Completion Report for
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Dredged Materials Research Program
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Lower Columbia River Studies; Miller Sands

An Annotated Bibliography
of

THE EFFECTS OF DREDGING AND DREDGE DISPOSAL ON AQUATIC ORGANISMS IN THE PACIFIC NORTHWEST

with
Selected references on biological studies of
the lower Columbia River and on related
dredge and disposal studies.

by

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INTRODUCTION

This bibliography was prepared in conjunction with studies by the National Marine Fisheries Service on channel maintenance dredging and habitat creation in the Columbia River Estuary. Although much literature on dredging deals with negative impact of disposal of polluted and/or fine-grained spoil, Columbia River dredge spoils are generally clean and sandy. Some of the dredging studies in the annotated section of the bibliography concern polluted dredged areas; other related studies are included in the supplementary reference list.

No attempt was made to catalog the envoronmental impact statements which have been prepared for navigation and construction projects in the Pacific Northwest (see reference by Ortolando and Hill). These may serve as additional sources of information.

The division of the bibliography into five sections was somewhat arbitary. The first section contains a sampling of references which are not directly concerned with dredging, but which provide background physical and biological information about the project region.

Dredging and disposal studies that concern a specific site or area form the second and third sections. The second section contains studies done in Washington and Oregon; the third section lists studies done elsewhere.

The fourth section includes studies of habitat development and of the effects on biota of conditions such as turbidity and lowered dissolved oxygen levels which are associated with dredging and disposal operations. A more complete listing of studies done on the effects of suspended and deposited matter is found in the paper by Sherk and Cronin (Biological Studies Halibut Development, page 33).

The fifth section contains general application studies and references which did not seem to fit in the other four sections.

The supplementary reference list includes further references on diked disposal and the uses of dredge spoil, references relevant to modeling and environmental study planning, and other miscellaneous studies.

BACKGROUND REFERENCES ON THE COLUMBIA RIVER AND PACIFIC NORTHWEST COAST

Bourke, R.H. et al. The Nearshore Physical Oceanographic Environment of the Pacific Northwest Coast. Reference 71-45, Feb 1971, Oregon State University Department of Oceanography, Corvallis, Ore.

The oceanographic, meteorologic, and geologic environment of the nearshore region of the Pacific Northwest Coast is described in this report. Specifically, it is a compilation and summary of the available data from the coastline to ten nautical miles offshore extending from Cape Flattery, Washington to Cape Mendocino, California. Environmental parameters are reviewed and presented in separate chapters. These include a list of the available navigational charts applicable to this region, a geological description with bottom profiles of the nearshore area, a summary of the discharge rates of major coastal rivers, seasonal wind patterns, temperature and salinity variations, descriptions of the heat budget, and the seasonal variations in the wave regime and current flow.

from Author's Introduction

Conomos, J.T. and M.G. Gross. "Mixing of the Columbia River and Ocean Waters, Summer," Proceedings of the National Symposium on Estuarine Pollution, Aug 1967, American Society of Civil Engineers, Stanford, Calif. pp 486-516.

This paper reviews recent work on the Columbia River estuary and the nearby Northeast Pacific Ocean. Particular attention is focused on circulation and mixing near the river mouth and on those factors controlling the supply, distribution, and utilization of plant nutrients in this area during the summer of 1965 and 1966. The processes discussed here will also affect other substances discharged into the coastal ocean, making it possible, in some cases, to predict their behavior by analogy with the known behavior of these naturally occurring materials.

from Author's Introduction

Day, D.S. and W.G. Pearcy. "Species Association of Benthic Fishes on the Continental Shelf and Slope off Oregon," Journal of the Fisheries Research Board of Canada, Vol 25, No. 12, pp 2665-2675.

Four species associations of benthic fishes found off the coast of Oregon within the depth interval from 40 to 1829 m were characterized by two or three most abundant species, depth range, and average sediment type. Little overlap was found among species associations because many species had maximum abundance or were found only on one association. When a species occurred in more than one association, different size of fish were often found. Species on the lower continental slope had the broadest depth range, and a few species were found only in the deepest association. Sixty-seven species of bottom fishes representing twenty-one families were collected, but 86% of the total number of fishes were from the families Pleuronectidae, Scorpaenidae, and Bothidae.

Author's Abstract

Gaumer, et al. 1971 Columbia River Estuary Resource Use Study. Aug 1973, Fish Commission of Oregon.

This report briefly summarizes findings of a comprehensive study of recreational use of marine food fish, shellfish, and other miscellaneous invertebrates in the Columbia River Estuary. The report is one of a series done on 16 Oregon estuaries. Information is given on the boat fishery, the shore fishery, tideflat fishery, angler origin, the commercial fishery, food production areas, fish feeding areas, fish migration routes, and known herring spawning areas.

Lee, Patrick. Water Quality Report - The Columbia River below Longview, Washington, Dec 1971 - Nov 1972. Technical Report No. 74-7, Feb 1974, State of Washington Department of Ecology, Olympia, Wash.

The Washington State Department of Ecology collected water quality data from the Columbia River at a point 12 miles below Longview, Washington at Port Westward, Oregon from December 1971 to November 1972. The data was collected by a continuously operating automatic water quality data acquisition system. Backup data was obtained from the routine monitoring program of the Washington State Department of Ecology and the Oregon State Department of Environmental Quality. The Columbia River at this point (river mile 53.5) is designated by Washington State Water Quality Standards as Class A waters. The river exceeded maximum allowable coliform standards during most of the year. Sporadically, during late summer and early fall, the river did not meet water quality standards for temperature and dissolved oxygen. These instances occurred during the low flow period of the year. The Columbia was also monitored for dissolved oxygen and temperature by the National Marine Fisheries Service near Prescott, Oregon (river mile 73.0) about six miles upstream from Longview. No apparent water quality violations of dissolved oxygen and temperature standards were observed during the year at this location. It is concluded that the industrial and municipal discharges in the Longview-Kelso area significantly contribute to the apparent water quality violations recorded at Port Westward. The conclusions support the results obtained by EPA in 1970 and 1971 on water quality conditions in the Lower Columbia River.

Author's Abstract

Lie, U. "Standing Crop of Benthic Infauna in Puget Sound and off the Coast of Washington," Journal of the Fisheries Research Board of Canada, Vol 26, No. 1, 1967, pp 55-62.

During the period May 28 to August 1, 1967, benthic infauna was collected at 37 stations in Puget Sound and off the coast of Washington. When large but rare species were excluded from the samples, the variability in standing crop (ash-free dry weight) among replicate samples was less than among means from different stations. The mean standing crop for the offshore stations was 1.92 g/m^2, which is comparable with the standing crop on the shelf in the Gulf of Alaska, but less

than half the mean standing crop for the Puget Sound stations; the difference may be explained in part by differences previously reported, in primary productivity of the water masses. For the offshore stations there was a weak trend of increasing standing crop with depth. The standing crop at the shallow-water offshore stations, in substrates characterized as fine sand, was dominated by crustaceans and small lamellibranchs, whereas at the deeper stations, in sediments with high percentages of silt and clay, polychaetes and echinoderms were the most important contributors.

Author's Abstract

Lie, U. and J.C. Kelley. "Benthic Infauna Communities off the Coast of Washington and in Puget Sound: Identification and Distribution of the Communities," Journal of the Fisheries Research Board of Canada, Vol 27, No. 4, 1970, pp 621-651.

Benthic infauna was collected at 37 stations in Puget Sound, in Juan de Fuca Strait, and off the northwestern coast of Washington during the summer of 1967 and at 18 additional stations off the southwestern coast of Washington during the summer of 1968. The crustaceans, lamellibranchs, and echinoderms were identified and counted, and the data were subjected to an analysis of affinity among stations, to Fager's recurrent group analysis, and to factor analysis for identifications of the benthic communities and the groupings of benthic species in the investigated area. Trellis-diagrams of indices of affinity among the stations based on the presence or absence of species, indicated four rather distinct groups of stations with specific geographic distributions or relations to certain sediment types. Fager's recurrent group analysis for the 36 most frequently occurring species resulted in eight groups and five species that were strongly associated with one or more of the recurrent groups. Most tests of interspecific relations among the species within the groups were not significant, and it was concluded that the analysis was only partly useful for delimiting species groups with ecological significance. The Q-mode of the factor analysis resulted in three groups of stations distributed in bands parallel to the coast, and each group of stations (community) could be recognized by its distinct sediment types of depth distribution. The R-mode of the factor analysis gave six groups of species with specific preferences of depths, sediment types, or geographic distribution. The results of the various techniques were compared, and their application in benthic synecology was discussed.

Author's Abstract

Lie, U. and D.R. Kisker. "Species Composition and Structure of Benthic Infauna Communities off the Coast of Washington," Journal of the Fisheries Research Board of Canada, Vol 27, No. 12, Dec 1970, pp 2273-2285.

The deepwater mud-bottom community identified previously as one of three benthic infauna communities off the coast of Washington was found at mean depths of 154.5 m in sediments with mean mud percentages of 50.09%. The mean standing crop was 3.058 g/m^2 (ash-free dry weight). The intermediate depth sand-bottom community was found at stations with a mean depth of 95.8 m in sediments with a mean sand percentage of 67.81%. The mean standing crop was 2.533 g/m^2. The shallow water sand-bottom community was found at stations with a mean depth of 36.0 m in sediments with mean sand percentages of 96.33%. The mean standing crop was 1.398 g/m^2. The most abundant species as well as the main contributors to the mean standing crop are listed for each community. There was a distinctly lower species diversity in the shallow water sand-bottom community than in the two communities in deeper water.

Modified Author's Abstract

Lockett, J.B. "Phenomena Affecting Improvement of the Lower Columbia Estuary and Entrance," Proceedings, Federal Interagency Sedimentation Conference. U.S. Department of Agriculture, Agriculture Research Service Miscellaneous Publication No. 970, Jan 1963, Paper No. 68, pp 626-668.

This paper describes work undertaken to improve the lower Columbia estuary and entrance for navigation and discusses past concepts of phenomena controlling the regimes of this area as related to these improvements. Recent advances in technology have given birth to a new concept of tidal hydraulic phenomena that emphasizes the relation of salinity intrusion and littoral movement to the degree of shoaling experienced in estuarine areas. The findings of prototype measurements undertaken in 1959 along the lower Columbia and other endeavors to expand the knowledge of controlling phenomena, including statistical wave studies, analyses of offshore changes, studies of attrition and accretion of adjacent shorelines, and comprehensive investigations of the distribution of Columbia River sediments are reviewed in the light of this new concept. Authorization, construction, and verification of the comprehensive lower Columbia estuary hydraulic model are discussed, as well as tests proposed for identification of controlling phenomena and for development of the most effective and economical plan of improvement. Finally, the paper summarizes the extent of present knowledge and outlines considerations for the future under conditions of controlled upland discharge resulting from contemplated headwater reservoir operation.

Author's Synopsis

McDaniel, N.G. A Survey of the Benthic Macroinvertebrate Fauna and Solid Pollutants in Howe Sound. Technical Report No. 385, 1973, Fisheries Research Board of Canada, Pacific Environment Institute, West Vancouver, B.C.

Solid pollutants resulting from industrial activities, such as log booming and mining, cause a marked reduction in the ability of the substrate to support colonization by benthic organisms. Where input of solid waste is intense, or of long duration, establishment of benthic fauna is sometimes entirely precluded. Long-term log storage and dumping activities in Howe Sound have resulted in massive, although localized, accumulations of sunken logs and wood debris which blanket the natural substrate and support only a few species of invertebrates. Long-term mining operations at Britannia have resulted in the buildup of a thick layer of tailing on the bottom adjacent to the mine which have not been colonized by benthic organisms. Commercial marina operations have resulted in the accumulation of inorganic refuse on the bottom, which in some instances provides artificial hard substrate for the attachment of epifauna or crevice space for motile forms, but which is more often aesthetically unpleasant. Meaningful water quality regulations must include provisions to prevent these kinds of activities from operating in or adjacent to National Marine Parks.

Author's Abstract

Pamatmat, M.M. The Ecology and Metabolism of a Benthic Community on an Intertidal Sandflat (False Bay, San Juan Island, Washington), Dissertation. 1966, University of Washington, Seattle, Wash.

The plant and animal community of a temperate intertidal sandflat was studied by sampling and experiments. Field sampling was done at three representative stations. Laboratory measurements were made of the respiration of macrofaunal species, the tidal pattern of community metabolism, and potential photosynthesis activity of subsurface sediment. The interactions of incipient radiation, temperature, and tide were determining factors of the ecology and metabolism of the benthic community, with other factors being minor.

from Author's Abstract

Pruter, A.T. and D.L. Alverson, eds. The Columbia River Estuary and Adjacent Ocean Waters, Bioenvironmental Studies. 1972, University of Washington Press, Seattle, Wash.

This compilation of related studies carried out by several agencies and institutions was prepared under the auspices of the AEC in connection with the location of the Hanford Atomic Works on the Columbia River. However, the book is not limited to analyses of radionuclides in the aquatic environment. Characteristics of the Columbia River, its living systems, and its relationships with the Pacific Ocean are examined in a broad scope which does provide background information

as to the fate of radioactive material discharges, but which is not limited to that purpose. The book is divided into four sections: Background Papers, Columbia River-Ocean Relationships, Composition and Distribution of Marine-Environment Biota, and Radionuclides in the Ecosystem.

