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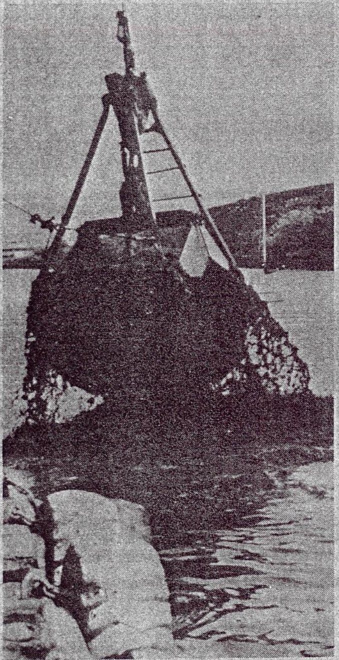

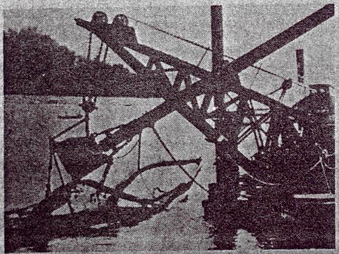

REMR RESEARCH PROGRAM

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-EI-2

BIBLIOGRAPHY OF ENVIRONMENTAL RESEARCH RELATED TO REMR

by

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Final Report

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The following two letters used as part of the number designating technical reports of research published under the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program identify the problem area under which the report was prepared:

Problem Area		Problem Area	
CS	Concrete and Steel Structures	EM	Electrical and Mechanical
GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

For example, Technical Report REMR-CS-1 is the first report published under the Concrete and Steel Structures problem area.

COVER PHOTOS:

TOP—Snag removal, Ohio River

BOTTOM—Maintenance dredging using clamshell, Black Rock Harbor, Connecticut

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Maintenance	Debris removal	Dredged material
Pollution	Environmental impacts	disposal

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The REMR research program of the US Army Corps of Engineers (CE) is designed to research problems associated with evaluating the condition of existing Civil Works structures and maintaining, repairing, and rehabilitating those structures. This report is an annotated bibliography that assesses the applicability to REMR activities of previous environmental research done by the CE. Environmental reports and publications produced by the US Army Engineer Waterways Experiment Station (WES), the Coastal Engineering Research Center (CERC), and the Cold Regions Research and Engineering Laboratory (CRREL) were reviewed, and those with potential applicability to REMR were included in the annotated bibliography. The narrative portion of the document contains tables summarizing potential environmental consequences of REMR activities and indicating which bibliographic entries should be consulted for applicable environmental research. Much work has been done at WES,

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16. SUPPLEMENTARY NOTATION (Continued).

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. A report of the Environmental Impacts problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program.

19. ABSTRACT (Continued).

CERC, and CRREL within the last decade that has produced results applicable to REMR activities. Conversely, several categories of REMR actions and associated environmental impacts have few or no references.

PREFACE

This report was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32339, "Evaluation of Environmental Impacts for REMR." The study was part of the work under the Environmental Impacts Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The Overview Committee at HQUSACE for the REMR Research Program consists of Mr. John R. Mikel, Mr. Bruce L. McCartney, and Dr. Tony C. Liu. Technical Monitor for the study was Mr. Mikel.

The report was prepared by Dr. Nelson R. Nunnally of the Water Resources Engineering Group (WREG), Environmental Engineering Division (EED), Environmental Laboratory (EL). Dr. Nunnally was assisted by Ms. Janet S. Condra of WREG. Technical review was provided by Dr. Jerome L. Mahloch and Dr. John D. Lunz, both of EL. Dr. Nunnally and Ms. Condra worked under the direct supervision of Dr. Michael R. Palermo, Chief, WREG, and under the general supervision of Dr. Raymond L. Montgomery, Chief, EED, and Dr. John Harrison, Chief, EL. Problem Area Leader for the Environmental Impacts Problem Area is Dr. Mahloch. Program Manager for REMR is Mr. William F. McCleese, Concrete Technology Division, Structures Laboratory, WES. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is the Technical Director.

CONTENTS

BIBLIOGRAPHY OF ENVIRONMENTAL RESEARCH RELATED TO REMR

PART I: INTRODUCTION

Background

1. The Civil Works program of the US Army Corps of Engineers (CE) is involved in water resources development responsibilities for a variety of purposes. The CE plans, designs, constructs, operates, and maintains projects for flood damage reduction, navigation, streambank and reservoir shoreline erosion control, hydropower generation, water supply, recreation resource management, beach erosion control, fish and wildlife enhancement, and environmental enhancement.

2. Many of the Civil Works structures built by the CE are in serious need of repair or rehabilitation. Many early projects built by the CE were small and normally were replaced by larger, more modern, and better engineered facilities before they became too deteriorated. In recent decades, the rate of new project starts has decreased as navigation master plans have neared completion, acceptable reservoir sites have become scarce, construction costs have soared, and environmental concerns have increased. Many structures have exceeded their planned project life and must be maintained or rehabilitated if they are to continue to function properly.

