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MFR PAPER 1221

Effects of Dredging on Aquatic Organisms—With Special Application to Areas Adjacent to the Northeastern Pacific Ocean

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INTRODUCTION

One of the most extensive, noticeable, and controversial of man's activities in the rivers and harbors of the United States is the dredging and disposing of approximately 380 million cubic yards of material each year (May, 1972). The associated cost exceeds 150 million dollars annually (Boyd et al., 1972). Disposal of dredged material is potentially the most important environmental alteration imposed on aquatic resources of our rivers and estuaries. It is becoming an important issue when related to disposal of material offshore. Concern has been expressed by water users, mainly from the standpoint of the real or potential effects on aquatic organisms, water quality, and land use (Montgomery and Griffis, 1973).

The National Water Quality Act of 1969 necessitated the description of environmental impact of construction activities, but it was not until 1973 that the major dredging agencies (primarily the U.S. Army Corps of Engineers) initiated the preparation of Environmental Impact Statements (EIS) for dredging and material disposal programs.

IMPACT OF DREDGING ON AQUATIC ORGANISMS

Background

The Federal agency with the responsibility for maintaining U.S. navigation channels in rivers and harbors is the U.S. Army Corps of Engineers. The Rivers and Harbors Act of 1889 gave the Corps this authority; before that, Congressional authorization was approved in 1824 for the Corps to remove sand bars and snags from major navigable waterways. In Canada, dredging is the responsibility of, and is accomplished primarily by, the Public Works Department, Pacific Region, for the Pacific Northwest area.

Dredging is the excavation of underwater material, usually sand, silt, or gravel. There are three basic processes by which dredging is actually accomplished, i.e., hydraulic or mechanical dredging and a combination of the two. Pipeline and hopper dredging, which use the hydraulic principle, are the most common techniques utilized.

Pipeline dredges are extensively used in the Pacific Northwest for maintenance of navigation channels (Fig. 1). The equipment utilized is basically a barge containing a cutter-head and a suction pipe that is held in position by anchors and lines. An additional pipe floated by pontoons is attached to this basic unit to feed the displaced material to a point of deposition. Booster pumps are needed where long distances from the barge to the discharge point are encountered (O'Neal and Sceva, 1971). The larger the discharge pipe, the greater pump capacity required on the barge. The effluent from the pipeline is usually ponded to develop land fills. Large volumes of material can be moved with this system in a short period of time in water or onshore disposal.

A hopper dredge is a self-propelled vessel (usually ocean-eoing), designed for the hydraulic dredging and the transportation of material to a dumping area. The advantage of the hopper dredge over the pipeline dredge is the ability to operate in rough water and in areas where land fill is not available or