Sanborn, H.R. Benthic Infauna Observed at Five Sites in the Columbia River from August 1973 to July 1974. Mar 1975, National Marine Fisheries Service, Completion Report to the U.S. Army Corps of Engineers and Columbia River Programs Office.

This study was undertaken to investigate seasonal patterns of Columbia River infauna which are possibly important as food for the Columbia's anadromous and indigenous fish. Three definite patterns were observed: (1) Shallow water stations showed greater numbers of species during all sample periods compared with deep water stations, possibly due to a more stable environment conducive to organic detrital settling. The site located in the estuary was an exception to this trend shown by the river stations. (2) Substantially more individuals were noted during the first year as compared with the second year of sampling. The higher flow and current rates of the second year may have caused physical dislodgement and interfered with the detrital deposition. (3) The amphipod Corophium salmonis and the clam Corbicula fluminea were present and in many cases dominant at all the stations except the one located in the estuary, and can therefore be characterized as dominant benthic species of the Columbia River.

Shelford, V.E. et al. Some Marine Biotic Communities of the Pacific Coast of North America, Part I General Survey of the Communities. Ecological Monographs, Vol 5, Jul 1935, pp 249-354.

The pelagic communities and communities associated with the bottom and shore of the Pacific Coast are discussed. Described are interactions, physiological characteristics, conditions and extents, associations, and biome prevalents or predominants. The dynamics of bottom and shore communities are also discussed in terms of factors controlling arrangement of organisms, population fluctuations, community changes, and succession.

Snyder, G.R. et al. Checklist of Aquatic Organisms in the Lower Columbia and Willamette Rivers. Nov 1973, National Marine Fisheries Service, Completion Report to U.S. Army Corps of Engineers, Portland, Ore.

An assessment of aquatic resources of the lower Columbia and Willamette Rivers was conducted using reviews of past findings and surveys in designated areas. The resulting inventory of species represents the uppermost layers of the food chain in the project region. The assessment consisted of four separate substudies. "A List of Fishes of the Lower Columbia and Willamette Rivers" identified approximately 70 fish

species. "A List of Crustacean Shellfish of the Lower Columbia River between the Mouth and River Mile 108, July to October 1973" identified four species of shellfish. "A List of Benthic Animals in the Lower Willamette and Columbia Rivers, August to October 1973 identified 26 species of new and previously described benthic and epibenthic organisms. "A Checklist of Zooplankton in the Lower Columbia and Willamette Rivers, July to October 1973" listed over 50 taxa excluding larval fish. Each of the separately authored substudies contained techniques, data, and literature cited.

Washington State Department of Fisheries. Fisheries Resources in Southwest Washington. Jun 1973, for the Washington State Department of Ecology, Olympia, Wa.

Southwestern Washington was divided into four main river basin areas. Habitat, inventory and distribution, production, propagation, harvest, and factors limiting production are described for the fisheries resources in each basin. Developments beneficial to fisheries are also described. Emphasis is placed on the salmon fishery.

Water Resources Information System. A Selected Annotated Bibliography on Columbia and Snake Rivers. 1973, for State of Washington Department of Ecology, Olympia, Wash.

This bibliography on the Columbia and Snake rivers is a selected list of publications contained in the Water Resources Scientific Information Center data base from 1968 through 1972 and covers a wide range of information on the main stem of the Columbia and Snake rivers.

Author's Abstract

NORTHWEST DREDGING STUDIES

Durkin, J.T. An Investigation of Fish and Decapod Shellfish Found at Four Spoil Disposal Sites and Two Dredge Sites Adjacent to the Mouth of the Columbia River. Nov 1974, National Marine Fisheries Service, Completion Report to the U.S. Army Corps of Engineers and Columbia River Program Office.

This study was undertaken to document physical site characteristics, variables affecting catch, and the species of fish and shellfish associated with each site; and to determine species composition changes associated with either dredge or spoil activity, and the availability of each species in catch per unit effort. Forty-eight species of fish and four species of decapod shellfish were found at the six sites studied. Fish numbers and species were generally reduced immediately following both dredging and spoil disposal, but shellfish numbers showed an increase following some operations. More long-term work is needed to document these apparent trends.

Goodwin, C.L. Padilla Bay Dredge Spoil Disposal Project. Interim Report Mar 1974, Final Report Jul 1974, Washington State Department of Fisheries, Pt. Whitney, Wash.

The Interim Report discussed investigations conducted to designate a suitable spoil disposal site for maintenance hopper dredgings from the Swinomish Channel. The report concluded that the entire Padilla Bay area was important to the Dungeness crab fishery, but suggested a site in the Bay with muddy substrate as being less subject to adverse impact from disposal. The report also recommended that other areas outside the Bay be further investigated to find another more suitable site.

The Final Report summarized investigations conducted after the termination of the disposal operation. The extent of the disposed spoil was difficult to determine due to similarities with naturally-occurring substrate, but sandy dredged material appeared to extend beyond the designated disposal area. Divers reported no apparent extensive damage to the benthic community. However, sampling intensity was not sufficient to entirely rule out any negative impact.

LeGore, R.S. and D.M. Des Voigne. "Absence of Acute Effects on Threespine Sticklebacks (Gasterosteus aculeatus) and Coho Salmon (Oncorhyncus kisutch) Exposed to Resuspended Harbor Sediment Contaminants," Journal of the Fisheries Research Board of Canada, Vol 30, No. 8, 1973, pp 1240-1242.

Threespine sticklebacks (Gasterosteus aculeatus) and coho salmon fry (Oncorhynchus kisutch) were challenged in static 96-hr bioassays with suspensions of sediment from the Duwamish Waterway, Seattle, Washington. Doses of up to 5% wet weight (28.8 g/liter dry weight

basis) were used. No observable effect on the fish of contaminants released from the sediment was elicited, although high levels of these contaminants, such as volatile solids, cod, organic nitrogen, oil and grease, zinc, and lead, were present.

Author's Abstract

Murray, H.R. Study on Effect of Dredging on Water Quality and Sediment Transport in the Duwamish Estuary. 1972, U.S. Army Corps of Engineers; Consult. Rep. for the Seattle District Headquarters by Stevens, Thompson, and Runyon, Contract No DACW67-72-C-0116.

The hydrology, sediments, and water quality of the Duwamish estuary were studied in terms of the impact that dredging and disposal operations could be expected to have on these parameters. Besides a discussion of the probable direct impact of navigation projects in the estuary, alternatives for dredging and disposal operations were given, and recommendations were presented for improved methods of dredging and disposal. Short term effects of engineering activities in the estuary would be a significant increase in turbidity and a much smaller effect on dissolved oxygen and release of nutrients and metals. Long term effects would include changes in the hydraulics, sediment transport, and water quality of the estuary.

Northwest Environmental Consultants. Environmental Evaluation, Willapa River and Harbor Navigation Project, Washington. Sep 1974, prepared for U.S. Army Corps of Engineers, Seattle, Wash.

The environmental evaluation of the Willapa River and Harbor Navigation Project necessitated a broad based study of the Willapa Bay area. The major components of this study included the natural systems, the social systems, and the economic systems. Following the establishment of a wide, firm base of information which included extensive field observations, the study looks carefully at the project and area. Particular emphasis is placed on the effects of dredging, both in the environmental area and social-economic area. The area of bio-economics is discussed in an effort to apply various new models developed for other wetland areas. The models' limitations are pointed out as well as their potentials. The main body of the report sets the stage for the impact assessment of the proposed project and the available alternatives. A special matrix analysis is used to try and clearly indicate the relative impacts of the various project alternatives on selected environmental factors and community resources. The report is designed to integrate information from a variety of disciplines to present a clear concise picture of the complex issues surrounding the navigation project.

Author's Introduction

O'Neal, G. and J. Sceva. The Effects of Dredging on Water Quality in the Northwest. Jul 1971, Environmental Protection Agency, Office of Water Programs, Region X, Seattle, Wash.

The purpose of this study was to provide background data on river bottom materials, operating characteristics of dredging equipment, and spoil disposal practices, in order to aid in the review of proposed projects by environmental and fisheries agencies. A general description, the mode of operation, and the advantages and limitations of the kinds of dredges operating in the Northwest are given, as well as descriptions of water and land disposal and the double-handling of spoil. A literature review on environmental problems associated with dredging is presented. Characteristics of sediment in Northwest harbors are given, and a description of field studies of Northwest dredging projects is made. The study found that the location of spoil disposal sites is often on a job-to-job or "emergency" basis due to timing requirements. Pipeline dredging, the overflow of hopper dredges, and the hydraulic unloading of barges create large turbidity plumes, while the emptying of hopper dredges on bottom-dump barges produces less visible effect. The disturbance of bottom materials and the discharge of spoil can reduce dissolved oxygen levels and smother benthic organisms. Maintenance dredging of channels and harbors in the Northwest does not seem to foster the adverse impacts on bottom life and water quality that can be created by the discharge of polluted sediment. Disposal behind a dike or breakwater can prevent submarine mudflows, but dikes for land disposal of spoil often do not provide adequate detention time for settling. Settling occurs faster in salt water than in fresh.

Servizi, J.A., R.W. Gordon, and D.W. Martens. Marine Disposal of Sediments from Bellingham Harbor as Related to Sockeye and Pink Salmon Fisheries. Progress Report No. 23, 1969, International Pacific Salmon Fisheries Commission, New Westminster, B.C.

A recent proposal for dredging and marine disposal of sediment from Whatcom Waterway, Bellingham was of concern to fisheries agencies since the proposed disposal area was utilized by several fish stocks, including migrating Fraser River sockeye and pink salmon. Laboratory study indicated that two types of sediment were involved. Sediment from the inner harbor consisted primarily of putrefying pulp fibers which exerted a significant oxygen demand, created substantial turbidity, and were toxic to juvenile sockeye salmon because of their hydrogen sulfide content. Hydrogen sulfide was readily dissipated from inner harbor sediment by diffused air but was not removed by exposure for a few hours to the atmosphere. Various methods of widespread dispersal to dilute the sediment appeared impractical, and it was concluded that land disposal of inner harbor sediment would be necessary to protect fish stocks. Sediment from the outer harbor was a natural silt, not containing hydrogen sulfide, but exerted an oxygen demand and created a highly turbid mixture which settled

very slowly. Because dumping of this sediment at the proposed site could also prove harmful to fisheries, hydraulic dredging and local disposal adjacent to the outer harbor was recommended.

Author's Abstract

Slotta, L.S. et al. Effects of Hopper Dredging and In Channel Spoiling in Coos Bay, Oregon. July, 1973, Oregon Interdisciplinary Studies of the Schools of Engineering and Oceanography, Oregon State University, Corvallis, Ore.

An integrated study was conducted to gain insight on actual chemical, physical, and biological effects associated with the dredging and disposal activities of a hopper dredge in Coos Bay. Changes in median grain size, porosity, and volatile solids content of the sediments at both the dredging and disposal sites were determined. Bottom sediment instability was pronounced; frequent resuspension of the surface sediments was in evidence as sediment profiles revealed coarse material near the surface and finer materials settled at depth. Natural deposition provided more fines in bottom deposits than dredge spoiling. Chronic environmental impacts caused by continuous marine traffic may be more significant than the acute impacts caused by singular dredging operations. Free sulfides were not detected in interstitial waters of the sediments at the dredging site, nor overlying waters. Turbidity levels rose from 80 JTU to over 500 JTU in the wake of the dredge. The benthic fauna in the study area were representative of a moderately polluted environment. Significant reduction of infaunal abundance was observed following dredging and spoiling. The sampling techniques employed were adequate for describing acute effects of dredging, but more efficient techniques would be necessary to investigate the spatial and temporal distribution of chronic, long-term effects.

Modified Author's Abstract

Lynn D. Steiger and Associates. Proposed Modification of the Tillamook Bay and Bar Project, Tillamook, Oregon. Apr 1975, for U.S. Army Corps of Engineers, Portland, Ore.

Report prepared in association with the Tillamook County Board of Commissioners and the Ports of Tillamook Bay and Bay City to investigate the impacts of proposed navigation project.

Stevens, Thompson, and Runyon, Inc. Long Range Plan for Management of Dredge Spoils in Coos Bay, Oregon. Jan 1972, Portland, Ore.

This is a comprehensive report on dredging operations in the Coos Bay estuary and its possible environmental impact. A historical description of dredging practices is given along with specific case studies. The report listed probable physical impacts, the effects of dredging on water quality in terms of chemical and sediment data,

and the probable effects on estuarine ecology through direct destruction and the presence of suspended solids. The short range management plan involved consideration of site classifications, site selection criteria, physical and chemical factors, biological conditions, land use and economic factors, existing and new spoil disposal areas, environmental effects, and guidelines for private dredging. The long range management plan would consider factors relevant to the use, priority, and capacity of spoil disposal sites, and would include a consideration of possible alternatives.

Westley, R.E. Swinomish Dredge Spoils Disposal Project. 1973, Washington State Department of Fisheries, Pt. Whitney, Wash.

A three-part study was conducted to determine the effect of dredge spoil disposal on Skagit Bay. The study was concerned with three areas of the Bay: one area was the site of recent pipeline disposal, the second area was a site used previously for pipeline disposal, and the third area was the site of a proposed hopper dredge disposal operation. Before and after sampling of the first area indicated that the disposal of dredged material did not appear to affect either the benthic community or the substrate composition. The second area included sites used variously for spoil disposal for 16 years. The area showed low abundance and diversity of benthic organisms, but there was no correlation of abundance and diversity with time since disposal. The area did not appear able to support a large benthic community due to unstable substrate and its relatively high position in the tidal zone. The third area was similar to the first two in its low abundance and diversity of organisms. The Dungeness crab fishery could be impacted adversely by the proposed hopper disposal operation, but this possibility is remote because the material to be disposed of in the operation was the sandy substrate preferred by the crabs rather than the naturally occurring muddy substrate.

