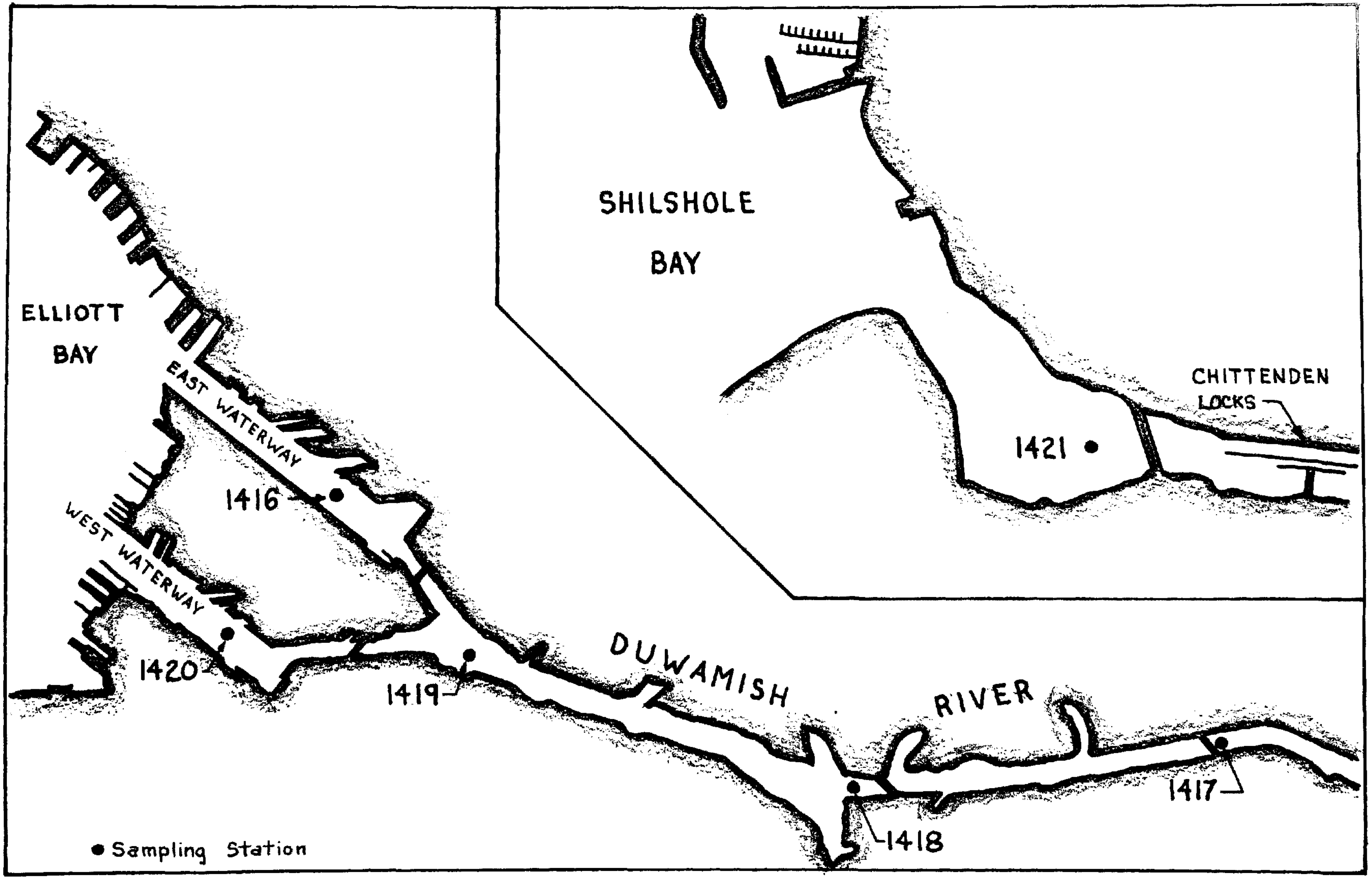

FIGURE B-4. Seattle Area, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. 1416

Station Location: Seattle, Washington. East waterway just north of sewer outfall.

Latitude: 47° 34' 41" N

Longitude: 122° 20' 35" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	6
Sand	27%		
Silt and Clay (-200 mesh)	73%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	25.5
Chemical Oxygen Demand (COD)	g/kg	282
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.16
Sulfides	g/kg	
Total Phosphorus	g/kg	0.96
Kjeldahl Nitrogen	g/kg	3.33
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	18.0

BOTTOM SAMPLE NO. 1417

Station Location: Seattle, Washington. Duwamish River immediately upstream from the 14th Ave. Bridge.

Latitude: 47^{o} 31' 44" N

Longitude: 122^{o} 18' 42" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	24%
Silt and Clay (-200 mesh)	76%

Coefficient of Uniformity 6

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.8
Chemical Oxygen Demand (COD)	g/kg	70
Initial Oxygen Demand (IDOD)	g/kg	0.41
Oxidation-Reduction Potential	millivolts	-0.05
Sulfides	g/kg	
Total Phosphorus	g/kg	0.74
Kjeldahl Nitrogen	g/kg	1.60
Ammonia Nitrogen	g/kg	3.4
Grease and Oil	g/kg	

BOTTOM SAMPLE NO. 1418

Station Location: Seattle, Washington. Duwamish River immediately downstream from 1st Ave. Bridge.

Latitude: 47° 32' 37" N

Longitude: 122° 20' 04" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	11%
Silt and Clay (-200 mesh)	89%

Coefficient of Uniformity 4

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	10.2
Chemical Oxygen Demand (COD)	g/kg	100
Initial Oxygen Demand (IDOD)	g/kg	1.01
Oxidation-Reduction Potential	millivolts	-0.12
Sulfides	g/kg	
Total Phosphorus	g/kg	1.31
Kjeldahl Nitrogen	g/kg	2.44
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	5.48

BOTTOM SAMPLE NO. 1419

Station Location: Seattle, Washington. Duwamish River at north end of Riverside Reach.

Latitude: 47° 33' 53" N   Longitude: 122° 20' 45" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	5
Sand	28%		
Silt and Clay (-200 mesh)	72%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	6.4
Chemical Oxygen Demand (COD)	g/kg	80
Initial Oxygen Demand (DOD)	g/kg	0.38
Oxidation-Reduction Potential	millivolts	-0.19
Sulfides	g/kg	
Total Phosphorus	g/kg	0.78
Kjeldahl Nitrogen	g/kg	1.60
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	5.22

BOTTOM SAMPLE NO. 1420

Station Location: Seattle, Washington. West Waterway at mouth of Duwamish River.

Latitude: 47° 34'40" N

Longitude: 122° 21' 41" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) 0%

Sand 14%

Silt and Clay (-200 mesh) 86%

Coefficient of Uniformity 6

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.5
Chemical Oxygen Demand (COD)	g/kg	85
Initial Oxygen Demand (IDOD)	g/kg	0.67
Oxidation-Reduction Potential	millivolts	-0.15
Sulfides	g/kg	
Total Phosphorus	g/kg	1.19
Kjeldahl Nitrogen	g/kg	2.11
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	6.88

BOTTOM SAMPLE NO. 1421

Station Location: Seattle, Washington. Lake Washington Ship Canal just below railroad bridge in Shilshole Bay.