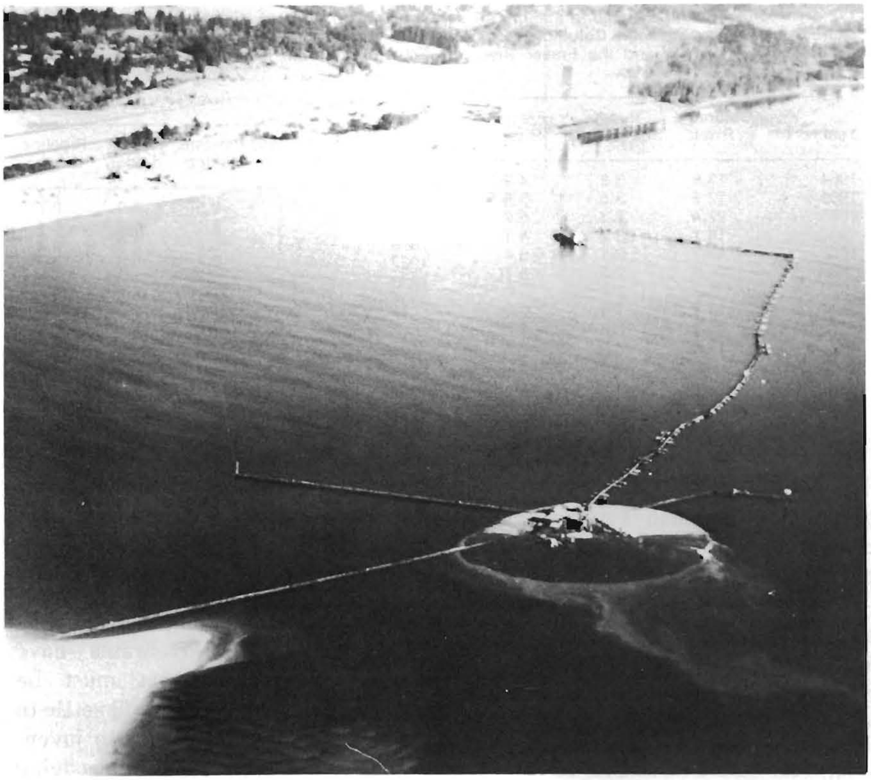

Figure 1.—Pipeline dredge in operation in the Columbia River at Hunters Bar near Kalama, Wash.

desirable. Hopper dredges in the Pacific Northwest vary in capacity from 500 to 3,000 cubic yards. They operate using suction intakes that can be lowered to a desirable depth with scrapers (or shoes) that feed a thin layer of bottom material through the suction pipe into the hopper (Fig. 2). When the hopper is filled, the vessel moves to a disposal site and flushes the material.

Other types of dredges found in the Pacific Northwest include bucket, sidecaster, dipper, and ladder dredges. In addition, specially converted vessels are being used to move material through a "propellor-wash" operation (agitation dredging).

Navigation and development are the major reasons for dredging. Channel dredging is necessary to maintain commerce on our nation's waterways and is accomplished on a regular basis within the confines of a specific channel. Offshore dredging is normally conducted to obtain or recover mineral deposits. Normally the material is deposited inshore ("beach nourishment"). Estuarine and inshore dredging are accomplished primarily for channel maintenance, recovery of minerals, and for shellfish operations. The latter apparently has little application in the Pacific Northwest at this time but is of significant proportion in the eastern United States. Size of vessel and deeper draft vessels are increasing the need for the widening and deepening of our waterways. The distance to the entrance of a harbor from the ocean is becoming more important as costs per day of operation for the larger vessels increase. This necessitates the development of deeper ports closer to the ocean. Additional berthing spaces and turning basins are needed for commercial craft. The ensuing construction and development that follow any given port development increase the requirement for new dredging and disposal projects.

Further, the consideration of the exploration and mining of mineral resources from estuaries and offshore