Westley, R.E. et al. Evaluation of Effects of Channel Maintenance Dredging and Disposal on the Marine Environment in Southern Puget Sound, Washington. Dec 1973, Department of Fisheries, State of Washington, Olympia, Washington.

The effects of a pipeline dredge and a clamshell dredge operating in Olympia Harbor were studied. Spoil from the clamshell operation was disposed in two locations to study the effect of spoil on differing marine environments. The study was complicated by major unforseen toxicity due to phytoplankton which interfered with bioassays and difficulties associated with discharge of sewage into Olympia Harbor. The major findings were as follows. Pipeline Dredging: Bioassays revealed no additional toxicity attributable to pipeline operation, and no inhibiting effect on phytoplankton. Silt in water was widespread, resulting in much spoil settling outside designated disposal area. No major change was noted in macrobenthos. Operation caused minor decrease in oxygen and minor increase in "biochemical oxygen demand". Barge Disposal in Budd Inlet: No additional toxicity or phytoplankton

inhibition was noted. Material primarily went to bottom with limited silt dispersal and was largely confined to disposal zone. Benthic organisms decreased in abundance but were not eradicated. Water quality was not significantly affected. Barge Dumping in Dana Passage: Material fell to bottom with little silt dispersal and spread laterally in water strata near bottom. Deposited material eroded at current velocities exceeding 26 cm/sec. Initially, depth of burial determined the presence or absence of geoducks, but observations after 5 months revealed geoducks in entire disposal area. Water quality was not significantly affected, and no additional toxicity was observed.

U.S. Army Engineer District, CE, Portland. Study of Hopper Dredging Coastal Harbor Entrances and Columbia River Estuary Bars, States of Oregon and Washington. Dec, 1973, Portland, Ore.

This report was prepared to provide information necessary to identify problems, determine solutions, and evaluate the operations carried out by the Portland District concerning coastal and Columbia River projects. Improper timing of dredging operations and poor spoil disposal locations can create negative environmental impacts such as topographical changes, habitat alterations, oxygen depletion, and biostimulation. Generally, the spoil produced by the dredging of navigation channels for the coastal harbor entrances and the Columbia River is disposed of in deep ocean water. Although the disposal of polluted spoil in open water can foster significant water quality problems, the greatest portion of dredged material produced by the projects covered in this report (including that from the Columbia River) is clean and sandy, not considered polluted by EPA cirteria. The human activities which primarily affect dredging needs are port facilities, industries, and the development of recreation opportunities. There is a lack of solid data concerning the impact of dredging operations. Recommendations are made for data collection and documentation.

Wick, W.Q. "Some Problems of the Coastal Zone: Estuaries--Dredging and Landfill," Northwest Estuarine and Coastal Zone Symposium, Proceedings, U.S. Bureau of Sports Fisheries and Wildlife, Oct 1970, Portland, Ore., pp 135-142.

This paper discusses the threat to Northwest estuaries which is posed by widespread dredging and filling activities. Although estuaries fill through natural processes, the disposal of waste spoil from channel dredging on wetlands, or the deliberate diking and filling of estuarine marginal areas to "reclaim useless land" represent planned destruction of a valuable resource. Studies have shown estuarine areas to be 20 times as productive as the open sea and twice as productive as cultivated land. The author recommends comprehensive planning which employs land and water zoning to avert the same type of massive destruction of Northwest estuarine areas as has occurred in other locations.

OTHER SITE SPECIFIC DREDGING STUDIES

Bassi, D.E. and D.R. Basco. Field Study of an Unconfined Spoil Disposal Area of the Gulf Intracoastal Waterway in Galveston Bay, Texas. Report No. TAMU-SG-74-208, Jan 1974, Coastal and Ocean Engineering Division, Civil Engineering Department, Texas A&M University, College Station, Texas.

Material obtained from maintenance dredging of the Gulf Intracoastal Waterway is presently deposited in unconfined, submerged disposal areas alongside the channel. Of interest, for economic and environmental reasons, is the dispersion of material with time. Grain-size analysis of bottom sediment samples, depth soundings, and wooden stakes were employed in field investigations to determine the approximate location of material from one such disposal area over a 5-month period after disposal. Immediately following deposition, over 40 percent of the material (based on original in-channel volume) had left the designated disposal area and spread out over the bay floor primarily as a mud-density flow. Eventually the material covered an area about three times larger than the original disposal area. Return of the material to the newly dredged channel did not appear significant during the study period primarily because of the predominant direction of tidal currents and the presence of a submerged dike along the channel. A brief summary of dredging and disposal practices is also included.

(from DMRP Newsletter)

Bastian, D.J. Effects of Open-Water Disposal of Dredged Material on Bottom Topography Along Texas Gulf Coast. Miscellaneous Paper D-74-13, Nov 1974, U.S. Army Engineers Waterways Experiment Station, CE, Vicksburg, Miss.

Analysis of hydrographic surveys of hopper dredge disposal areas in the Gulf of Mexico off the coast of Texas indicated that dumping at these sites had little effect on bottom topography. Apparently there are no definitive, discrete mounds of dredged material formed as a result of open-water disposal.

Author's Abstract

Brown, C.L. and R. Clark. "Observation on Dredging and Dissolved Oxygen in a Tidal Waterway," Water Resources Research, 1968, pp 1381-1384.

Many investigators contend that settled bottom deposits often caused a reduction in dissolved oxygen when they are resuspended in the water column. In addition, it might be expected that resuspension would cause increases in turbidity, settleable and suspended solids, and biochemical oxygen demands. Obviously, the severity of these increases and their effect on water quality would depend on the

amount of bottom material resuspended, the volume and dilution rate of the body of water, and the length of time the material remained in suspension. Evidence [in this study] indicates that resuspension of oxidizable bottom sediments in a tidal waterway caused significant reductions in the dissolved oxygen concentration of the water. During dredging, dissolved oxygen was reduced between 16-83% below normal.

Author's Abstract and Introduction

Chapman, C.R. "Channelization and Spoiling in Gulf Coast and South Atlantic Estuaries," Proceedings of the Marsh and Estuary Management Symposium, J.D. Newsom, ed., 1967, Baton Rouge, La. pp 93-106.

Channels and spoil banks are now a part of the estuarine environment. Several methods of construction are used that permit varying degrees of control over spoil. Mechanical excavation with bucket dredges or draglines provides good control on a small area. Hydraulic excavation, however, requires large spoil areas and affords poor control unless the spoil is removed from the construction site (hopper dredging) or retained within ring levees. More than 200,000 acres of shallow coastal bays (not including marshes) in the Gulf and South Atlantic areas have been lost by dredging and filling over the past 20 years. Other disadvantages of channelization and spoil dumping include segmentation of bays which promotes shoaling; increased salt-water intrusion; increased flushing time; altered tidal exchange, mixing and circulation; increased turbidity; and loss of submerged aquatic vegetation. None of these changes are as significant as the direct physical loss of habitat. Advantages of channels and spoil deposition include connection of isolated waters and marshes to make them available as fish nursery areas, provision of routes of escape or refuge for fish during cold periods, improvement of water exchange and circulation, and release of nutrients trapped in bottom sediments. Suggestions are made to reduce loss of habitat and to rehabilitate spoil areas.

Modified Author's Abstract

Courtenay, W.R. Jr. et al. Ecological Monitoring of Beach Erosion Control Projects, Broward County, Florida, and Adjacent Areas. Feb 1974, Florida Atlantic University for the U.S. Army Corps of Engineers, Contract No. DACW72-71-c-0004.

Ecological monitoring of algae, invertebrates, and fishes was conducted in the southeast Florida coast in connection with offshore dredging and beach nourishment projects. The Pompano Beach to Lauderdale-by-the-Sea segment of the Broward County Beach Erosion Control Project was surveyed from 3 August 1970 to 1 September 1972. No adverse ecological effects can be attributed to this beach restoration project. A community beach nourishment project at Hallandale, Broward County, was studied from 28 August 1971 to 1 September 1972. Damage to reefs

near borrow areas from sedimentation and physical destruction by dredging equipment was found. Three other study areas, Dania Beach and Deerfield Beach in Broward County, and South Lake Worth (Boynton) Inlet in Palm Beach County were surveyed from 30 October 1971 to 1 September 1972.

Modified Author's Abstract (from DDC Report Bibliography)

Cronin, L.E. Gross Physical and Biological Effects of Overboard Disposal in Upper Chesapeake Bay. NRI Special Report No. 3, Jul 1970, Chesapeake Biological Laboratory, Solomons, Md.

Six separate projects (Geology and Hydrography, Phytoplankton, Benthos, Zooplankton, Fish Eggs and Larvae, Fish) were conducted to investigate the effects of deepening the Chesapeake Bay approach to the Chesapeake and Delaware Canal. The individual investigators contributed the results of their respective projects, and the overall results were summarized by Cronin, who prepared the following list of effects: (1) Fine sediments were released as a semi-liquid mixture. (2) The turbidity which spread over an area of 1.5 to 1.9 sq. miles was within observed natural variation but occurred at a different time of year. (3) Suspended sediments formed a tide-related plume which extended a maximum of 3.1 miles and virtually disappeared two hours after pumping ceased. (4) Total phosphate and nitrogen increased by factors of 50 and 1000 respectively, but no effect on phytoplankton was observed. (5) The spoil covered to at least 1 foot an area 5 times the size of the defined disposal area. (6) About 12% of the spoil "pile" disappeared in 150 days after disposal. (7) No gross effect was observed on phytoplankton primary production, zooplankton, fish eggs and larvae, or fish. (8) In the spoil disposal area the benthic numerical abundance, biomass, and species diversity dropped (70% reduction, 65% reduction, marked reduction,respectively) but had assumed near predisposal levels in 1½ years. (9) The dredging site showed erratic species fluctuation. Also included in the summary are guidelines for dredging and spoil disposal, and additional recommendations.

Note: The participants of this study have published numerous other reports on research done at least in part under this contract. These publications may appear as progress or interim reports by the Chesapeake Biological Laboratory, or under the names Biggs, Cronin, Dovel, Flemer, Pfitzenmeyer, Schubel, and others.

Davis, J.D. "Dredge Spoil Disposal in Long Island Sound: A Coordinated Approach to a Power Project," Proceedings of the 19th Annual Technical Meeting, Apr 1973, Institute of Environmental Sciences, Anaheim, Ca.

Intensive predredging biological, chemical, and physical studies are under way as part of aquatic environmental studies developed

by Normandeau Associates for a power company constructing a generating station in New Haven, Connecticut. Sediment contaminant levels, bacterial content, and physical properties have been examined, and factors affecting potential disposal sites are being monitored. Characteristics of several potential dump sites are being examined in detail and effects of sediment deposition on epibenthic and benthic communities are being projected from laboratory and field studies.

(from DMRP Newsletter)

Harrison, W. "Environmental Effects of Dredging and Spoil Deposition," Proceedings of WODCON (World Dredging Conference), Tokyo, Japan, 1970.

The effects of dredging and associated spoil disposal are reviewed for two dredge operations in the lower Chesapeake Bay area. In one operation 1,260,000 cu. yds. of spoil were dumped from a hopper dredge on a target rectangle measuring 0.5 by 1.0 naut. mi., in water depths of 75 to 96 ft. Owing to the strong similarity in composition and size gradation of the spoil and natural bottom sediments, it was necessary to make an exhaustive sedimentological study of the dump area in order to identify concentrations of spoil. The most promising method for delineation of spoil utilized anomolous profiles of sediment strength and void ratio, as determined from piston core samples. Spoil disposal appeared to have only a transitory effect on the populations of infauna and epifauna. Resettlement in both the areas of dredging and spoil deposition was very rapid, occurring by active navigation of the animals and by the hydrodynamic distribution of juvenile in larval stages. It was found important to differentiate between transitory high populations of juveniles at certain seasons and normal fauna distributional patterns when attempting to assess the effect of dredging or spoil deposition on benthic organisms by means of "before" and "after" faunal surveys. Precise monitoring of possible spoil buildup on an oyster ground near a spoil outfall was accomplished by repeated diver measurements of the distance from the water-sediment interface to the tops of steel reference rods located along the perimeter of the oyster ground. Details of the field procedures are presented. Because the observed bottom fluctuations can be attributed exclusively to natural variations in erosion and deposition, the data presented constitute a useful reference on the variability in bottom level to be expected in the absence of spoil-induced sedimentation. The variations are of the order of a few millimeters per week.

Author's Abstract

Hellier, T.R. and L.S. Kornicker. Sedimentation from a Hydraulic Dredge in a Bay. Publication of the Texas Institute of Marine Science, 1962, Vol 8, pp 147-150.

It is routine in the digging of channels in Texas bays and lagoons for a hydraulic dredge to deposit sediment removed from channels in discrete piles called "spoil islands" or "spoil banks". The objective of the present study was to ascertain the amount of sediment distributed on a shallow fertile bay bottom as a result of sediment bypassing the spoil island during the dredging operations, and by later erosion of the spoil island. Red gravel was used to mark the bay sediment surface at 5 stations in turtle grass flats near Aransas Pass, Texas prior to the dredging of an intracoastal waterway. Cores were taken and sediments were studied before, one week after dredging, and 18 months later. 22 to 27 cm of sediment (11 to 55% silt-clay) were deposited within 0.5 mile of the dredge, but effects at greater distance were negligible. Little sediment sorting was observed during dredging.