Latitude: 47° 40' 02" N

Longitude: 122° 24' 09" W

Sampling Date: 1-16-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	3
Sand	37%		
Silt and Clay (-200 mesh)	63%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	5.0
Chemical Oxygen Demand (COD)	g/kg	48
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.18
Sulfides	g/kg	
Total Phosphorus	g/kg	0.53
Kjeldahl Nitrogen	g/kg	1.31
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	1.31

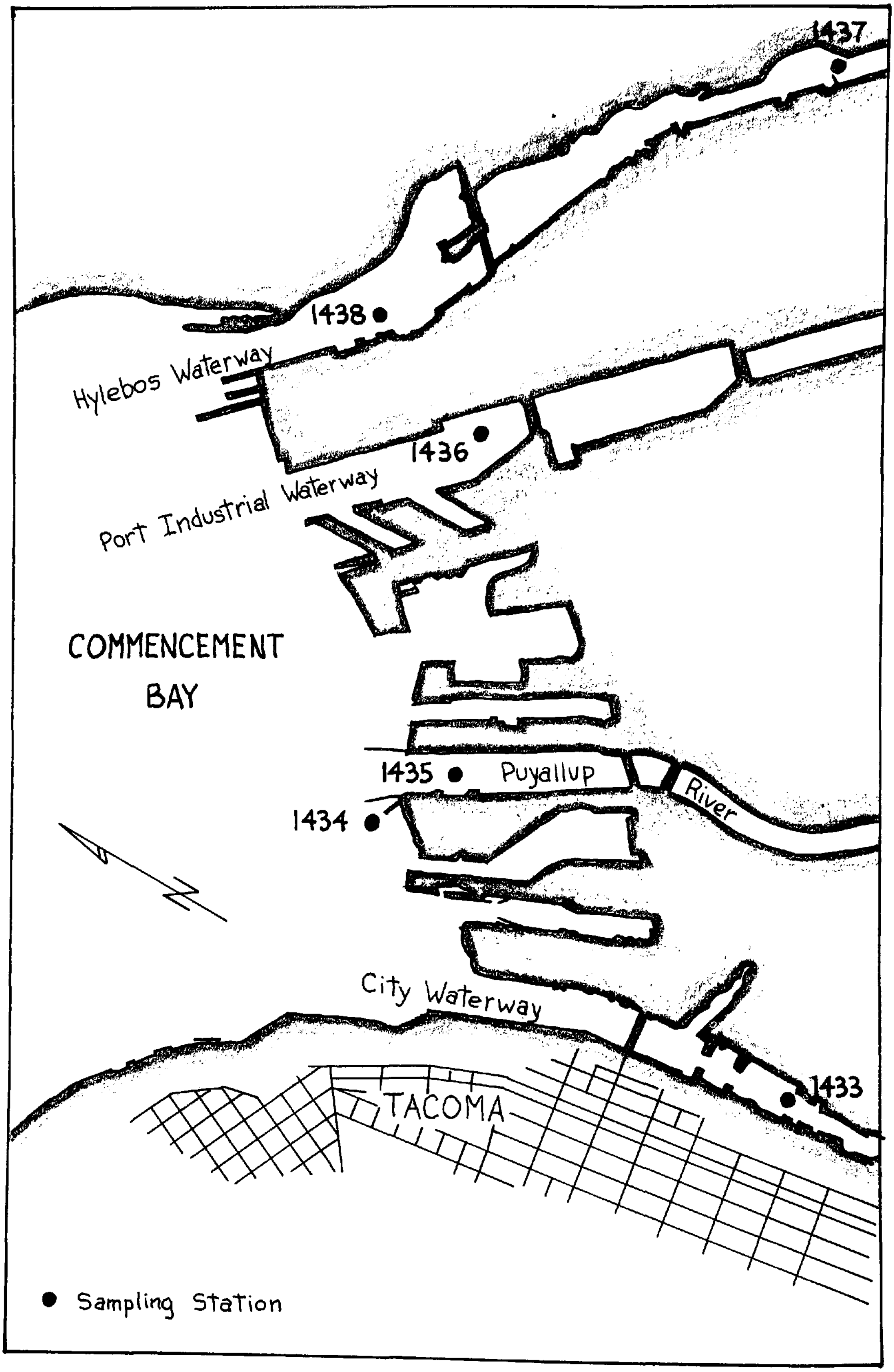

FIGURE B-5. Tacoma Harbor, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. 1433

Station Location: Tacoma, Washington. City Waterway opposite from Union Station.

Latitude: 47° 14' 48" N

Longitude: 122° 25' 51" W

Sampling Date: 3-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	1%	Coefficienf of Uniformity	4
Sand	43%		
Silt and Clay (-200 mesh)	56%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	19.7
Chemical Oxygen Demand (COD)	g/kg	203
Initial Oxygen Demand (IDOD)	g/kg	4.65
Oxidation-Reduction POtential	millivolts	-0.16
Sulfides	g/kg	2.56
Total Phosphorus	g/kg	1.21
Kjeldahl Nitrogen	g/kg	3.38
Ammonia Nitrogen	g/kg	——
Grease and Oil	g/kg	19.9

BOTTOM SAMPLE NO. 1434

Station Location: Tacoma, Washington. End of St. Regis Paper Company dock.

Latitude: 47° 16' 10" N   Longitude: 122° 25' 51" W

Sampling Date: 3-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	3%	Coefficient of Uniformity	4
Sand	49%		
Silt and Clay (-200 mesh)	48%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	13.1
Chemical Oxygen Demand (COD)	g/kg	126
Initial Oxygen Demand (IDOD)	g/kg	5.16
Oxidation-Reduction Potential	millivolts	-0.18
Sulfides	g/kg	2.32
Total Phosphorus	g/kg	0.92
Kjeldahl Nitrogen	g/kg	1.60
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	6.86

BOTTOM SAMPLE NO. 1435

Station Location: Tacoma, Washington. Puyallup Waterway opposite from St. Regis Paper Company Plant.

Latitude: 47° 16' 01" N   Longitude: 122° 25' 30" W

Sampling Date: 3-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	98%
Silt and Clay (-200 mesh)	2%

Coefficient of Uniformity 2

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	0.7
Chemical Oxygen Demand (COD)	g/kg	2.6
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	+0.27
Sulfides	g/kg	0.02
Total Phosphorus	g/kg	0.70
Kjeldahl Nitrogen	g/kg	0.01
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.16

BOTTOM SAMPLE NO. 1436

Station Location: Tacoma, Washington. Center of Port Industrial Waterway near East 11th Street.

Latitude: 47° 16' 25" N Longitude: 122° 24' 14" W

Sampling Date: 3-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	5
Sand	17%		
Silt and Clay (-200 mesh)	83%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	3.5
Chemical Oxygen Demand (COD)	g/kg	36
Initial Oxygen Demand (IDOD)	g/kg	1.24
Oxidation-Reduction Potential	millivolts	-0.04
Sulfides	g/kg	0.51
Total Phosphorus	g/kg	0.95
Kjeldahl Nitrogen	g/kg	0.76
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	1.75

BOTTOM SAMPLE NO. 1437

Station Location: Tacoma, Washington. Hylebos Waterway turning basin.