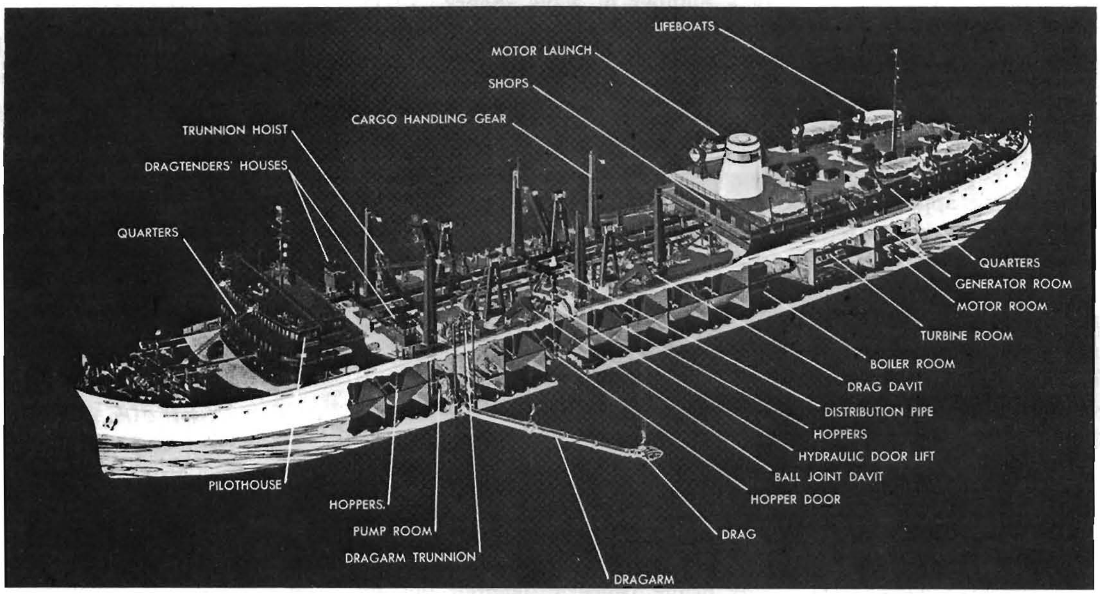

Figure 2.—Cross section of a typical hopper dredge.

areas will increase the demand for material displacement and for a knowledge of the resources that are impacted.

Quantities of Dredge and Disposal Material

Quantities of material that were dredged over a 10-year period from the Columbia and Fraser rivers and the Puget Sound area are shown in Table 1. Dredging on the Fraser River has increased; dredging in the Puget Sound area seems to have remained fairly stable, and the Columbia River dredging varies markedly from year to year. The quantities of material removed average 14.4 million cubic yards annually for the Columbia River and 5.6 million cubic yards annually for the Fraser River; on both rivers, the pipeline dredging method is used to remove most of this material (Table 2). The 14.4 million cubic yards of material dredged annually from the Columbia River would cover over 8,900 acres with 1 foot of material.

General Impacts of Material Removal

Dredging alters the topography of the channel. Between dredging operations, upstream water-borne material gradually restores the river bottom towards its natural shape. Continuous shoaling is the reason for the requirement of continuing programs of maintenance dredging.

In general there are three types of impacts on aquatic resources produced by material removal by dredges: 1) Mechanical effects; 2) turbidity; 3) other miscellaneous effects.

Mechanical Effects

Gutterhead dredging appears to be the type of operation with the most potential for creating adverse direct and indirect effects on the biological communities. This technique is usually utilized to remove loose or hard compacted materials in either new work or maintenance projects. Organisms can be dredged up and physically removed from the area, and the naturally vegetated material is destroyed. It has been shown that most species of aquatic organisms prefer a naturally vegetated bottom (Briggs and O'Connor, 1971). Hydraulic dredging uproots all vegetation, and more than a year may be required for recolonization of aquatic plants (Godcharles, 1971).

Table 1.—Quantities of material in millions of cubic yards dredged from the Columbia River, the Puget Sound area, and the Fraser River from 1964 to 1973.

Year	Columbia River	Puget Sound area	Fraser River
1964	13.6	3.8	4.9
1965	12.2	3.5	5.6
1966	22.4	2.3	5.2
1967	14.1	3.2	5.1
1968	13.7	3.1	5.4
1969	14.2	2.9	5.7
1970	8.7	3.8	5.0
1971	15.4	3.5	6.0
1972	13.3	2.8	6.3
1973	16.5	3.5	6.8
Total	144.1	32.4	56.0
Average	14.4	3.2	5.6

Table 2.—Type and quantity (millions of cubic yards) of dredge activity in the Columbia and Fraser rivers from 1964 to 1973.

	Columbia River		Fraser River	
Year	Hopper dredge	Pipeline dredge	Hopper dredge	Pipeline dredge
1964	5.1	8.5	1.2	3.7
1965	6.1	6.1	1.2	4.4
1966	6.1	16.3	0.9	4.3
1967	4.3	9.8	0.8	4.3
1968	3.6	10.1	1.0	4.4
1969	2.5	11.7	1.2	4.5
1970	4.3	4.4	1.1	3.9
1971	4.3	11.1	1.2	4.8
1972	6.3	7.0	1.2	5.1
1973	6.8	9.7	1.2	5.6
Total	49.4	94.7	11.0	45.0
Average	4.9	9.5	1.1	4.5

Clamshell dredging leaves depressions in the bottom substrate that affect the resource. These holes contain dissolved oxygen and hydrogen sulfide levels that will not sustain fish life or benthic invertebrates (Murawski, 1969).