Author's Abstract and Partial Introduction

Johnson, G.A. and C.C. Cable. "Dredging in the Great Lakes--Impact of Environmental Factors," The Society of Naval Architects and Marine Engineers, Spring Meeting, Convention Preprint, May 1974, Chicago, Ill.

The paper outlines the changes made by the Corps of Engineers, U.S. Army, in both dredging equipment and disposal methods to provide the desired environmental quality envisioned by Congressional law authorizing contained disposal facilities for the Great Lakes. The impact of these changes has tended to increase the cost of providing adequate channels and harbors for navigation purposes. The paper reviews past dredging practices; results of a pilot program, conducted 1966-1969, intended to develop the most practicable methods for management of pollution problems related to dredging operations on the lakes; and equipment changes required to meet new dredging requirements.

Author's Abstract

MacFarlane, I.C. "Predredging Study Clears LNG Ships Berth Plan," World Dredging and Marine Construction, May 1974, pp 42-46.

Results are presented and methodology is discussed for a study to provide data for an assessment of the potential impact of dredging and dredged material disposal on water quality and marine biota at a site near Port Hueneme Harbor, California. This case history contains a discussion of the steps taken to meet the criteria, standards, and policies in effect in the area.

(from DMRP Newsletter)

Mackin, J.F. Canal Dredging and Silting in Louisiana Bays. Publication of the Texas Institute of Marine Science, 1961, Vol 7, pp 262-314.

Effects of dredging on oysters were studied in shallow bays of Louisiana and discussed relative to the normally high turbidities of an eroding marsh area. High levels of turbidity and organic matter were measured in the bays of Louisiana and related to action of tides, waves, general land subsidence, disintegration of the shoreline, and seasonal patterns of equilibrium between scouring and redeposition. Erosion of the marsh islands was demonstrated as accentuated by the Mississippi levels. Calculations were made on sediment load, settling velocity, and transport. Three case histories of dredging were followed. Silt was carried a maximum of 1300 ft from the dredge with rapid disposal by dilution and sedimentation. A maximum of one percent of the material drifts away from the site of operation. Turbidities beyond a few hundred feet did not exceed the natural levels (20 to 200 ppm). Experiments showed no harmful effect on oysters of turbidities tested (5 to 700 ppm). Experiments indicate that dead oysters did not consume oxygen during decomposition at rates much greater than live oysters. Oxygen demand of sediments dispersed in dredging was relatively less than the surface sediments. Oxygen depletion with dredging in Louisiana marshes was found to be a relatively minor factor not responsible for mortality. By microscopic core comparisons, many soft silt conditions affecting the distribution of oyster reefs were traced to marsh erosion, disintegration, and subsidence, with cores unmistakably different from those in spoil deposits. Some legal controversies were discussed.

Modified Author's Abstract

May, E.B. "Effects on Water Quality When Dredging a Polluted Harbor Using Confined Spoil Disposal," Alabama Marine Resources Bulletin No. 10, May 1974, pp 1-8.

Dredging a polluted harbor using confined spoil disposal did not degrade water quality. Quality of water returned to the waterway was better than in the stream before or during dredging due to an increase in dissolved oxygen and removal of solids and hydrogen sulfide. There was no significant increase in trace elements.

Author's Abstract

May, E.B. "Environmental Effects of Hydraulic Dredging in Estuaries," Alabama Marine Resources Bulletin, No. 9, Apr 1973, Alabama Department of Conservation and Natural Resources, Dauphin Island, Ala.

Hydraulic channel and shell dredging and open water spoil disposal have little significant immediate effect on water quality in Alabama estuaries. Almost all of the sediment discharged by dredges settles very rapidly and is transported by gravity along the bottom as a separate flocculated density layer and potentially harmful components

of the mud are not dissolved into the water. There is a limited, temporary reduction in benthic organisms in areas affected by dredging. Spoil piles from channel dredges can indirectly affect the ecology and usefulness of estuaries by interfering with water circulation and affecting salinity. The basic hydrological concepts which determine the effects of dredging should be applicable in other areas. Extensive regulations apparently are not necessary to protect water quality in open water dredging situations but spoil disposal practices from channel dredges must be reconsidered and appropriate new disposal plans developed.

Author's Abstract

Naval Oceanographic Office, Physical Oceanography Division. Preliminary Report, Environmental Investigation of a Dredge Spoil Disposal Site near New London, Connecticut. NAVOCEANO Technical Note No. 7300-3-73, May 1973, Washington, D.C.

This report contains the results of a predump and immediately post-dump environmental monitoring program at a disposal site off New London, Connecticut, in June and November 1972. The measurement suite consisted of physical properities of the water, nutrients, bathymetry, currents, and selected heavy metals in sediments, and studies of the benthic fauna were also conducted. It was found that the disposal of 92,500 cu yd of dredged material caused minor changes in bathymetry but did not significantly change levels of heavy metals in either the water or sediment. Both the biomass and the species diversity of the area were reduced. Additional postdump monitoring will be conducted in May-June 1973.

(from DMRP Newsletter)

Pararas-Carayannis, G. Ocean Dumping in the New York Bight: An Assessment of Environmental Studies. Technical Memorandum No. 39, May 1973, U.S. Army Coastal Engineering Research Center, CE, Washington, D.C.

Individual studies by the Sandy Hook Lab of the National Marine Fisheries Service, the State University of New York at Stony Brook, and the Woods Hole Oceanographic Institution are summarized. These included hydrographic, geological, chemical, and biological investigations of the impact of the disposal of large quantities of dredged material, industrial wastes, sewage sludge, construction/demolition debris, and other materials on the ecology, water quality, and total environment of the area. The report also contains a summary of a feasibility study by the Sperry Rand Corp. of an electronic surveillance system for the area and it presents a discussion of the effect of ocean dumping in other regions.

(from DMRP Newsletter)

Reish, D.J. "A Study of Benthic Fauna in a Recently Constructed Boat Harbor in Southern California," Ecology, Vol 42, No. 1, 1961, pp 84-91.

A periodic quantitative study was made in a newly dredged marine boat harbor to determine whether or not the subtidal benthic fauna succession occurred on the bottom. Polychaetes comprised 60% of the species and 87% of the specimens collected. Molluscans, crustaceans, and nemerteans were the other important groups taken. A peak in the number of species and specimens was reached about two years after sea water was first let in. The population decreased markedly in the ensuing year. Various explanations for this reduction in the number of species and specimens are discussed. The principal bottom-dwelling species in Alamitos Bay Marina include 11 species of polychaetes, unidentified nemerteans, and one species of pelecypod. The occurrence, abundance, and ecology of these species are discussed. There was no evidence of succession in Alamitos Bay Marina. The principal species were dominant during the entire period of study. The bottom fauna was compared with the other portions of Alamitos Bay, Lower Newport Bay, and outer Los Angeles-Long Beach Harbors. In general, the fauna of all regions were similar. The polychaete Cossura candida was only encountered sparingly in the marina, but this species constitutes an important element of the benthic fauna in the other area.

Author's Summary

Reish, D.J. "A Study of Succession in Recently Constructed Marine Harbors in Southern California," Proceedings, First National Coastal and Shallow Water Resources Conference. 1961, Baltimore, Los Angeles, and Tallahassee. abst. p 73.

Four small boat harbors have been or are in the process of being constructed in Southern California. Since these harbors were dredged from land, it offered an opportunity to study the appearance and community development in the benthos, pilings, floats, and jetties. Emphasis has been placed on the bottom-dwelling and fouling organisms in Alamitos Bay and upon the intertidal organisms of the rock jetties of Playa del Rey and Ventura County Marinas.
In general, succession takes place in areas where organisms attach to solid substrate but there is little or no indication of the process occurring in the sediments. The earliest macroscopic inhabitants on rock jetties are the green algae Enteromorpha minima in the upper zone and Ulva dactylifera in the mid-intertidal zone. These algae reach their peak in growth about four months after first exposure to sea water. The algae are gradually replaced by barnacles, limpets, snails, and shore crabs in the upper zone, and by the mussel Mytilus californianus in the mid-intertidal zone.

Benthic animals were first observed six weeks following the completion of dredging activity at a particular locality. Appearance of additional species was rapid with a plateau in numbers being attained within ten months. Approximately one year following dredging, the number of species began to diminish at the innermost stations but not the stations in the main channel. This was attributed to limited water circulation which lead to a decrease in dissolved oxygen and the appearance of sulfide odors.

Author's Abstract

Reish, D.J. and T. Kawling. "A Comparison of the Benthic Polychaetous Annelids from a Dredged and Undisturbed Area of Anaheim Bay, California," Second National Coastal and Shallow Water Research Conference, Abstract Volume. 1971, D.S. Gorsline, ed., Baton Rouge, Newark, and Los Angeles.

The southern reaches of Anaheim Bay were dredged and developed into the Huntington Harbour marina-residential complex during the years 1961-1965. A quantitative benthic survey of the polychaetous annelids was made of this region and the undisturbed area which lies within the boundaries of the Seal Beach Naval Weapons Depot in July 1970. Since it was known from earlier studies from nearby Alamitos Bay that benthic stability is reached within 2-3 years, these results gave some indication of the effects of dredging on estuarine, subtidal polychaete population. A total of 18 stations was occupied of which 7 were in the dredged region and 11 from the undisturbed part of the bay. A total of 45 species of polychaetes was collected; the number of species averaged 12 and 10 from the dredged and undredged areas, respectively; whereas, the number of specimens averaged only 100 from the dredged region as compared to 430 from the undisturbed area. Nine dominant species were present in reduced numbers from the dredged area. Only four species increased in numbers in the dredged as compared to the undisturbed area. Not one species, among the more prevalent ones, was found in equal numbers from both areas. Since the majority of these species either reproduce throughout the year or have extended reproductive seasons, the differences in the polychaete fauna composition are believed to be the result of habitat change rather than an insufficient length of time for community development.

Modified Author's Abstract

Saila, S.B., S.D. Pratt, and T.T. Polgar. Dredge Spoil Disposal in Rhode Island Sound. Marine Tech. Report No. 2, 1972, University of Rhode Island, Kingston, R.I.

Spoil was taken from a navigation channel in Providence Harbor and Providence River to a 1 mile sq. dumping site in Rhode Island Sound. An investigation was undertaken to determine the disposition of spoil on site, sediment characteristics, and effects of the spoil on benthic fauna and fish. Polluted sediment from Providence Harbor was largely covered by sediments from the river. Although the spoil

had a larger silt/clay fraction and was therefore more subject to erosion than the surrounding fine sands of the dump site, the deposition and characteristics of the spoil resulted in a degree of erosion resistance, primarily due to the formation of lag deposits by coarser fractions. No large scale loss of spoiled sediment from the dump site occurred during or after the operation. Waves in the dump area develop bottom velocities effective in resuspending sediments, but currents in the region are not alone effective in resuspension. Literature concerning the reactions of benthic fauna to burial, turbidity, anoxia, and metal- or hydrocarbon-contaminated sediments was reviewed. Recently dumped spoil yielded few benthic animals but areas of spoil which had been subject to colonization for up to 3 years yielded large numbers of species. Several species were transported from the dredge area, but most of the colonizers were characteristic of the surrounding sand bottom community. Ocean quahogs were found which were killed by burial, but the trawl fishery in the area did not seem greatly affected. Lobstering was the least affected fishery. Recommendations were made for future dump site management and for research needs.

Smalley, A.H. et al. "Sand, Gravel Dredging Effects on Tennessee River Analyzed," World Dredging and Marine Construction, Jun 1974, pp 33-35.

In a study designed to measure only gross effects, it was found that sand and gravel dredging has a brief and generally minor localized effect on the aquatic environment. The article discusses the effects of turbidity, destruction of benthic fauna, effects on zooplankton and phytoplankton populations, and differences in effects due to the manner in which dredging is done as discerned in studies in the Kentucky and Fort Loudon Reservoirs.

(from DMRP Newsletter)

Soloman, C.H. Physical, Chemical, and Biological Characteristics of of Nearshore Zone of Sand Key, Florida, Prior to Beach Restoration. June 1974. National Marine Fisheries Service, Panama City, Florida.

The study defines some of the major physical, chemical, and biological characteristics of nearshore zone off Sand Key, Florida before restoration by dredging. Results of a supplemental study on the effects of hydraulic dredging for emergency restoration of Sunset Beach on Treasure Island, Florida, are included. An extensive bibliography is also presented. Included also is data on benthic invertebrates.

(from DDC Report Bibliography)

Soloman, R.C. et al. Physical, Biological, and Chemical Inventory and Analysis of Selected Dredged and Disposal Sites, Middle Mississippi River. Miscellaneous Paper Y-74-6, Nov 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

A study was conducted to describe the physical, biological, and chemical characteristics of selected Mississippi River sites, to establish uniform sampling techniques, and to describe environmental impacts of dredging and disposal activities. Parameters discussed include: dissolved oxygen; pH; alkalinity; temperature; turbidity; settleable solids; sediment characteristics; phytoplankton, zooplankton, and benthic populations; river stages; and meteorological conditions. The sediments in the dredged channels were found to be coarser and not as suitable for substrate as those found in spoil disposal and river border areas. Recolonization of benthic areas was generally found to occur within a year, dependent on substrate. The mean number of benthic organisms was greatest in river border areas, intermediate in disposal areas, and least in dredged areas.