Latitude: 47° 16' 07" N   Longitude: 122° 22' 16" W

Sampling Date: 3-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	15%
Silt and Clay (-200 mesh)	85%

Coefficient of Uniformity 2

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	13.4
Chemical Oxygen Demand (COD)	g/kg	53
Initial Oxygen Demand (IDOD)	g/kg	1.69
Oxidation-Reduction Potential	millivolts	-0.15
Sulfides	g/kg	1.73
Total Phosphorus	g/kg	1.25
Kjeldahl Nitrogen	g/kg	1.34
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	3.87

BOTTOM SAMPLE NO. 1438

Station Location: Tacoma, Washington. Hylebos Waterway opposite Hooker Chemical.

Latitude: 47° 16' 47" N

Longitude: 122° 24' 02" W

Sampling Date: 3-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	1%
Sand	31%
Silt and Clay (-200 mesh)	68%

Coefficient of Uniformity 2

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	12.8
Chemical Oxygen Demand (COD)	g/kg	39
Initial Oxygen Demand (IDOD)	g/kg	1.39
Oxidation-Reduction Potential	millivolts	-0.22
Sulfides	g/kg	1.24
Total Phosphorus	g/kg	0.87
Kjeldahl Nitrogen	g/kg	0.58
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	1.38

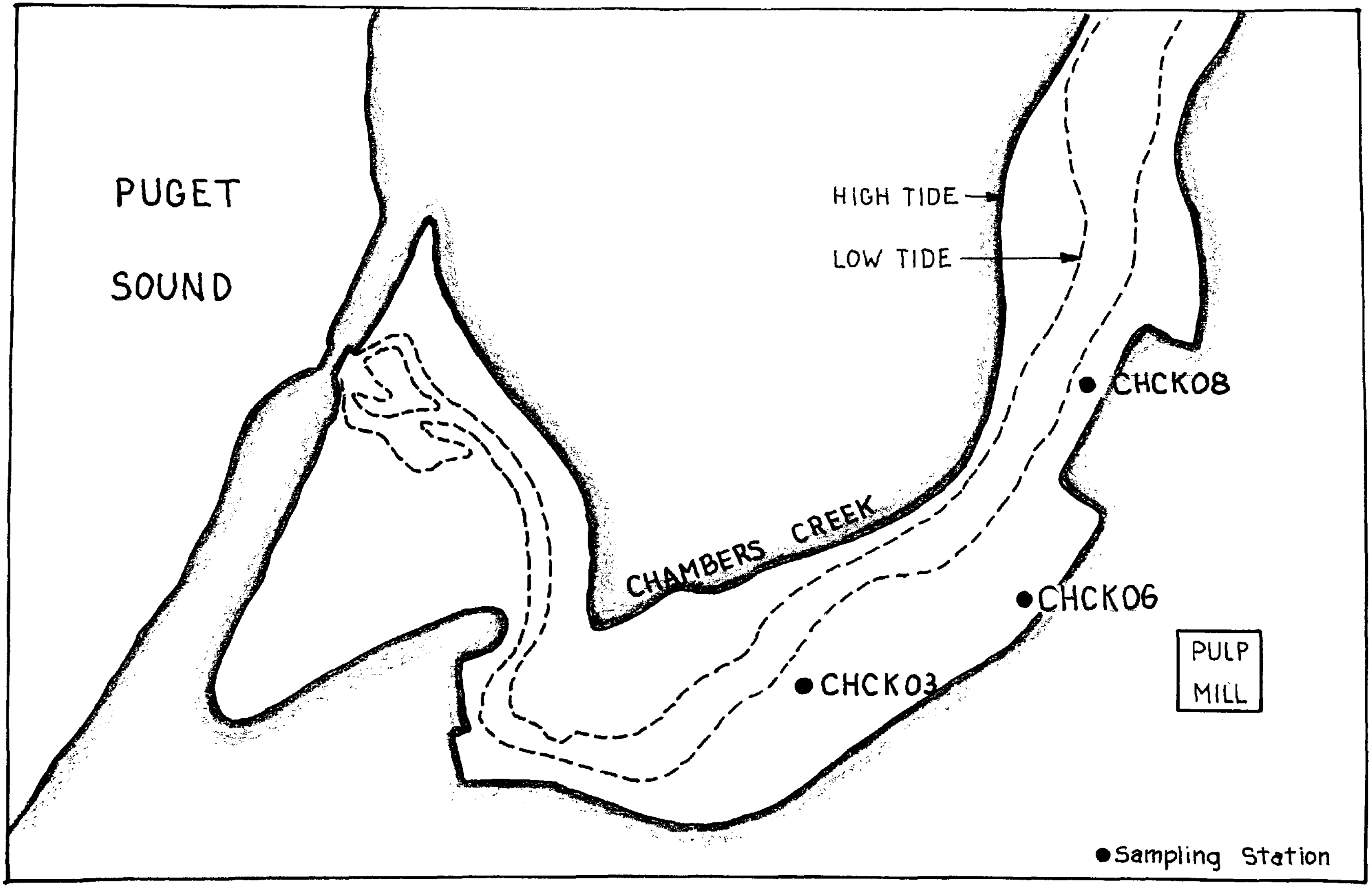

FIGURE B-6. Chambers Creek, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. CHCK-03

Station Location: Chambers Creek estuary near Steilacoom, Washington.

Latitude: 47° 11' 06" N   Longitude: 122° 34' 40" W

Sampling Date: 6-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	29.6
Chemical Oxygen Demand (COD)	g/kg	169
Initial Oxygen Demand (IDOD)	g/kg	2.02
Oxidation-Reduction Potential	millivolts	-0.15
Sulfides	g/kg	3.50
Total Phosphorus	g/kg	0.91
Kjeldahl Nitrogen	g/kg	2.94
Grease and Oil	g/kg	7.76

BOTTOM SAMPLE NO. CHCK-06

Station Location: Chambers Creek estuary near Steilacoom, Washington.

Latitude: 47° 11' 08" N Longitude: 122° 34' 35" W

Sampling Date: 6-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	___%	Coefficient of Uniformity	______
Sand	___%		
Silt and Clay (-200 mesh)	___%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	46.4
Chemical Oxygen Demand (COD)	g/kg	395
Initial Oxygen Demand (IDOD)	g/kg	4.23
Oxidation-Reduction Potential	millivolts	-0.15
Sulfides	g/kg	3.77
Total Phosphorus	g/kg	0.88
Kjeldahl Nitrogen	g/kg	4.13
Grease and Oil	g/kg	11.2

BOTTOM SAMPLE NO. CHCK-08

Station Location: Chambers Creek estuary near Steilacoom, Washington.