The removal of benthic organisms by dredging prevents the benthic community from developing its full potential of productivity.

Turbidity and Sediment Effects

A review of the effects of suspended and deposited sediments indicated that sediment loads and deposited material will affect living resources and systems in a number of ways (Sherk, 1971). Turbidity and sediment load of the water column affect primary energy production, which occurs as a result of photosynthetic activities of planktonic algae. Secondary sources of energy conversion in shallow water are other algae, rooted plants, and benthic bacteria. The algae that convert the sun's energy are consumed by small animals adrift in water, or the algae sink and are eaten by bottom dwellers, and so forth through the food chain. However, the primary source of energy is the sun; turbidity can reduce or eliminate production in rivers, estuaries, and the ocean at a time when productivity could be at a maximum.

Miscellaneous Effects

A prime concern, pointed out by Thompson (1973), of the ecological effects of offshore dredging is the change in water clarity and the effects of bottom deposits on larval development and larval settlement. Larvae of bottom-dwelling invertebrates have subtle requirements that must be satisfied before the larvae will settle to the bottom and transform into juveniles. Evidence of the impact of dredging on larval forms of aquatic organisms indigenous to the Pacific Northwest is not available.

In the Pacific Northwest, large volumes of sediments which are high in levels of volatile solids and hydrogen sulfide have been found in major estuaries and bays. When these sediments are disturbed by dredging, the water column contains hydrogen sulfide concentrations that can be lethal to many organisms (Servizi, Gordon, and Martens, 1969). Although the lethal concentration is short-term, the result can be a substantial loss of a year class of indigenous or migratory organisms.

Although there has been concern expressed, little experimentation has been done to determine whether or not high concentrations of potentially deleterious chemicals in the mud are actually released into the water column during dredging in a manner that affects aquatic organisms.

IMPACT OF MATERIAL DISPOSAL ON LIVING RESOURCES

Background

The problem of how to dispose of dredged material is considered to be the number one problem throughout the nation for the U.S. Army Corps of

Engineers. Through the Corps' Waterways Experiment Station, a multi-million-dollar research project has been initiated by the Dredged Material Research Program to provide a better insight into the problem. It has been generally recognized that the impact of the disposal of dredged material far outweighs the problem of removing the material. In any case, thousands of acres of marshland have been lost and are continuing to be lost to various reclamation projects throughout this country. Additional volumes of dredged materials are being placed within freshwater swamps, shorelines, and backwater areas.

The problem compounds itself because deeper and wider channels are being dredged, resulting in the need to dispose of larger quantities of material; disposal sites, however, are becoming harder to locate. This problem is acute where the quality of bottom sediments is undesirable. The problems of material disposal are receiving considerable attention by researchers and in some projects receive high priority funding. In the Pacific Northwest, the Waterways Experiment Station, U.S. Army Corps of Engineers, is funding three research programs directed at finding solutions to the material disposal problems.

Thousands of acres of productive waterways have been lost through disposal of dredged material. Examples of loss of estuarine area due to dredge "spoiling" can be cited for most of our nation's major estuaries. Notable examples on the Pacific coast are in San Francisco Bay and the estuaries of the Columbia and Fraser rivers. The normal technique used in the river is to dredge the channel and place the "spoil" in dikes parallel to the river flow. Then, in subsequent maintenance-dredging operations, the dikes are raised above water level as the first step and filled from the dikes to the existing river bank for the second step. The amount of productive water area lost in the past has not been ascertained for areas of the Pacific Northwest, but the preservation of the aquatic resource requires that it be predicted for the future.