Taylor, J.L. and C.H. Soloman. "Some Effects of Hydraulic Dredging and Coastal Development in Boca Ceiga Bay, Florida," Fishery Bulletin, Vol 67, No. 2, 1968, U.S. Fish and Wildlife Service, Washington, D.C.

Filling of 1,400 hectares (3,500 acres) of bay by hydraulic dredging has reduced the area of Boga Ciega Bay, Fla., by about 20 percent since 1950. An estimate of the annual standing crop destroyed is 1,133 metric tons (798 kg per hectare, dry whole weight) of sea grass, and about 1,812 metric tons (1,277 kg per hectare, dry weight) of associated infauna. In terms of annual production, the loss of biological resources is far greater--minimum estimates are 25,841 metric tons of sea grass, 73 metric tons of fishery products, and 1,091 metric tons of infauna exclusive of meiofauna. Natural areas remaining in the Bay support local and offshore fisheries and are of value for recreation, public utilities, commerce, and industry. At an estimated value of $988 per hectare per year, worth of the estuarine area already eliminated is $1.4 million annually. In addition, inestimable secondary losses occur, principally from sedimentation, turbidity, and domestic sewage.

Author's Abstract

Technical Committee for Analysis of Mobile Bay Dredging. Environmental Investigations of Mobile Bay, Alabama. Jul 1973, for the Environmental Protection Agency, Washington, D.C.

The Technical Committee was charged with investigating dredging in Mobile Bay by determining the extent of existing and proposed operations, reviewing available data, and conducting a baseline environmental study. Four main areas are described along with background information on Mobile Bay. Shell Dredging: was found not

to affect bottom topography and hence has a negligible effect on circulation; creates a small increase in turbidity; has little effect on dissolved oxygen, pH, or water content of pollutants such as heavy metals; is characterized by good benthic recovery. Channel Maintenance Dredging: causes more profound physical modifications which tend to intensify summer conditions of stratification and depressed dissolved oxygen levels; is similar to shell dredging in other effects. New Channel Construction : has little effect on water quality; causes heavy but short-term benthic destruction. Dike Spoil Disposal: is characterized by little or no information. Recommendations are made concerning further research and improved dredging operations.

U.S. Army Engineer District, San Francisco, CE. Dredge Disposal Study for San Francisco Bay and Estuary. 1971, San Francisco, Ca.

A comprehensive study is being done on the effects of dredging and spoil disposal on the San Francisco Bay estuary. The completed study will include definition of sediment types, reaction of the sediments in the water column and on the bottom, the reaction of biological communities to dredging and disposal activities, and the possible presence of pollutants. Completed presently are Appendix A: Main Ship Channel (San Francisco Bay) and Appendix J; Land Disposal. The final report will include the following appendices: B: Pollutant Distribution, C: Water Column (Water Column and Oxygen Sag), D: Biological Community, E: Material Release, F: Crystalline Matrix, G: Physical Impact, H: Pollutant Uptake, I: Pollutant Availability, K: Marsh Development, L: Ocean Disposal, and M: Dredging Technology.

U.S. Fish and Wildlife Service. Effects on Fish Resources of Dredging and Spoil Disposal in San Francisco and San Pablo Bays, California. Nov 1970, Washington, D.C.

Field and laboratory studies were conducted during the period Sept. 1967 to Aug. 1969 to determine effects dredging and spoil disposal would have on fish and wildlife environment in selected and representative reaches of San Francisco and San Pablo Bays. These studies were restricted to key indicator species. Study results indicated that variables, such as rapidly fluctuating salinities, influence the variety and size of the biological communities. The effects of dredging and spoil disposal were not clearly apparent in certain localities such as deep channel areas near Mare Is. and shallow portions of San Pablo Bay. Data collected in more stable areas (near Marin Is. and Pt. San Pablo) indicated dredging and spoil disposal significantly reduced the number and species composition of various benthic organisms, bottom associated invertebrates, and demersal (bottom associated) fishes. While certain species were reestablished in a period of a few months after spoiling, the "general health" of the environment in this area, as measured by diversity of benthic organisms, was not restored during the study period.

Laboratory studies on selected Bay fishes demonstrated that turbidity levels in excess of 500 JTU (Jackson Turbidity Units) generally adversely affected their viability. Data also indicate that organisms, when exposed to turbid waters, generally accumulate greater concentrations of pesticides.

Author's Abstract

BIOLOGICAL STUDIES; HABITAT DEVELOPMENT

Beaman, B. Patterns of Plant Community Structure and Vegetational Zones on Spoil Islands in Sarasota Bay and Charlotte Harbor, Florida. Jun 1973, New College, Sarasota, Fla.

As part of a thesis project, patterns of vegetation were studied on islands created by the disposal of dredged material. These islands represent areas of primary succession. Data on density, cover, and sociability were obtained. Four major plant communities are described: (a) a pioneering community of strand plants on open beaches and spits represents the first stage of colonization, (b) a second community of mangroves (Avicennia germinans, Rhizophora mangle, and Laguncularia racemosa) located in the intertidal zones of leeward shores is formed from mangrove seedlings in the first community, (c) a third community at the storm tide zone is dominated by the australian pine (Casuarina equisetifolia), and (d) the fourth community, located in open sandy upland areas, consists of herbaceous plants and shrubs. The availability of water as a controlling factor is discussed. Two trends in the succession of upland areas were observed: (a) the first is characterized by an increase in plant biomass and diversity, and (b) the second is common to zones colonized by the australian pine and shows a reduction in species diversity.

(from DMRP Newsletter)

Carlisle, J.G. "Marine Habitat Improvement in California," Proceedings First National Coastal and Shallow Water Resources Conference, 1961. Baltimore, Los Angeles, and Tallahassee, abst. p 66.

The California Department of Fish and Game initiated an Ocean Fish Habitat Development Project in April, 1958, designed as an experimental program to evaluate artificial reefs as a method of attracting fish in coastal waters and to test the practicability of establishing giant kelp beds on artificial reefs and other suitable areas by transplantation and natural seeding. Evaluation and kelp transplantation have been carried out by biologist-divers using self-contained diving gear. During dives the biologists determine species of fish attracted and their total numbers, collect and study encrusting organisms, and make observations of the environment. Barren sandy areas have been chosen for artificial reefs. Transect lines were run by the divers to determine life in the area. Artificial reefs have been built using old car bodies, streetcars, quarry rock, and concrete shelters. A peak population has been observed on a reef of 20 car bodies of 24,000 semi-resident fishes plus transient pelagic species. A replication experiment, designed to give information on fish preferences, relative cost, and life of materials, has been set up. Although natural seeding has produced a good kelp bed on one of the reefs, transplantation techniques have not been successful. Both local kelp and a warm-water resistant strain from

Mexico have been used. Plant loss has resulted from heavy grazing of fishes or from physiological causes. Three full-time diver-biologists have been engaged in this study which probably terminate sometime around its sixth year.

Author's Abstract

Cordone, A.J. and D.W. Kelley. "The Influence of Inorganic Sediment on the Aquatic Life of Streams," California Fish and Game, Vol 47, No. 2, 1961, pp 189-228.

This report is a summary of the investigations most pertinent in determining the effects of inorganic sediment on the aquatic life of streams. The sections of the review are: direct effect of sediment upon bottom organisms, influences of sediment upon aquatic plants, influences of sediment upon chemical and physical characteristics, influences upon fish habitat and fish populations, sediment standards, and long-term siltation research. The authors conclude that there is abundant evidence that sediment is harmful to aquatic life in streams, and that much of the damage could be avoided by careful land use methods.

Davis, H.C. "Effects of Turbidity Producing Materials in Sea Water on Eggs and Larvae of the Clam (Venus (Mercenaria) mercenaria)," Biological Bulletin, Vol 118, No. 1, 1960, pp 48-54.

The results of this study are: (1) Some clam eggs developed normally in concentrations of 4.0 g/l of clay, precipitated chalk or finely ground Fuller earth, although the percentage developing normally decreased as the concentration of these suspended materials increased; (2) In silt concentrations below 0.75 g/l the percentage of clam eggs developing normally was not significantly different from that in control cultures but decreased progressively in successively higher concentrations; (3) None of the clam eggs developed normally in silt concentrations of 3.0 or 4.0 g/l; (4) Larvae resulting from clam eggs developing in high concentrations of each of the suspended materials were reared to metamorphosis after being returned to normal sea water at 48 hrs; (5) Clam larvae were unable to grow in concentrations of clay, chalk, or Fuller's earth as high as those in which some eggs developed; (6) The highest concentration of chalk was 0.25 g/l, and 0.5 was the highest concentration of clay and Fuller's earth at which clam larvae showed any growth and mortality, and mortality exceeded 90% at all higher concentrations; (7) In a silt concentration of 0.75 g/l growth of clam larvae was approximately normal and at lower concentrations was slightly faster than that of larvae in control cultures; (8) In silt concentrations of 1.0 to 2.0 g/l growth was negligible; (9) Even at a silt concentration of 4.0 g/l there was no appreciable mortality of clam larvae within 12 days.

Author's Summary

Davis, H.C. and H. Hidu. "Effects of Turbidity Producing Substances in Sea Water on Eggs and Larvae of Three Genera of Bivalve Mollusks," Veliger, Vol II, No. 4, 1969, pp 316-320.

The results of this study are: (1) As little as 0.188 g/l of silt caused a significant decrease in the percentage of oyster eggs developing normally, as did 3 g/l of kaolin or 4 g/l of Fuller's earth; (2) The percentage of American oyster eggs developing normally was not affected by concentrations of silicon dioxide of 4 g/l, regardless of particle size; clam eggs were affected only at 4 g/l of the smallest particles; (3) Survival of European oyster larvae was less affected by silt, kaolin, and Fuller's earth than was survival of larvae of either American oysters or hard clams; (4) The smallest particles of silicon dioxide had the greatest effect on survival and growth of clam and oyster larvae; larger particles had little effect on survival of either species or on growth of clam larvae; growth of American oyster larvae decreased progressively as the size of silicon particle was decreased; (5) Growth of European oyster larvae was less affected by kaolin and Fuller's earth than was growth of larvae of the American oyster or hard clam, but was more strongly affected by silt than was the larvae of either of the other two species; (6) Bivalve larvae grew faster in low concentrations of turbidity-producing substances than in clear sea water, possibly because the suspended particles chelate or absorb toxins present in oyster cultures; the "optimum" concentration of suspended material probably depends upon the amount of toxin to be chelated or absorbed.

Author's Summary

Howell, B.R. and R.G.S. Skelton. "The Effect of China Clay on the Bottom Fauna of St. Austell and Mevagissey Bays," Journal, Marine Biological Association, Vol 50, 1970, pp 593-607.

The deposition of china-clay wastes has had a marked effect on the bottom fauna of St. Austell and Mevagissey Bays. Apart from an immediately inshore zone, where the rate of clay deposition is apparently severely limiting, the clay-affected zones support a rich community of deposit-feeding animals. Suspension-feeding forms which are common outside the clay deposits and in an adjoining bay, are largely absent from St. Austell and Mevagissey Bays.

Author's Abstract

Ingle, R.M. Studies on the Effect of Dredging Operations Upon Fish and Shellfish. Technical Series No. 5, 1952, Florida State Board of Conservation, St. Petersburg, Fla.

Investigations were made to determine the effects of dredging operations upon fish and shellfish in the vicinity of Great Point Clear, Alabama. Damage to scalefish and motile crustacea was not observed, even within 25-50 yards of an active dredge. Shellfish were not found to suffer damage when suspended from dredge itself. Damage

due to larger particles of mud occurred on bottom in immediate neighborhood of dredge, but did not extend beyond 400 yards. In most cases this distance was much less, in some cases being about 75 yards. Because momentary conditions of tide, speed of current, speed of dredging vary, and variations exist in various bay bottoms, every situation merits separate consideration. Controlled dredging is suggested as the best solution. By this method the dredging activity is coordinated with local conditions, spatial and temporal. In the areas under consideration (West Florida and Alabama), controlled dredging should begin to operate at 400 yards distance from live oyster reefs. There is some evidence that dredging stirs up organic detritus resulting in a beneficial effect to shellfish and crustaceans.

Author's Abstract

Jones, J.R.E. Fish and River Pollution. 1964, Butterworth and Co. Ltd., Toronto.

This book describes the physiological effects of pollutants on fish, their behavioral reactions to polluted waters, and research which has been conducted to investigate the effect on fish of river pollution. Included are chapters on low dissolved oxygen, toxicity, metals, cyanides and sulphides, inorganic gases, acids and alkalis, synthetic detergents and soaps, insecticides and herbicides, phenols, thermal pollution, suspended matter, complex effluents, and pollution effects on fish eggs.

Loosanoff, V.L. and F.D. Tommers. "Effects of Suspended Silt and other Substances on the Rate of Feeding of Oysters," Science, Vol 107, 1948, pp 69-70.

The rate of pumping, and therefore feeding, of oysters was measured in response to various concentrations of inorganic turbidity-creating materials and silt. The oysters showed a sensitivity to even low concentrations of suspended particles. Pumping was significantly reduced by concentrations as low as 0.1 g/l, and increasingly higher concentrations promoted a greater and greater reduction in pumping rate until pumping sometimes ceased altogether. Suspended sediment concentrations of 3 to 4 g/l caused reduction in pumping rate of 94%. These concentrations are similar to those occurring during heavy floods or dredging operations.