Latitude: 47° 11' 12" N

Longitude: 122° 34' 25" W

Sampling Date: 6-11-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh) ___%

Sand ___%

Silt and Clay (-200 mesh) ___%

Coefficient of Uniformity ______

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	27.5
Chemical Oxygen Demand (COD)	g/kg	352
Initial Oxygen Demand (IDOD)	g/kg	2.15
Oxidation-Reduction Potential	millivolts	-0.05
Sulfides	g/kg	1.56
Total Phosphorus	g/kg	0.59
Kjeldahl Nitrogen	g/kg	1.77
Grease and Oil	g/kg	

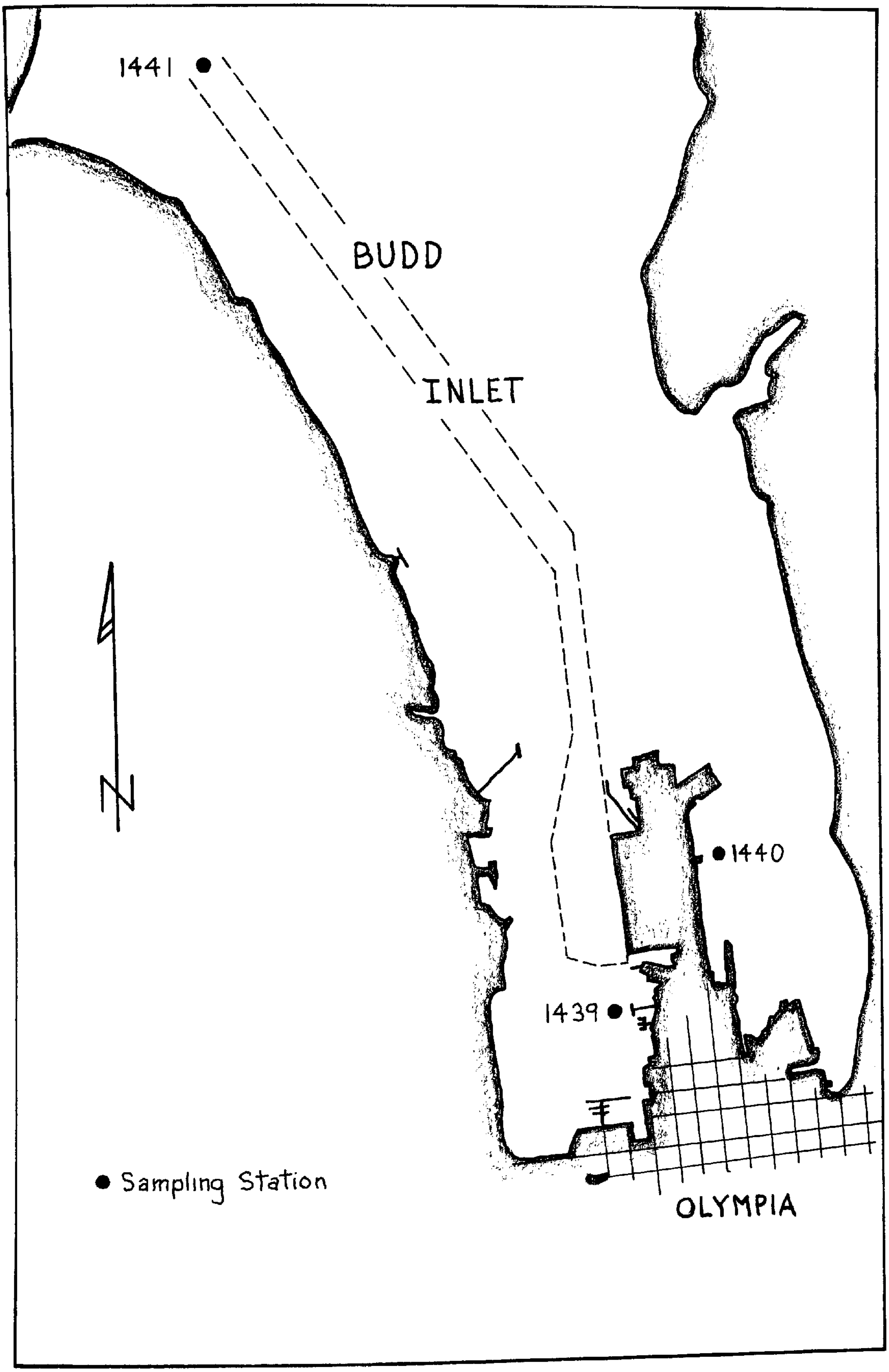

FIGURE B-7. Olympia Harbor, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. 1439

Station Location: Olympia, Washington. South end of Inner Harbor.

Latitude: 47° 03' 00" N

Longitude: 122° 54' 16" W

Sampling Date: 3-12-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	9%
Silt and Clay (-200 mesh)	91%

Coefficient of Uniformity 4

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	10.9
Chemical Oxygen Demand (COD)	g/kg	100
Initial Oxygen Demand (IDOD)	g/kg	1.83
Oxidation-Reduction Potential	millivolts	-0.11
Sulfides	g/kg	1.21
Total Phosphorus	g/kg	1.09
Kjeldahl Nitrogen	g/kg	3.12
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	3.19

BOTTOM SAMPLE NO. 1440

Station Location: Olympia, Washington. Bay on east side of dock area.

Latitude: 47° 03' 20" N   Longitude: 122° 53' 58" W

Sampling Date: 3-12-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	2%	Coefficient of Uniformity	8
Sand	40%		
Silt and Clay (-200 mesh)	58%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	12.3
Chemical Oxygen Demand (COD)	g/kg	12.8
Initial Oxygen Demand (IDOD)	g/kg	1.78
Oxidation-Reduction Potential	millivolts	-0.13
Sulfides	g/kg	1.01
Total Phosphorus	g/kg	0.68
Kjeldahl Nitrogen	g/kg	2.94
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	2.56

BOTTOM SAMPLE NO. 1441

Station Location: Olympia, Washington. Outer channel.

Latitude: 47° 04' 57" N Longitude: 122° 55' 28" W

Sampling Date: 3-12-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	5
Sand	8%		
Silt and Clay (-200 mesh)	92%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	10.2
Chemical Oxygen Demand (COD)	g/kg	84
Initial Oxygen Demand (IDOD)	g/kg	2.07
Oxidation-Reduction Potential	millivolts	-0.06
Sulfides	g/kg	1.17
Total Phosphorus	g/kg	0.82
Kjeldahl Nitrogen	g/kg	3.20
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	2.78