In-channel deposition of material has been resorted to in the rivers of the Pacific Northwest, but the effects on aquatic resources have not yet been assessed.

General Impacts of Material Disposal

General categories of direct effects of spoil disposal on aquatic organisms include:

1) Loss of organisms through incompatibility of dredge and disposal sites; 2) burial of organisms; 3) turbidity; 4) anoxia; 5) toxic chemical release. The impact of material disposal is first seen when the dredging barge or pipeline is moved to a specific dump site and the material is released. Special consideration needs to be given to the environment of the source of the material and the environment of the dump site. More profound impacts can be predicted to occur if the environments are not compatible, i.e., the removal of bottom organisms and material from fresh water or from slightly saline waters and the subsequent deposition in highly saline waters, or the movement of incompatible bottom material from one area to another, which can be disastrous to impacted organisms (Wilson, 1950).

Loss Through Burial

Burial of organisms has been noted as an important short-term impact on the resource; fixed epifauna, such as oysters, perish when covered by sediment (Lunz, 1942). Apparently, some benthic species (primarily invertebrates) reach the surface of newly deposited sediments after burial of more than 20 cm (Saila, Pratt, and Polgar, 1972). Larger and mobile invertebrates have survived burial under as much as 3 feet of material (Westley et al., 1973).

Turbidity and Water Quality

Mechanical or abrasive action of suspended silt and detritus is important to filter feeding organisms with respect to gill clogging, impairment or proper respiratory and excretory functioning, and feeding activity. Moreover, the deposition of suspended materials may interfere with or prevent reproduction by destruction of demersal eggs in upper estuarine nursery areas (Taylor and Saloman, 1968).

High turbidities can and do cause death from littoral suffocation and can disrupt primary productivity and community structure, increasing oxygen demand. There is a wide diversity between the types of materials that are being dredged and deposited and the potential effect on the aquatic resources. In general, the material continually dredged from an active navigation channel in the Pacific Northwest (the Columbia or Fraser rivers) differs markedly in quality from materials dredged from berthing spaces, old turning basins, or near outfalls from industries where pollution may have accumulated over a long period.

Silt loads above 4,000 ppm will prevent salmonids from migrating, while streams with silt averaging between 80 and 4,000 ppm are not desirable for supporting freshwater fisheries (Bell, 1973).

Miscellaneous Effects

Apparently, no far-reaching, long-lasting, or detrimental effects have been seen from the deposition of offshore sediments as beach fill; flora and fauna of beaches are accustomed to change and constant changes are part of the daily pattern of living (Thompson, 1973).

Changes in water quality as a result of large magnitudes of dredged material deposition have received a considerable amount of attention from biological researchers throughout the country (contained in review by Sherk, 1971). Effects on biological systems can be listed as follows: 1) Loss of habitat; 2) decreased euphotic zone depth; 3) increased oxygen demand; 4) increased nurient uptake and release; 5) reduced primary production; 6) community disruption.

The extent and importance of pesticide pollution in estuaries are not fully understood. Chlorinated hydrocarbons that are not of a magnitude to cause damage in specific organisms or constitute a human health problem do pose a threat, however, to other organisms through potential recycling or biological magnification. The potential effect of resuspended sediments containing pesticides and related contaminants is not clearly understood.

Evidence tends to support the contention that nutrient release and possible release of toxic materials occur in the water column with resuspension of bottom materials. This action could occur during dredging and subsequent material disposal from re-agitation during storms, floods, and beach erosion.

In addition, it has been found that organisms generally accumulate greater concentrations of chlorinated hydrocarbons when they are exposed to turbid waters (U.S. Fish and Wildlife Service, 1970); pesticide concentrations in fish tissues increase with turbidity.

Little information is available on the effect of heavy metals on organisms in the natural state, and levels in most water bodies and their significance are not well known. Trace quantities of heavy metals are known constituents of living matter, but in high concentrations these same metals are highly toxic. Toxicity of heavy metals varies with the presence of phosphorous and nitrogen compounds.

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