Peeling, T.J. A Proximate Biological Survey of San Diego Bay, California Report No. NUC-TP-389, Jun 1973, Naval Undersea Center, San Diego, Ca.

From December 1972 to June 1973 a literature review and field-sampling program were conducted to acquire environmental information concerning San Diego Bay, California. The primary goal was to obtain data in the vicinity of local naval installations that could be used as a baseline in evaluating environmental conditions at other naval

installations in temperate waters. A secondary goal was to document existing conditions in the bay. This report presents the results of the survey, including data on the historical uses of the bay, changes in water quality, and past and present biological conditions.

Modified Author's Abstract (from DDC Report Bibliography)

Reish, D.J. "Seasonal Settlement of Polychaetous Annelids on Test Panels in Los Angeles-Long Beach Harbors, 1950-1951, "Journal of the Fisheries Research Board of Canada, Vol 28, No. 10, 1971, pp 1459-1467.

Twenty-four species of polychaetes settled on test blocks suspended at 13 stations in Los Angeles-Long Beach Harbors in 1950-1951. *Polydora limicola*, *Capitella capitata*, and *Hydroides pacificus* were the three most frequently occurring species. Although a peak in settling occurred during the spring months, in general, the warmer the water, the greater the number of species present. However, *H. pacificus* possessed a summer-fall peak, and *C. capitata* exhibited no apparent peak. Many of the species reproduced throughout the year, as indicated by settlement data. A suppression in the number of species was observed whenever the dissolved oxygen concentration was below 4.0 mg/liter.

Author's Abstract

Romig, R.F. and L.J. Contoir. "Effect of Oxygen on Zonation, Growth, and Reproduction of Salt Marsh Grasses," Second National Coastal and Shallow Water Research Conference, Abstract Volume, 1971, D.S. Gorsline, ed., Baton Rouge, Newark, and Los Angeles.

The dissolved oxygen content of water in wells established on a transect across plant zones was determined at frequent intervals. Factors controlling variations in the oxygen content were examined. Plant zonal differences appear to be related to the degree of water saturation of the marsh soil, which in turn controls the degree of soil water aeration. Higher oxygen levels are associated with taller growth, more profuse flowering and greater depth of viable roots of *Spartina alterniflora*. Cubic foot blocks of *S. alterniflora*, dwarf form, *S. alterniflora*, tall form, and *S. patens* when transplanted from their zone of natural occurrence to other zones, substantiated their preference for suitable soil water aeration. For example, the dwarf form became substantially taller when transplanted into an area normally occupied by the tall form, while the tall form did not thrive as well when transplanted into an area normally occupied by the dwarf form. Salinity measurements were also made at periodic intervals in the wells. The salinity of the water has considerably less influence on the growth of the marsh grasses than does the dissolved oxygen.

Modified Author's Abstract

Schubel, A.H. et al. Effects of Suspended Sediment on the Development and Hatching Success of Yellow Perch and Striped Bass Eggs. 1973. Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Md.

Yellow perch and striped bass eggs were incubated in suspensions of different concentrations of natural, fine-grained sediments. The results showed that in the laboratory concentrations of up to 500 mg/l did not significantly affect the hatching success of yellow perch or striped bass eggs, but that concentrations of 1000 mg/l did significantly affect their hatching success.

Author's Abstract

Sherk, J.A. et al. Effects of Suspended and Deposited Sediments on Estuarine Organisms, Phase II. Final Report, Mar 1974, Department of Environmental Research, Chesapeake Biological Laboratory, University of Maryland, Solomans, Md.

A 3-year laboratory study identified biological components of selected populations of estuarine organisms which were most sensitive to the effects of particle size and concentration of (1) suspended mineral solids similar in size to sediments likely to be found in, or added to, estuarine systems in concentrations typically found during flooding, dredging, and disposal of dredged material, and (2) natural sediments in identical experiments. Significant mortality of estuarine fishes was demonstrated. Generally, bottom-dwelling fish were most tolerant to suspended solids; filter feeders were most sensitive. Early life stages were more sensitive to suspended solids than adults. Bioassays with natural sediments indicated that suspensions of natural muds affect fishes in the same way as Fuller's earth, but higher concentrations were required to produce the same level of response. Sublethal solids effects on fishes were identified. Suspended sediment reduced carbon assimilation by phytoplankton, and the ingestion of food by copepods. With adequate knowledge of local conditions at estuarine sites selected for environmental modification, our efforts provide baseline data for preproject decision making based upon concentration effects of different types of suspended sediments.

Modified Author's Abstract

Sherk, J.A. Jr. and L.E. Cronin. The Effects of Suspended and Deposited Sediments on Estuarine Organisms, An Annotated Bibliography of Selected References. Reference No. 70-19, 1970, Natural Resources Institute, University of Maryland, Solomans, Md.

Interest in the effects of suspended loads and deposited sediments on estuarine organisms has been accelerated by the present need to establish water quality criteria and standards on a national scale and by a wide variety of coastal engineering projects which

involve temporary or enduring changes in the suspended loads and deposition of sediments in rivers, bays, sounds, channels, or coastal areas. Estuarine sites selected for projects are often inhabited by unusually important biotic communities which become centers of conflict among navigational, recreational, commercial fisheries, conservation, and municipal interests. This set of abstracts and summaries of pertinent reports has been prepared to assist in the evaluation of probable effects of suspended and deposited sediments.

(from DDC Report Bibliography)

Skidaway Institute of Oceanography. Research to Determine the Environmental Response to the Deposition of Spoil on Salt Marshes Using Diked and Undiked Techniques. Mar 1973, prepared for U.S. Army Corps of Engineers under Contract No. DACW-21-71-C-0020.

This report summarizes initial findings and outlines continuing objectives of the comprehensive study. Water quality studies indicated that water quality changes during dredging and disposal activities could not be predicted on the basis of the bulk composition of the dredged sediments. The quality of water leaving spoil disposal areas was shown to vary considerably. Longer retention of water in diked disposal areas did not necessarily lead to improved water quality because of a high ammonia content which could be diluted by immediate runoff. A dynamic approach to the prediction of water quality changes which utilizes test situations is recommended. Biological studies included trawling for ichthyofauna and macroinvertebrates, and on-going benthic sampling. There was no apparent effect of dredging on standing crops or species composition in areas having undiked spoil disposal. Studies were conducted into the regeneration of marshes using salt grass seeding and transplanting.

Smith, W.G. Spartina Die-back in Louisiana Marshes. Report No. TR-91, Dec 1970, Louisiana State University, Baton Rouge, La.

"Die-back" is a term applied to degeneration and death of large areas of *Spartina townsendii* marshes in England. What appears to be the same condition affects *S. alterniflora* marshes in Louisiana and possibly elsewhere in North America. Several factors are likely to be involved and should be assessed in future work. These include (1) excess salinity, (2) pathogenic organisms, (3) lack of available iron, (4) hydrogen sulfide toxicity, (5) change of tidal regime, and (6) pollution. It is especially important that the effects of pollution and alteration of tidal regime through dredging be investigated.

Author's Abstract

Sweeney, R.A. Proposed Modifications of Corps of Engineers Disposal Sites as Wild-Life Refuges and Breeding Areas. Final Report, Dec 1973, Great Lakes Laboratory, State University College, Buffalo, N.Y.

Under a grant from the New York State Sea Grant Program, two filled disposal sites in the Buffalo Harbor were evaluated for their potential use as wildlife feeding and breeding areas. Individual studies considered the engineering characteristics of the fill, including drainage, consolidation characteristics, bearing capacity, and slope stability (by D.L. Wright), mercury accumulation in diked disposal area ecosystems (by L. Perrott), and the present and potential ecological status of the sites (by R.A. Sweeney). The studies concluded there are no significant constraints on the economical employment of the sites for the considered use.

(from DMRP Newsletter)

Warren, C.E. et al. Development of Dissolved Oxygen Criteria for Fresh Water Fish. EPA 660/3-73-019, Feb 1973, Environmental Protection Agency, Washington, D.C.

The research reported involved laboratory studies on the survival, development, bioenergetics and growth, swimming performance, and avoidance behavior of chinook and coho salmon, steelhead trout, and largemouth bass. In some important cases, close correspondence was found between the effects of reduced oxygen concentrations in aquarium studies of growth at maximum rations and its effects under more natural conditions in laboratory streams and ponds. Some of the biological responses of the fish studies were affected by any appreciable reduction in dissolved oxygen below the air saturation levels, whereas others were affected only at levels below about 50% the air saturation levels.

from Author's Abstract

Whitmore, C.M. et al. "Avoidance Reactions of Salmonid and Centrarchid Fishes to Low Oxygen Concentrations," Trans. American Fisheries Society, Vol 89, No. 1, 1960, pp 17-26.

All of four fish species used in 174 laboratory experiments with a "channeled avoidance tank" avoided some low oxygen concentration, the degree of avoidance generally decreasing with increasing concentration. Avoidance indices computed were based on numbers of entries into two experimental channels with reduced oxygen concentrations and two control channels, on numbers of crossings of a transverse line located well inside each channel, and on numbers of fish observed in the channels at 60-second intervals. Juvenile chinook salmon showed marked avoidance of oxygen concentrations of 1.5, 3.0, and 4.0 mg/l in summer at high temperatures. A decrease of the avoidance observed in the fall is ascribable to lower temperatures. The chinook salmon showed little avoidance of concentrations near 4.5 mg/l in

the fall, and no avoidance of concentrations near 6.0 mg/l at anytime. At summer temperatures, juvenile coho salmon showed some avoidance of all the above oxygen concentrations, including 6.0 mg/l, but their behavior was erratic and their avoidance of concentrations near 4.5 mg/l and less was not as pronounced as that of chinook salmon at corresponding temperatures. Largemouth bass and bluegill markedly avoided concentrations near 1.5 mg/l, but showed little or no avoidance of the higher concentrations, only the bass showing any avoidance of concentrations near 4.5 mg/l. The nature and significance of the observed avoidance reactions are not quite clear. The prompt avoidance by some fish of oxygen concentrations well above those known to be lethal cannot be ascribed entirely to mere stimulation or increase of activity due to oxygen deficiency. It may not be assumed, however, that oxygen concentrations avoided under the experimental conditions are usually avoided likewise under natural conditions.

Author's Abstract

Windom, H.L. "Environmental Aspects of Dredging in Estuaries," Journal, Waterways, Harbors, and Coastal Engineering Division, American Society of Civil Engineers, Vol 98, No. WW4, Nov 1972, pp 475-487.

Salt marsh estuarine environments along the Intracoastal Waterway of the southeastern Atlantic coast were studied to determine the environmental effects of dredging in these areas. The study dealt with the chemical response of salt marsh sediments to the deposition of dredge materials and with the water quality response to dredging and deposition of sediments in a salt marsh estuarine environment. After the initial destruction of the salt marsh plants due to spoil deposition, the rate of reequilibration of the marsh sediments to their original state (suitable for revegetation) is greatly dependent on the depth of the dredge spoil deposit. In natural and relatively unpolluted areas, dredging has no significant effects on water quality when either diked or undiked confinement techniques are used. In polluted areas in marine environments, water quality impairment caused by dredging activities does not necessarily bear any simple relation to the composition of the sediments to be dredged.

Author's Abstract

Woodburn, K.D."Dredging and Filling, Shellfish Cultures, Artificial Reefs: Their Effects on Marine Productivity in Florida," Proceedings, First National Coastal and Shallow Water Resources Conference, 1961, Baltimore, Los Angeles, and Tallahassee, abst. p 54.

Dredging and filling of waterfronts real estage, drainage canals, and navigational channels are the most serious threats to marine life, marine environments, and sports and commercial fishing in

Florida. The Florida State Board of Conservation evaluates dredging and filling proposals, recommends bulkhead line settings, and suggests plan modifications when requested by government bodies interested in minimizing damages to marine resources. State-wide ecological data is recorded from the biological surveys evaluating the different projects. Shellfish culture and artificial reefs are encouraged by the Conservation Department as prime means of compensating for human destruction of natural habitats of marine life.

Author's Abstract

Woodhouse, W.W. et al. Propogation of Spartina alterniflora for Substrate Stabilization and Salt Marsh Development. Technical Memorandum No. 46, Aug 1974, U.S. Army Coastal Engineering Research Center, CE, Fort Belvoir, Va.

Techniques were developed for propogation of Spartina alterniflora Loisel., smooth cordgrass, in the intertidal zone on dredged material and eroding shorelines. Transplants proved to be more tolerant of rigorous conditions, but seeding was more economical and was successful on protected sites. Vegetative development of both kinds of areas was rapid. Plants and soils in natural stands were sampled and analyzed for productivity interrelationships using multiple regression techniques. Salinity of the soil solution, plant and soil manganese concentrations, and plant sulfur concentrations were negatively associated with aboveground production. Variables positively associated with production included phosphorus concentration in the plant tissue and in the soil. Fertilizer experiments showed that the production of a natural stand of S. alterniflora growing on sand was increased threefold when both nitrogen and phosphorus were added. The production of natural marsh growing on finer-textured sediments doubled when nitrogen was added, but there was no response to phosphorus. Nitrogen and phosphorus fertilizers also enhanced growth of transplants and seedlings on sandy dredged material.