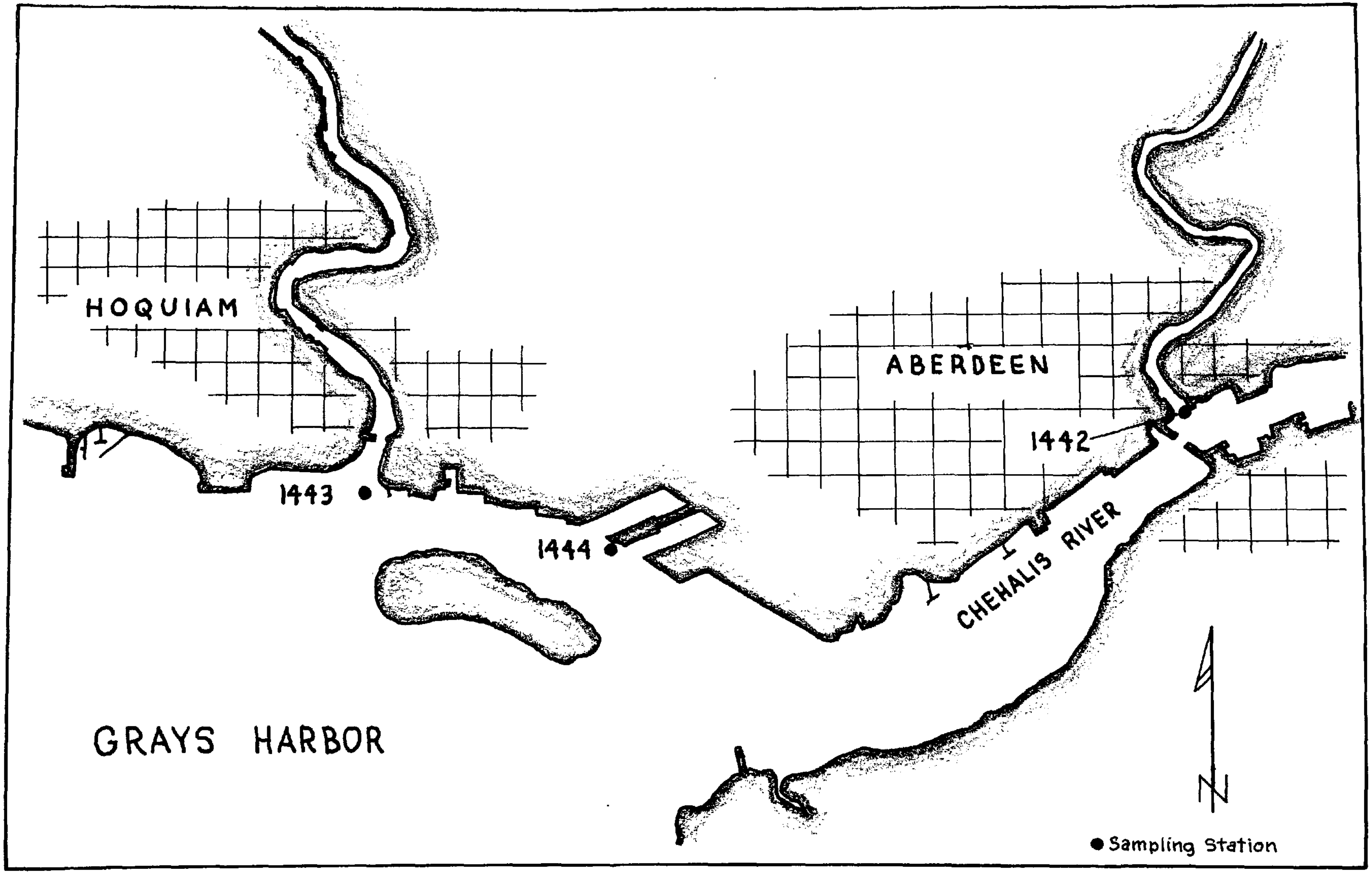

FIGURE B-8. Grays Harbor, Washington showing location of sampling stations.

BOTTOM SAMPLE NO. 1442

Station Location: Grays Harbor, Washington. Harbor at Aberdeen near mouth of Wishkah River.

Latitude: 46° 58' 28" N   Longitude: 123° 48' 26" W

Sampling Date: 3-12-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	5
Sand	23%		
Silt and Clay (-200 mesh)	77%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.7
Chemical Oxygen Demand (COD)	g/kg	64
Initial Oxygen Demand (IDOD)	g/kg	1.10
Oxidation-Reduction POtential	millivolts	-0.02
Sulfides	g/kg	0.62
Total Phosphorus	g/kg	0.85
Kjeldahl Nitrogen	g/kg	1.96
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	1.92

BOTTOM SAMPLE NO. 1443

Station Location: Grays Harbor, Washington. Hoquiam at mouth of Hoquiam River.

Latitude: 46° 58' 10" N

Longitude: 123° 52' 35" W

Sampling Date: 3-12-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	51%
Silt and Clay (-200 mesh)	49%

Coefficient of Uniformity 7

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.4
Chemical Oxygen Demand (COD)	g/kg	67
Initial Oxygen Demand (IDOD)	g/kg	1.07
Oxidation-Reduction Potential	millivolts	-0.06
Sulfides	g/kg	1.34
Total Phosphorus	g/kg	0.82
Kjeldahl Nitrogen	g/kg	1.78
Ammonia Nitrogen	g/kg	———
Grease and Oil	g/kg	3.32

BOTTOM SAMPLE NO. 1444

Station Location: Grays Harbor, Washington. Channel at Port Dock at Slip No. 2.

Latitude: 46° 58' 10" N

Longitude: 123° 52' 35" W

Sampling Date: 3-12-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	42%
Silt and Clay (-200 mesh)	58%

Coefficient of Uniformity 6

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	8.2
Chemical Oxygen Demand (COD)	g/kg	62
Initial Oxygen Demand (IDOD)	g/kg	0.82
Oxidation-Reduction Potential	millivolts	-0.04
Sulfides	g/kg	0.72
Total Phosphorus	g/kg	0.80
Kjeldahl Nitrogen	g/kg	1.82
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	1.44

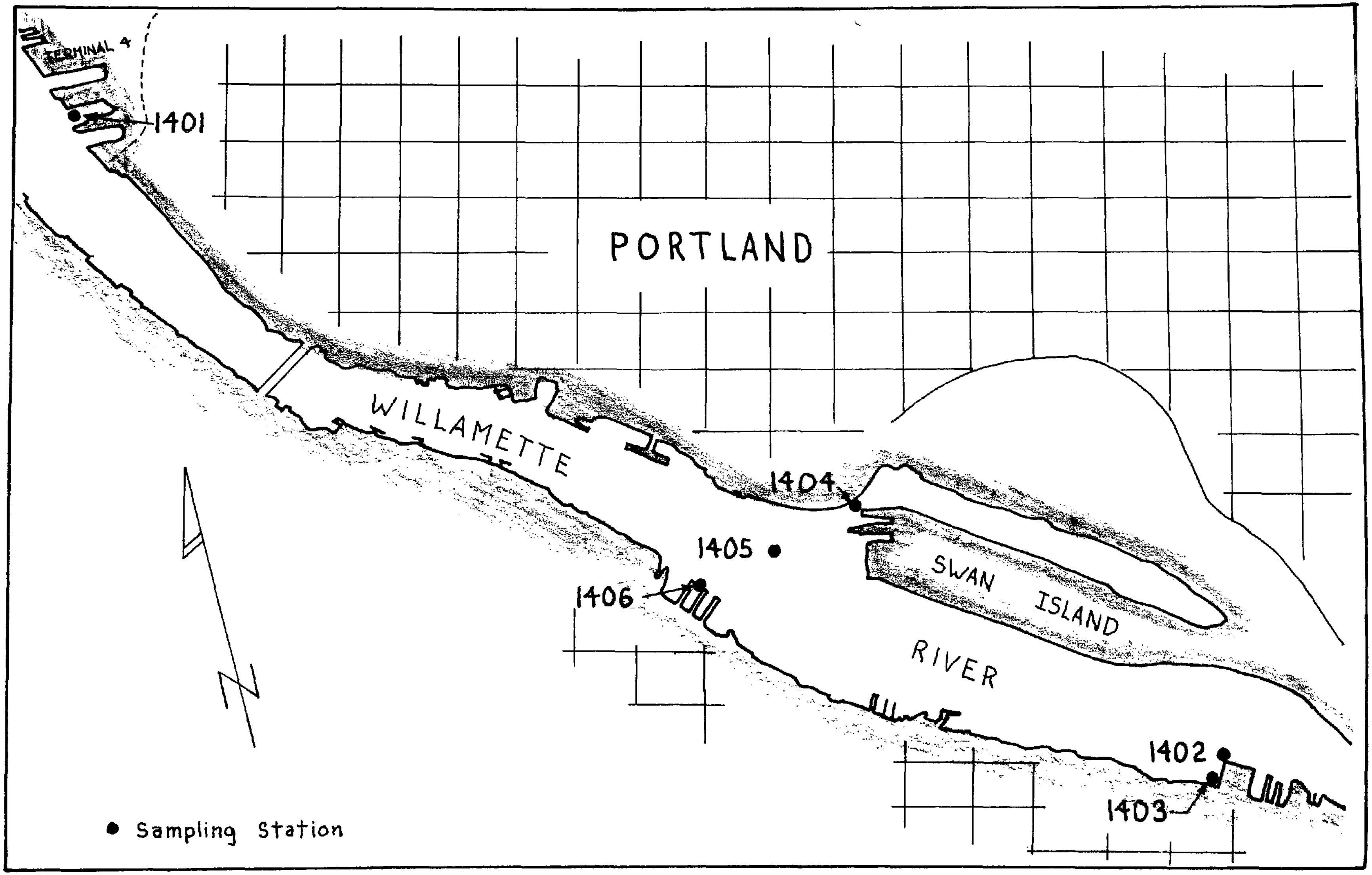

FIGURE B-9. Portland Harbor, Oregon showing location of sampling stations.

BOTTOM SAMPLE NO. 1401

Station Location: Portland Harbor, Oregon. Slip 2, Terminal 4, Portland Public Docks.

Latitude: 45^{o} 36' 08" N

Longitude: 122^{o} 46' 29" W

Sampling Date: 12-9-68

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	38%
Silt and Clay (-200 mesh)	62%
Coefficient of Uniformity	

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.2
Chemical Oxygen Demand (COD)	g/kg	57
Initial Oxygen Demand (IDOD)	g/kg	0.42
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	
Total Phosphorus	g/kg	1.27
Kjeldahl Nitrogen	g/kg	1.26
Ammonia Nitrogen	g/kg	0.16
Grease and Oil	g/kg	0.19

BOTTOM SAMPLE NO. 1402

Station Location: Portland Harbor, Oregon. Berth 2, Terminal 2, Portland Public Docks

Latitude: 45° 33' 01" N Longitude: 122° 42' 08" W

Sampling Date: 12-9-68

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	
Sand	10%		
Silt and Clay (-200 mesh)	90%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.7
Chemical Oxygen Demand (COD)	g/kg	78
Initial Oxygen Demand (IDOD)	g/kg	0.49
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	
Total Phosphorus	g/kg	1.46
Kjeldahl Nitrogen	g/kg	2.9
Ammonia Nitrogen	g/kg	0.24
Grease and Oil	g/kg	2.07

BOTTOM SAMPLE NO. 1403

Station Location: Portland Harbor, Oregon. West end Berth 1, Terminal 2, Portland Public Docks

Latitude: 45° 33' 56" N   Longitude: 122° 42' 13" W

Sample Date: 12-9-68

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	
Sand	37%		
Silt and Clay (-200 mesh)	63%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	8.8
Chemical Oxygen Demand (COD)	g/kg	127
Initial Oxygen Demand (IDOD)	g/kg	0.38
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	
Total Phosphorus	g/kg	1.65
Kjeldahl Nitrogen	g/kg	1.22
Ammonia Nitrogen	g/kg	0.20
Grease and Oil	g/kg	1.03

BOTTOM SAMPLE NO. 1404

Station Location: Portland Harbor, Oregon. Channel at north end of Swan Island

Latitude: 45° 34' 11" N   Longitude: 122° 43' 25" W

Sampling Date: 12-9-68

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	
Sand	12%		
Silt and Clay (-200 mesh)	88%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.5
Chemical Oxygen Demand (COD)	g/kg	71
Initial Oxygen Demand (IDOD)	g/kg	0.78
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	
Total Phosphorus	g/kg	1.65
Kjeldahl Nitrogen	g/kg	1.57
Ammonia Nitrogen	g/kg	0.22
Grease and Oil	g/kg	1.65

BOTTOM SAMPLE NO. 1405

Station Location: Portland Harbor, Oregon. Mid channel of Willamette River at north end of Swan Island.

Latitude: 45° 34' 11" N   Longitude: 122° 43' 52" W

Sampling Date: 12-9-68

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	
Sand	25%		
Silt and Clay (-200 mesh)	75%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.1
Chemical Oxygen Demand (COD)	g/kg	41
Initial Oxygen Demand (IDOD)	g/kg	0.40
Oxidation-Reduction Potential	millivolts	
Sulfides	g/kg	
Total Phosphorus	g/kg	1.14
Kjeldahl Nitrogen	g/kg	1.04
Ammonia Nitrogen	g/kg	0.22
Grease and Oil	g/kg	1.67

BOTTOM SAMPLE NO. 1406

Station Location: Portland Harbor, Oregon. Slip between oil company docks along west side Willamette River opposite north end Swan Island.

Latitude: 45° 34' 03" N Longitude: 122° 44' 12" W

Sampling Date: 12-9-68

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	______
Sand	15%		
Silt and Clay (-200 mesh)	85%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.4
Chemical Oxygen Demand (COD)	g/kg	64
Initial Oxygen Demand (IDOD)	g/kg	0.99
Oxidation-Reduction Potential	millivolts	______
Sulfides	g/kg	______
Total Phosphorus	g/kg	1.44
Kjeldahl Nitrogen	g/kg	1.48
Ammonia Nitrogen	g/kg	0.21
Grease and Oil	g/kg	______