Modified Author's Abstract

Bartsch, A.F. "Settleable Solids, Turbidity and Light Penetration as Factors Affecting Water Quality," Biological Problems in Water Pollution, Transactions of 1959 Seminar. Tech. Report W 60-3, 1960, Cincinnati, Ohio.

Settleable solids, turbidity, and light are so interrelated as to require discussion as a single factor affecting the environment. Settleable solids include inorganic particles from soil erosion and various industrial operations as well as living and dead suspended organic matter of natural or man-influenced origin. Particles that settle on the bottom can destroy fish food organisms, interfere of successful hatching of fish eggs, obliterate otherwise suitable spawning areas and carry unstable organic matter to the bottom where undesirable decomposition products are found. While suspended, particles in sufficient concentration or of sufficient hardness and size may directly injure fishes and fish food animals. Specific cases are described. Suspended particles also affect the optical properties of water so as to create turbidity. By impairing light penetration, turbidity diminishes the thickness of the euphotic zone and this limits basic productivity. Rates of photosynthesis in relation to light extinction in a raw sewage stabilization pond and in the Ohio River near Cincinnati are discussed. Quantities of phytoplankton in clarified and turbid waters of the Missouri River are another expression of impairment of basic productivity by turbidity. Turbidity may also affect temperature relations. In sport fishing waters, turbidity limits the distance at which sport fish can see the lure and this affects both the yield and attractiveness of fishing waters.

Modified Author's Abstract

Bascom, W. "The Disposal of Waste in the Ocean," Scientific American, Vol 231, No. 2, Aug 1974, pp 16-25.

The article discussed various substances which are introduced to the ocean by human activities, and the impacts these substances may have. The following recommendations are made to provide a rational basis for decision making: (1) Separate the definition of ocean from freshwaters and coastal bays and inlets, and consider each environment when legislating controls. (2) Consider which substances cause damage and eliminate excesses of their discharge. (3) Prohibit all ocean disposal of radioactive material, halogenated hydrocarbons, and other highly toxic substances. (4) Set water quality standards on threshhold of damage information with safety factor of 10 or more. (5) Obtain international cooperation in eliminating litter and oily waste discharge from ships. (6) Designate certain deep water areas with slow currents as suitable dumping sites. (7) Require dischargers to provide studies of their effluents' impacts. (8) Support continuing research on ocean pollution. (9) Anticipate creation of new pollutants.

Boyd, M.B. et al. Disposal of Dredge Spoil; Problem Identification and Assessment and Research Program Development. Technical Report H-72-8, Nov 1972, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Considerable concern has developed as to the environmental impact of Corps of Engineers dredging operations, with particular emphasis on open water disposal, especially that involving polluted spoil. The Corps was authorized to conduct a four-phase comprehensive nationwide study of the environmental impact of current disposal operations, including research leading to new or improved spoil disposal practices. This report contains the results of the first two study phases. It is concluded that the nature and magnitude of effects of dredging and spoil disposal on water quality and aquatic organisms, and the consequences of confined land disposal, are poorly known and require extensive research. Research is needed to develop and implement pollution criteria for use in disposal alternative decision making. A broad-based research program is outlined. Major attention would be paid to improving land disposal, modifying dredging equipment and procedures, and developing dredge spoil as a manageable resource for utilization in marsh creation, wildlife habitat improvement, and beach nourishment.

Modified Author's Abstract

Bradley, J.S. "An Application of the Theory of Sediment Transport by Turbidity Currents to the Dredging of Navigable Channels," Journal of Sedimentary Petrology, Vol 26, 1956, pp 119-124.

By inducing artificial turbidity currents to transport the sediments of obstructing bars into deeper water, the natural phenomenon of sediment transport by turbidity currents may be applied to the dredging of navigable channels. The method may be used provided that sufficient slope is present to allow removal of the sediments by currents, that the sediments are of a type which can form turbidity currents, and that equipment is available for mixing the sediments and water. No accurate cost analysis is presently available.

Author's Abstract

Cable, C.C. "Optimum Dredging and Disposal Practices in Estuaries," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 95, No. HY1, Jan 1969, pp 103-114.

Various types of dredging plant are described; their capabilities and limitations are listed. The importance of selecting the most suitable disposal method for the job at hand is stressed. Present day emphasis on clean waters dictates that planning be redirected to study alternate disposal methods to reduce pollutional aspect of some dredging projects. The trend is towards more positive

containment of dredged materials to reduce repetitive redredging of material in the ship channels and to provide some control over water quality.

Author's Abstract

Environmental Protection Agency. Ocean Disposal of Barge-Delivered Liquid and Solid Wastes from U.S. Coastal Cities. Series No. SW-19c, 1971. Solid Waste Management Office, Washington, D.C.

This report details the results of a field and literature study on the oceanic disposal by barge of solid and liquid wastes from 20 U.S. cities. Present disposal practices are inventoried, regulatory monitoring and available information on environmental effects are evaluated, the legal framework within which the operations are conducted is summarized, problem areas are identified, and recommendations are made. Included in the study were the cities of San Francisco, Portland, and Seattle.

from Author's Summary

Harrison, J.E. and L.C. Chisholm. Identification of Objectionable Environmental Conditions and Issues Associated with Confined Disposal Areas. Contract Report D-74-4, Sep 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Objectionable conditions and sources related to disposal of dredged material were found to fall into three categories: conditions associated with disposal area effectiveness (e.g. dike failures); conditions associated with biological, chemical, and physical changes caused by the disposal area; and issues associated with site selection, such as ecological disruption and land-use changes. The relative importance of these conditions and issues as causes for public opposition was found to vary for each proposed project and was thought to be controlled by local public attitude toward confined disposal in general. Existing objectionable conditions also could be characterized on a regional basis. The regional dependency of objectionable conditions and issues probably results from the fact that past experience is the most influential factor in determining a district's practices as related to confined disposal, and regional reaction or attitude toward confined disposal is also related to past experience with the same disposal areas. Observations based on a limited sample indicate that techniques are currently available to prevent dike failure, seepage, channelization, and dike erosion, but not the preventation of standing water in disposal areas. Such techniques should be made part of overall effective operation and management practices for confined disposal areas. Solutions for other objectionable conditions should be sought. The extent and significance of objectionable conditions associated with biological, chemical, and physical changes caused by confined disposal areas have not been documented or clearly defined at this time; future research should

be programmed to identify and define such changes. Ecological issues have centered on the use of wetlands as disposal sites. Many of the land-use issues revolve around ultimate use and control of the completed disposal areas. Ways should be investigated to mitigate or to minimize these effects. For example, innovative disposal procedures should be considered in order to avoid disposal in or disraption of ecologically sensitive wetland areas.

Author's Abstract

Keeley, J.W. and R.M. Engler. Discussion of Regulatory Criteria for Ocean Disposal of Dredged Materials: Elutriate Test Rationale and Implementation Guidelines. Miscellaneous Paper 0-74-14, Mar 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Sediments normally contain constituents that exist in different chemical forms and are found in various concentrations in several locations within the sediment. Criteria to predict the pollution potential of dredged material (sediments) must measure the sediment fraction that has a detrimental effect on water quality and the associated biota. Regulatory criteria should differentiate that fraction of a sediment that does not have an adverse effect on the environment from that fraction that does. The immediate bioavailable fraction of a sediment is dissolved in the sediment interstitial water or in an ionic form that is bound to the ion exchange fraction of the sediment. The elutriate test indicates those constituents in the interstitial water and those ions loosely bound to the ion exchange fraction and, therefore, is a viable criterion for estimating the immediate impact on water quality. Procedures for the test are given.

from Author's Summary

Leckie, J.D. and S.K. Webster. "Chemical and Biological Impacts of Dredging and Spoil Disposal in Coastal and Estuarine Environments," Analyzing the Environmental Impacts of Water Projects. Mar 1973, Stanford University, prepared for U.S. Army Engineer Institute for Water Resources, Alexandria, Va. under Contract No. DACW 31-71-C-0127.

Dredging and the disposal of spoil in open water or on land can alter the coastal environment. In this article, physical and chemical changes brought about by dredging and disposal activities are discussed in terms of the impact these changes have on the biota of estuarine systems. Species composition, primary productivity, fish and wildlife populations, and biological magnification of pollutants are areas where reactions to environmental modifications can be expected.

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

An extensive literature review was made as a part of an effort to establish relationships between the presence of various contaminants within sediments and the effects of sediment dredging and disposal on water quality and aquatic organisms. The review revealed that the use of criteria for dredged material disposal that are based on parameters normally used in evaluating environmental impact of wastewaters is unrealistic because it is considered unlikely that there is a relation between environmental impact of a particular dredged sediment and a particular numerical value for any of these parameters in sediment. The use of a standard Elutriate test to determine pollution potential for dredged material is superior to bulk analysis because the test recognizes that all chemicals in sediment are not equally available to aquatic organisms. From the literature review and investigations of criteria based on bulk-sediment analysis and water-quality criteria, it is concluded that dredged material disposal criteria should be based on a time-concentration-toxicity relationship for each chemical constituent, which could be developed from short-term bioassays with selected organisms.

from Author's Abstract

Lehmann, E.J. Environmental and Ecological Effects of Dredging (A Bibliography with Abstracts). NTIS/PS-75/050/5GA, Jan 1975, National Technical Information Service, Springfield, Va.

Specific as well as general ecological and environmental effects of dredging and dredge spoil disposal are presented. Included in the 85 abstracts are topics; such as, land reclamation using dredge spoil, turbidity, effects on microorganisms, fish, shellfish, effects on the benthos, and spoil disposal techniques.

(from NTIS Government Reports Announcements)

Arthur D. Little, Inc. The National Dredging Study, Part II, Chapter II, "Environmental Regulations."

This section of the study discusses the future effects of environmental regulation on dredging operations and costs. Included is a summary of the history of regulatory development, from the initial Jensen, or Great Lakes, Criteria to the present guidelines for ocean and inland waters dumping. Literature concerning investigations into the impact of dredging and disposal reviewed, and some general conclusions drawn. Comments are given by the Corps of Engineers Districts on problem areas, including comments by the San Francisco, Portland, and Seattle Districts.

Morton, J.S. A Selected Bibliography on Dredging and the Disposal of Dredge Spoils. 1973, Cornell University, Ithaca, N.Y.

This selected bibliography covered the following topics: (1) effects of dredging and disposal of dredge spoils; (2) alternative disposal practices; (3) current regulations and legislation; (4) experimental design and research needs; (5) methods of dredging and dumping; (6) miscellaneous papers.

(from Annotated Bibliography of Grays Harbor Estuary)

Murphy, W.L. and T.W. Zeigler. Practices and Problems in the Confinement of Dredged Material in Corps of Engineers Projects. Technical Report D-74-2, May 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

The curtailment of open-water disposal of dredged materials considered to be polluted has increased the need for suitable confined disposal sites. Such sites are difficult to locate, and existing sites are often plagued by such problems as channelization of dredged material from the discharge point to the sluice, the effects of wind, mounding and uneven distribution of dredged material, and retaining dike stability. Most dredge spoil is delivered to confined disposal sites hydraulically with the introduction of large amounts of water. Guidance is needed with respect to effluent quality standards. Dike failures have occurred largely due to poor foundation conditions, poor construction materials, seepage, and inadequate attention to proper dike design, maintenance, and inspection.

from Author's Summary

Ocean Dumping, A National Policy. Report to the President by the Council on Environmental Quality, Washington, D.C. Oct, 1970.

This report was requested to obtain information nationwide on ocean dumping in order to facilitate management and legislative control in the future. Discussed in the report are ocean dumping in terms of its locations, quantities, composition, and trend; the pathways, effects, and impacts of ocean pollution; alternatives to ocean dumping; current legislative control and recommendations; and international aspects of ocean disposal. The report is relevant in consideration of dredging activities as it states that dredge spoils account for 80% by weight of all ocean dumping, 34% of which is polluted.

Ortolando, L. and W.W. Hill. An Analysis of Environmental Statements for Corps of Engineers Water Projects. Jun 1972, Stanford University for the U.S. Army Corps of Engineers, Contract No. DACW31-71-c-0127.

The publication presents the results of an intensive analysis of 234 Corps of Engineers environmental impact statements prepared in accordance with Sec. 102 (2)(C) of the National Environmental Policy Act. The analysis includes a detailed catalog and summary of impacts included in the statements for: projects on coastal waters including dredging, spoil disposal, breakwaters, jetties and groins, revetments, dikes and barriers; and projections on inland waters including channelization, dams and reservoirs, levees, dredging spoil disposal, construction and other miscellaneous structures and activities. In addition, the analysis catalogs and summarizes the impacts of various project purposes. A summary of the coverage of other points required by Sec. 102 (2)(C) of NEPA is also included. The proper role of environmental statements is suggested and, within that context, an assessment of the 234 statements is rendered, together with suggestions for improvement.

Author's Abstract

Pamatmat, M.M. et al. Oxidation of Organic Matter in Sediments. EPA 660/3-73-005, Sep 1973, Environmental Protection Agency, Washington, D.C.

Techniques and methods were developed for taking undisturbed sediment samples, measuring oxygen uptake by the sediments, and determining the dehydrogenase activity and metabolic heat release of sediment bacteria. The rate of oxygen uptake of sediments can be an indicator of the impact of human activities on the water column above. The oxygen consumption of 33 stations in Puget Sound was measured seasonally as a part of this investigation.

Postma, H. "Marine Pollution and Sedimentation," Pollution and Marine Ecology. Alsen and Burgess, eds., 1967, Intersciences Publishers, New York.

Solid wastes introduced in suspended form into natural water will show a behavior similar to that of natural sediments. The same applies to dissolved waste products which are absorbed by particulate matter. Our growing knowledge of marine sedimentological and geochemical processes may, therefore, be of some assistance in studying the behavior of wastes in the sea. Also it must be possible in principle, to use certain forms of suspended wastes as tracers in the study of sediment transport.

from Author's Introduction

Southard, J.F. et al. "Experimental Erosion of Calcareous Ooze," Journal of Geophysical Research, Vol 76, No. 24, 1971, pp 5903-5909.

Flume experiments on the erosion of abyssal calcareous ooze in shallow uniform flows of sea water show that erosion velocities range from 7-10 cm/sec soon after rapid deposition of the bed to 15-20 cm/sec after a few tens of hours. Continuing erosion produces shallow irregular longstream lineations but no sediment ripples. On the assumption of a hydrodynamically smooth boundary in the deep ocean, the measured erosion velocities can be approximately corrected for the effects of flowdepth and water temperature different from oceanic conditions; even with this correction, the measured velocities are less than twice as great as current velocities common in the deep ocean.

Author's Abstract

Thompson, J.R. Ecological Effects of Offshore Dredging and Beach Nourishment. 1971, University of Southern Mississippi, Hattiesburg, Miss.; Report to Coastal Engineering Research Center, Washington, D.C., under Contract No. DACW72-71-C-0001.

A review of ecological effects of offshore dredging is presented, based on literature review and personal contacts, to provide a framework for determination of need for further knowledge. In general, little concrete effort aimed specifically at the determination of effects of offshore dredging was uncovered, although basic ecological works that are generally applicable are available. Much additional research of basic, but practical, orientation is needed to approach full understanding. Report shows that the beach may be divided into three zones on the basis of moisture and biota found, and describes the possible effects on these biota resulting from offshore dredging and deposition of sediments on a beach. Background descriptive material and impacts on both offshore dredged areas and nourished beaches, and suggestions for further research follow. A selected bibliography is included.

Author's Abstract

Wakeford, R.C. and D. MacDonald. Legal, Policy, and Institutional Constraints Associated with Dredged Material Marketing and Land Enhancement. Contract Report D-74-7, Dec 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

This report deals with existing constraints on the use of dredged material as a marketable, commercial resource for use in land enhancement. Federal, statutes, regulations, and state laws which apply are discussed, along with public attitudes and institutional constraints on the use or disposition of dredged material. Criteria for determining ownership of dredged material are given, and statutes and Federal regulations which pertain to the sale and donation of material are listed. Examples are given of recent uses and currently

planned approaches to the disposal of dredged material. A procedure is recommended for updating the state of the law as it relates to the reclamation of dredged material. General conclusions are made, and a section is devoted to a discussion of Corps of Engineers regulations which apply.

U.S. Army Engineer Waterways Experiment Station. Dredged Material Research Program, First and Second Annual Reports. Mar 1974 and Jan 1975, Vicksburg, Miss.

This program seeks to provide, through research, definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource. Lists of projects, titles, and contractors are included.

(from DDC Report Bibliography)

SUPPLEMENTARY REFERENCE LIST

DIKED DISPOSAL; USES OF DREDGE SPOIL

Brebner, A. et al. Containment of Mercury Polluted Dredged Spoil in Diked Areas. Jul 1974, Queens University, Kingston, Ontario, for Canadian Department of Public Works.

Cedergren, H.R. Seepage, Drainage, and Flow Nets. 1967, Wiley, New York, N.Y.

Garbe, C.W. et al. Demonstration of a Methodology for Dredged Material Reclamation and Drainage. Contract Report D-74-5, Sep 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Giger, M.W. et al. "Electrical Resistivity Survey of Two Dredging Disposal Sites," Bulletin of the Association of Engineering Geologists, Vol 10, No. 2, Spring 1973, pp 107-119.

Heller, N.J. and E. Thelan. Building Materials from Dredge Spoil. 1971, Franklin Institute Research Laboratories, Philadelphia, Pa.

Johnson, S.J. "Foundation Precompression with Vertical Sand Drains," Journal, Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol 96, Jan 1970, pp 145-175.

Kolessar, M.A. "Some Engineering Aspects of Disposal of Sediments Dredged from Baltimore Harbor,: Proceedings, Federal Interagency Sedimentation Conference, U.S. Department of Agriculture, Agriculture Research Service Miscellaneous Publication No. 970, Jan 1963, pp 613-618.

Krizek, R.J. et al. "Seismic Survey of a Hydraulic Landfill Composed of Maintenance Dredgings," Bulletin of the Association of Engineering Geologists, Vol 11, No. 3, 1974, pp 173-202.

Mallory, C.W. and M.A. Nawrodki. Containment Area Facility Concepts for Dredged Material Separation, Drying, and Rehandling. Contract Report D-74-6, Oct 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Moran, Proctor, Mueser, and Rutledge, Consulting Engineers. Study of Deep Soil Stabilization by Vertical Sand Drains. 1958, for Bureau of Yards and Docks, Washington, D.C.

Reikenis, R. et al. Regional Landfill and Construction Material Needs in Terms of Dredged Material Characteristics and Availability. Contract Report D-74-2, 2 vols, May 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Terzaghi, K. and R.B. Peck. Soil Mechanics in Engineering Practice, 2nd edition. 1967, Wiley, New York, N.Y.

Toth, S.J. and B. Gold. Agricultural Value of Dredged Sediments, Final Report. 1970, Rutgers University, New Brunswick, N.J.

U.S. Army, Office, Chief of Engineers. Earth and Rock-Fill Dams, General Design and Construction. EM1110-2-2300, Mar 1971, U.S. Government Printing Office, Washington, D.C.

U.S. Army, Office, Chief of Engineers. Stability of Earth and Rock-Fill Dams. EM1110-2-1902, Apr 1970, U.S. Government Printing Office, Washington, D.C.

MODELING; STUDY DESIGN

Callaway, R.J. et al. Mathematical Model of the Columbia River from the Pacific Ocean to Bonneville Dam. 1969, Pacific Northwest Water Laboratory, Corvallis, Ore.

Ciaccio, L.L., ed. Water and Water Pollution Handbook (in 4 vols). 1972, Marcel Dekker, Inc., New York, N.Y.

Environmental Protection Agency. Methods for Chemical Analysis of Water and Wastes. 1971, Water Quality Office, Analytical Quality Control Laboratory, Cincinnati, Ohio.

Homan, W.J. "Model Tests of Shoaling and of Dredge Spoil Disposal in San Francisco Bay,: Proceedings, Federal Interagency Sedimentation Conference, U.S. Department of Agriculture, Agriculture Research Service Miscellaneous Publication No. 970, Jan 1963, pp 708-722.

Hummel, P.L and R.J. Krizek. "Sampling of Maintenance Dredgings," Journal of Testing and Evaluation, Vol 2, No. 3, May 1974, pp 139-145.

Johnson, B.H. Investigation of Mathematical Models for the Physical Fate Prediction of Dredged Material. Technical Report D-74-1, Mar 1974, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Koh, R.C.Y. and Y.C. Chang. Mathematical Model for Barged Ocean Disposal of Wastes. EPA-660/2-73-029, Dec 1973, Environmental Protection Agency, Washington, D.C.

Lassiter, R.R. Modeling Dynamics of Biological and Chemical Components of Aquatic Ecosystems. EPA-660/3-75-012, May 1975, Environmental Protection Agency, Corvallis, Ore.

Leopold, L.B. et al. A Procedure for Evaluating Environmental Impact. Circular 645, 1971, U.S. Geological Survey, Washington, D.C.

McKee, H.C. and D.S. Tarazi. Development of Sample Preparation Methods for Analyses of Marine Organisms. EPA-660/3-74-026, Jan 1974, Environmental Protection Agency, Washington, D.C.

Male, R. and D.R. Basco. A Dispersion Curve Study of Model Dredge Spoil Basins. Report No. TAMU-SG-75-201, Sep 1974, Texas A&M University, College Station, Texas.

O'Connor, D.J. et al. Dynamic Water Quality Forecasting and Management. EPA-660/3-73-009, Aug 1973, Environmental Protection Agency, Washington, D.C.

Sheldon, R.W. Direct Measurement of Particle Concentration in Natural Waters with a Model T. Coulter Counter. Technical Report No. 379, 1973, Fisheries Research Board of Canada, Marine Ecology Laboratory, Dartmouth, N.S.

Sorensen, J.C. A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone. 1971, Masters Thesis, University of California, Berkeley, Ca.

Standard Methods for the Examination of Water and Wastewater, 13th edition. 1971, prepared and published jointly by American Public Health Association, American Water Works Association, and Water Zollution Control Federation, New York, N.Y.

U.S. Army Engineer District, New York, CE. System Study for Surveillance of Ocean Dumping Operations. Sep 1971, New York, N.Y.

U.S. Department of Interior. Guidelines for Federal Permit Applications in Navigable Waters. Bureau of Sport Fisheries and Wildlife, Atlanta, Ga.

DREDGING AND POLLUTION STUDIES; MISCELLANEOUS

Bader, R.G. "Role of Organic Matter in Determining Distribution of Pelecypods in Marine Sediments," Journal of Marine Research, Vol 13, 1954, pp 32-47.

Casciano, F.M. and R.Q. Palmer. Potential of Offshore Sand as an Exploitable Resource in Hawaii. Technical Report No. 11, Sea Grant Publication 60-4, 1969, University of Hawaii, Honolulu, Hawaii.

Clark, J.A. Fish and Man; Conflict in Atlantic Estuaries. Special Publication No. 5, 1967, American Littoral Society, Highlands, N.J.

Department of the Army, Corps of Engineers. Report on the National Shoreline Study. 1971, Washington, D.C.

Federal Water Pollution Control Administration. The National Estuarine Pollution Study. Nov 1969, U.S. Department of Interior, Washington, D.C.

Gagliano, S.M. et al. Controlled Diversions in the Mississippi Delta System: An Approach to Environmental Management. 1971, Coastal Studies Institute, Louisiana State University, Baton, Rouge, La.

Goldberg, E.D. ed. A Guide to Marine Pollution, Seminar. 1972, held in conjunction with the FAO Technical Conference on Marine Pollution and its Effects on Resources and Fisheries, New York.

Hann, R.W. Jr. Bottom Sludge Accumulation and Oxygen Demand in a Polluted Estuary. 1968, Texas A&M University, College Station, Texas.

Hess, H.D. Marine Sand and Gravel Mining Industry of the United Kingdom. Technical Report ERL213-MMTC1, 1971, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Boulder, Colo.

Levin, J. A Literature Review of the Effects of Sand Removal on a Coral Reef Community. Sea Grant Publication 71-01, University of Hawaii, Honolulu, Hawaii.

Mills, E.J. "The Community Concept in Marine Zoology, with Comments on Continua and Instability in Some Marine Communities: A Review," Journal of the Fisheries Research Board of Canada, Vol 26, No. 6, 1969, pp 1415-1428.

Mohr, A.W. "Development and Future of Dredging," Journal of the Waterways, Harbors, and Coastal Engineering Division, American Society of Civil Engineers, Vol 100, No. WW2, May 1974, pp 69-83.

Ocean Waste Disposal, Hearings Before the Subcommittee on Oceans and Atmosphere of the Committee on Commerce, United States Senate. 92nd Congress, 1st Session, Serial No. 92-11, 1971, Washington, D.C.

Olson, T.A. and F.J. Burgess, eds. Pollution and Marine Ecology. 1967, Interscience Publishers, New York, N.Y.

Panuzio, F.L. "Lower Hudson River Siltation," Proceedings, Federal Sedimentation Conference, U.S. Department of Agriculture, Agriculture Research Service Miscellaneous Publication No. 970, 1963, pp 512-550.

Research Report: Effectiveness of a Hopper Dredge as an Aerator and Classifier of Sediments. Jul 1969, Great Lakes Laboratory, State University College, Buffalo, N.Y.

Salo, E. "The Effect of Pollution on the Estuaries of the Northwest Pacific Coast," Northwest Estuarine and Coastal Zone Symposium. Proceedings, U.S. Bureau of Sports Fisheries and Wildlife, Oct 1970, Portland, Ore, pp 123-124.

Smith, B.J. "Sedimentation in the San Francisco Bay System," Proceedings, Federal Sedimentation Conference, U.S. Department of Agriculture, Agriculture Research Service Miscellaneous Publication No. 970, 1963, pp 675-708.

Stanley, D.J. ed. The New Concepts of Continental Margin Sedimentation; Application to the Geological Record. Short Course Lecture Notes, 1969, American Geological Institute, Washington, D.C.

Teeters, R.D. "Present and Future Demands upon the Coastal Zone," PB184836, Seminar on Multiple Use of the Coastal Zone, 1968, Federal Interagency Committee on Multiple Use of the Coastal Zone, Clearinghouse Spring, Va.

Turner, T.M. "The Offshore Dredge--A Solution to Beach Restoration," Shore and Beach, Vol 40, No. 2, Oct 1972, pp 36-38.

U.S. Army Engineer District, Buffalo, CE. Dredging and Water Quality Problems in the Great Lakes. (in 12 vols), Jun 1969, Buffalo, N.Y.

U.S. Department of Interior. The National Estuary Study. (in 7 vols), 1970, Washington, D.C.