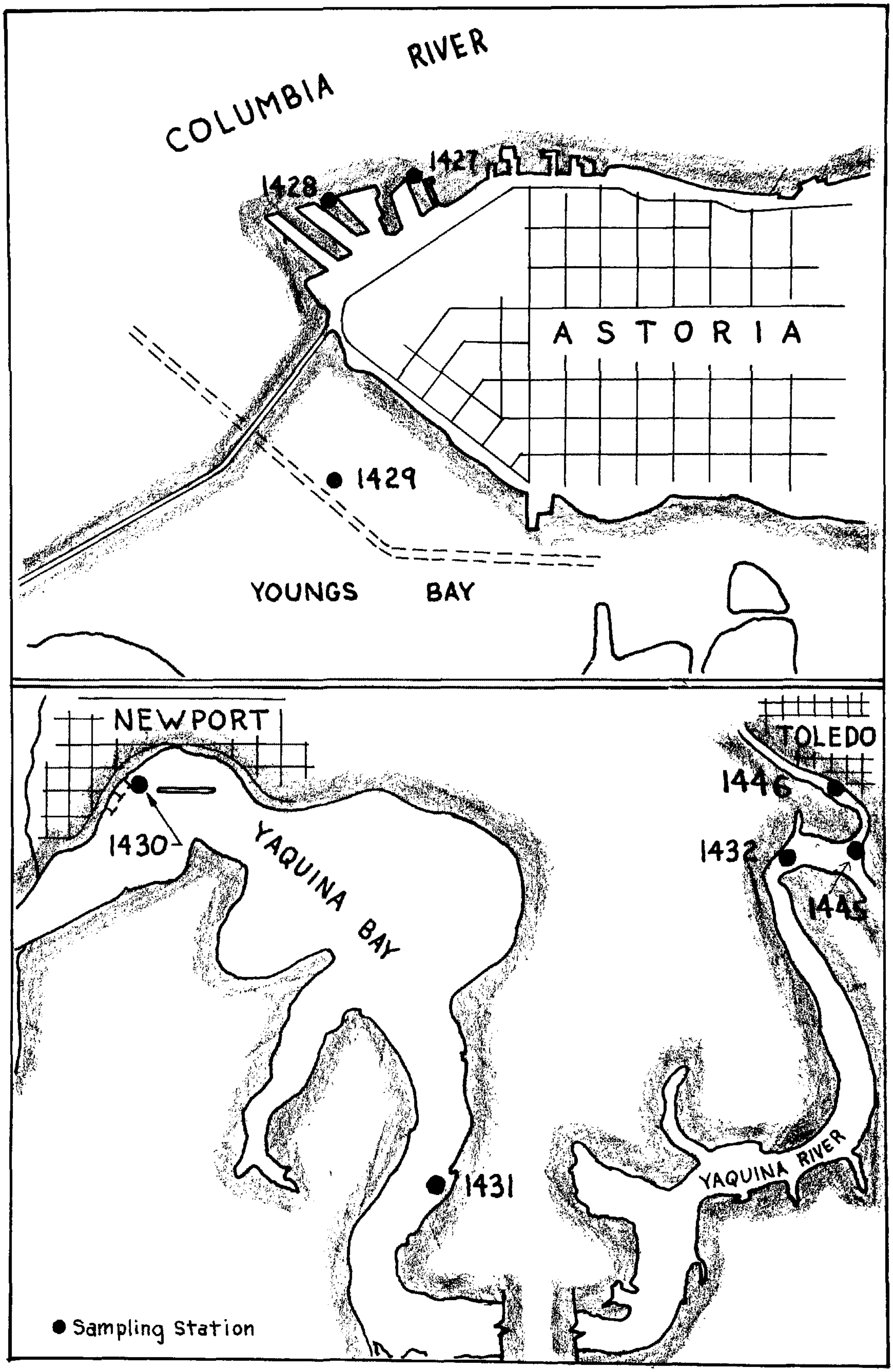

FIGURE B-10. Astoria and Newport areas, Oregon showing location of sampling stations.

BOTTOM SAMPLE NO. 1427

Station Location: Astoria, Oregon. Entrance to Fisherman's Coop. Slip.

Latitude: 46° 11' 27" N Longitude: 123° 51' 10" W

Sampling Date: 2-27-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient Uniformity	7
Sand	70%		
Silt and Clay	30%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	4.5
Chemical Oxygen Demand (COD)	g/kg	38
Initial Oxygen Demand (IDOD)	g/kg	0.45
Oxidation-Reduction Potential	millivolts	-0.13
Sulfides	g/kg	0.13
Total Phosphorus	g/kg	0.78
Kjeldahl Nitrogen	g/kg	0.84
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.61

BOTTOM SAMPLE NO. 1428

Station Location: Astoria, Oregon. Entrance to Slip No. 2.

Latitude: 46° 11' 24" N

Longitude: 123° 51' 36" W

Sampling Date: 2-27-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	1%
Sand	51%
Silt and Clay (-200 mesh)	48%

Coefficient of Uniformity 9

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	4.8
Chemical Oxygen Demand (COD)	g/kg	27
Initial Oxygen Demand (IDOD)	g/kg	0.49
Oxidation-Reduction Potential	millivolts	-0.11
Sulfides	g/kg	0.25
Total Phosphorus	g/kg	0.84
Kjeldahl Nitrogen	g/kg	1.18
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	1.01

BOTTOM SAMPLE NO. 1429

Station Location: Astoria, Oregon. Young's Bay along ship channel.

Latitude: 46° 10' 25" N

Longitude: 123° 51' 38" W

Sampling Date: 2-27-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%
Sand	93%
Silt and Clay (-200 mesh)	7%

Coefficient of Uniformity 3

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	2.2
Chemical Oxygen Demand (COD)	g/kg	20
Initial Oxygen Demand (IDOD)	g/kg	0.26
Oxidation-Reduction Potential	millivolts	+0.01
Sulfides	g/kg	0.04
Total Phosphorus	g/kg	0.74
Kjeldahl Nitrogen	g/kg	0.49
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.31

BOTTOM SAMPLE NO. 1430

Station Location: Yaquina Bay, Oregon.

Latitude: 44° 37' 39" N   Longitude: 124° 3' 14" W

Sampling Date: 2-27-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	29%	Coefficient of Uniformity	35
Sand	55%		
Silt and Clay (-200 mesh)	16%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	17.1
Chemical Oxygen Demand (COD)	g/kg	111
Initial Oxygen Demand (IDOD)	g/kg	0.95
Oxidation-Reduction Potential	millivolts	-0.14
Sulfides	g/kg	1.74
Total Phosphorus	g/kg	1.53
Kjeldahl Nitrogen	g/kg	0.72
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	2.08

BOTTOM SAMPLE NO. 1431

Station Location: Yaquina River, Oregon. Weiser Point.

Latitude: 44° 35' 39" N

Longitude: 124° 0' 41" W

Sampling Date: 2-27-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	9
Sand	56%		
Silt and Clay (-200 mesh)	44%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	7.0
Chemical Oxygen Demand (COD)	g/kg	58
Initial Oxygen Demand (IDOD)	g/kg	0.79
Oxidation-Reduction Potential	millivolts	-0.09
Sulfides	g/kg	1.03
Total Phosphorus	g/kg	0.66
Kjeldahl Nitrogen	g/kg	1.41
Ammonia Nitrogen	g/kg	———
Grease and Oil	g/kg	1.62

BOTTOM SAMPLE NO. 1432

Station Location: Yaquina River, Oregon. At Toledo.

Latitude: 44° 36' 55" N   Longitude: 123° 56' 48" W

Sampling Date: 2-27-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	5%
Sand	94%
Silt and Clay (-200 mesh)	1%

Coefficient of Uniformity 2

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	2.6
Chemical Oxygen Demand (COD)	g/kg	20
Initial Oxygen Demand (IDOD)	g/kg	0.08
Oxidation-Reduction Potential	millivolts	+0.41
Sulfides	g/kg	0.03
Total Phosphorus	g/kg	0.24
Kjeldahl Nitrogen	g/kg	0.11
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.17

BOTTOM SAMPLE NO. 1445

Station Location: Yaquina River, Oregon. Mouth of Depot Slough at Toledo.

Latitude: 44° 36' 56" N

Longitude: 123° 56' 19" W

Sampling Date: 5-1-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	______
Sand	11%		
Silt and Clay (-200 mesh)	89%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	13.7
Chemical Oxygen Demand (COD)	g/kg	160
Initial Oxygen Demand (IDOD)	g/kg	2.75
Oxidation-Reduction Potential	millivolts	+0.11
Sulfides	g/kg	0.11
Total Phosphorus	g/kg	1.27
Kjeldahl Nitrogen	g/kg	____
Ammonia Nitrogen	g/kg	____
Grease and Oil	g/kg	____

BOTTOM SAMPLE NO. 1446

Station Location: Yaquina River, Oregon. Depot Slough at Toledo near Georgia Pacific Plywood Plant.

Latitude: 44° 37' 09" N

Longitude: 123° 56' 16" W

Sampling Date: 5-1-69

PARTICLE SIZE DISTRIBUTION

Gravel & Wood Chips (+6 mesh)	5%	Coefficient of Uniformity	
Sand	39%		
Silt and Clay (-200 mesh)	56%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	21.8
Chemical Oxygen Demand (COD)	g/kg	268
Initial Oxygen Demand (IDOD)	g/kg	1.92
Oxidation-Reduction Potential	millivolts	+0.09
Sulfides	g/kg	0.10
Total Phosphorus	g/kg	1.19
Kjeldahl Nitrogen	g/kg	
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	

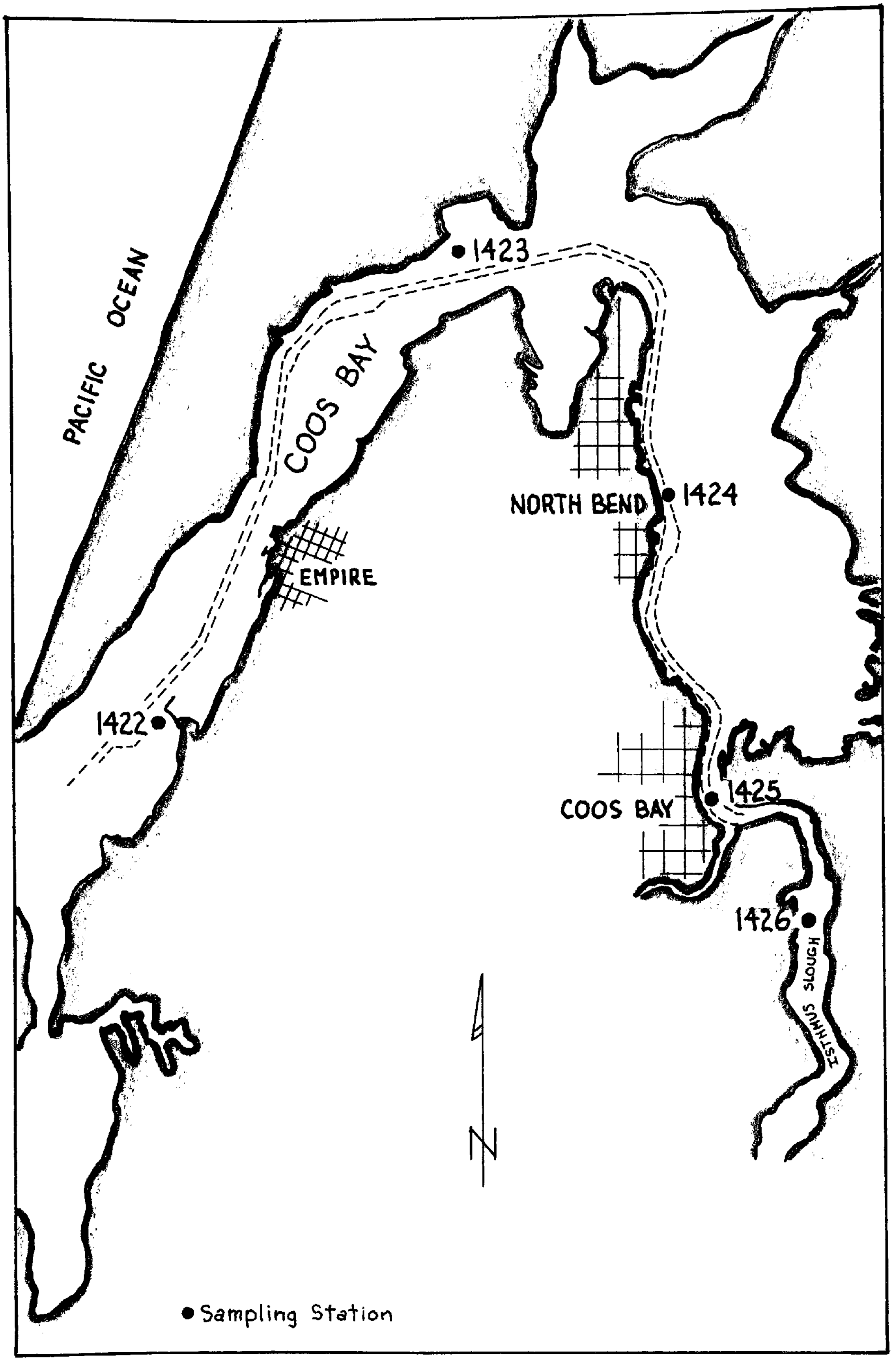

FIGURE B-11. Coos Bay, Oregon showing location of sampling stations.

BOTTOM SAMPLE NO. 1422

Station Location: Coos Bay, Oregon. Channel just below Sitka Dock.

Latitude: 43° 22' 27" N Longitude: 124° 17' 52" W

Sampling Date: 1-23-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	6
Sand	63%		
Silt and Clay (-200 mesh)	37%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	6.3
Chemical Oxygen Demand (COD)	g/kg	53
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.05
Sulfides	g/kg	
Total Phosphorus	g/kg	0.31
Kjeldahl Nitrogen	g/kg	0.75
Ammonia Nitrogen	g/kg	0.71
Grease and Oil	g/kg	

BOTTOM SAMPLE NO. 1423

Station Location: Coos Bay, Oregon. Channel at entrance to Jordan Cove.

Latitude: 43° 25' 42" N   Longitude: 124° 14' 48" W

Sampling Date: 1-23-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	1.4
Sand	96%		
Silt and Clay (-200 mesh)	4%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	1.3
Chemical Oxygen Demand (COD)	g/kg	12
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	+0.05
Sulfides	g/kg	
Total Phosphorus	g/kg	0.3
Kjeldahl Nitrogen	g/kg	0.37
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.13

BOTTOM SAMPLE NO. 1424

Station Location: Coos Bay, Oregon. Along west side of North Bend Upper Range Channel.

Latitude: 43° 23' 58" N

Longitude: 124° 12' 58" W

Sampling Date: 1-23-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	18
Sand	69%		
Silt and Clay (-200 mesh)	31%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	9.1
Chemical Oxygen Demand (COD)	g/kg	141
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.11
Sulfides	g/kg	
Total Phosphorus	g/kg	0.62
Kjeldahl Nitrogen	g/kg	1.28
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	0.98

BOTTOM SAMPLE NO. 1425

Station Location: Coos Bay, Oregon. West side of channel opposite FL G light.

Latitude: 43° 21' 50" N   Longitude: 124° 12' 34" W

Sampling Date: 1-23-69

PARTICLE SIZE DISTRIBUTION

Gravel (+6 mesh)	0%	Coefficient of Uniformity	7
Sand	12%		
Silt and Clay (-200 mesh)	88%		

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	12.8
Chemical Oxygen Demand (COD)	g/kg	105
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.12
Sulfides	g/kg	
Total Phosphorus	g/kg	2.55
Kjeldahl Nitrogen	g/kg	0.88
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	3.5

BOTTOM SAMPLE NO. 1426

Station Location: Coos Bay, Oregon. Isthmus Slough near Bay Park.

Latitude: 43° 20' 58" N

Longitude: 124° 11' 50" W

Sampling Date: 1-23-69

PARTICLE SIZE DISTRIBUTION

Bark Chips (+6 mesh)	5%
Sand	40%
Silt and Clay (-200)	55%

Coefficient of Uniformity 15

CHEMICAL CHARACTERISTICS (DRY WT.)

Parameter	Unit	Value
Volatile Solids	%	15.1
Chemical Oxygen Demand (COD)	g/kg	134
Initial Oxygen Demand (IDOD)	g/kg	
Oxidation-Reduction Potential	millivolts	-0.13
Sulfides	g/kg	
Total Phosphorus	g/kg	0.80
Kjeldahl Nitrogen	g/kg	2.44
Ammonia Nitrogen	g/kg	
Grease and Oil	g/kg	2.58