3. The US Army Engineer Waterways Experiment Station (WES) was given the responsibility of investigating Repair, Evaluation, Maintenance, and Rehabilitation (REMR) problems. This investigation specifically was to (a) address background and mission objectives, (b) identify and assess REMR problems, (c) identify areas of needed research, and (d) develop a research program and schedule, including associated costs. The resulting report, "REMR Research Program Development Report," identified seven primary problem areas to be considered by the REMR Research Program.*

- a. Concrete and Steel Structures
- b. Geotechnical
- c. Hydraulics

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* Scanlon, J. M., et al. 1983 (Feb). "REMR Research Program Development Report," US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

d. Coastal

e. Electrical and Mechanical

f. Environmental Impacts

g. Operations Management

4. This report is one of the products of the research under Work Unit 32339, Evaluation of Environmental Impacts for REMR. The overall objective of Work Unit 32339 is to develop procedures to evaluate environmental impacts associated with REMR activities. Recommended REMR techniques developed in other research areas are to be evaluated to identify adverse environmental impacts, quantify their magnitude, and recommend remedial procedures. Specifically, this report is the product of Work Unit 32339(c), which provides for review of previous CE environmental research to: (a) identify those operation and management (O&M) techniques developed for environmental reasons that might have application to REMR, (b) compile a bibliography of these techniques, and (c) assess their potential applicability to REMR.

Purpose and Scope

5. The purpose of this report is to identify potential environmental impacts of REMR activities and to provide a bibliography of all reports and publications pertaining to environmental impacts of O&M techniques produced at WES (to include the US Army Engineer Coastal Engineering Research Center (CERC) at Fort Belvoir before it became a part of WES) and at the Cold Regions Research and Engineering Laboratory (CRREL). Most of the WES documents evaluated were produced by the Environmental Laboratory, CERC, and the Geotechnical Laboratory. Often the results of environmental investigations published in detail in a series of reports are summarized in a single final report or summary report. In these cases only the summary report is included in the bibliography, unless the individual reports contain enough essential or important material to warrant their inclusion separately. In other cases, individual reports that contain some environmental data are not included because that information is covered in other reports with an environmental focus. For example, all of the environmental information from the Section 32 Streambank Evaluation and Demonstration Project is contained in WES Technical

Report E-84-11 (Henderson and Shields 1984). This annotated bibliography contains abstracts of all the project reports cited.

6. The narrative portion of this report is intentionally brief. It is included for the purpose of identifying environmental impacts of REMR activities and evaluating the applicability of environmental O&M techniques discussed in specific documents in the bibliography. Because this is an evaluation of existing information, much of what is included in this report will necessarily be supplemented by future REMR documents.

PART II: POTENTIAL ENVIRONMENTAL IMPACTS OF REMR ACTIVITIES

Potential Environmental Impacts of General Maintenance and Rehabilitation Activities

7. The REMR Research Program is largely directed toward the development of new technologies and materials for repairing, maintaining, and rehabilitating structures that are part of CE Civil Works projects. Specific environmental impacts associated with these activities are somewhat limited and are discussed in a later section of this report. It is apparent from work unit documentation that Work Unit 32339, Evaluation of Environmental Impacts for REMR, should include all REMR activities and not just those associated with the REMR Research Program. Accordingly, this section identifies some of the more general environmental impacts that may result from a wide range of maintenance and rehabilitation actions. Because of their general applicability, these impacts are widespread and potentially significant. Activities and associated impacts are grouped into the construction and maintenance categories.

Construction impacts

8. Any ground-disturbing construction activities may cause erosion and sedimentation problems. Several REMR activities will involve construction of some sort that is capable of causing erosion and sedimentation problems, including repair and rehabilitation of levees and embankment dams, repair of flood channels and streambank protection structures, and slope stabilization. The magnitude of these impacts depends on the size of the area disturbed, length of exposure, and site characteristics such as likelihood of erosive precipitation, soil erodibility, and slope length and inclination. In addition to aesthetic problems, offsite sedimentation can impact water quality and aquatic ecosystems. Land-disturbing activities usually result in some destruction of vegetative cover. Loss of vegetation can have serious impacts, especially if unique or scarce habitats are involved. In addition to its obvious aesthetic value, riparian vegetation along waterways projects is an important buffer zone and provides organic input, shade, and cover for animals and fish.

9. Although the search of WES documents revealed nothing that specifically addressed erosion and sediment control, several reports generated under the Environmental and Water Quality Operational Studies (EWQOS) Research

Program that deal with environmental aspects of waterways projects contain sections that review strategies for reducing impacts of construction activities. These include discussions of buffer zones along waterways, ways of minimizing disturbed areas, the importance of timing work activities to avoid critical periods, and revegetation of disturbed areas (Burch et al. 1984, Henderson and Shields 1984, Hynson et al. 1985, Nunnally and Shields 1985, Shields (1982), and Shields and Palermo 1982). Revegetation techniques are described in Allen (1978), and Whitlow and Harris (1979) discuss establishment of vegetation in periodically flooded areas. Clar et al. (1983) describe restoration techniques for problem soils, including erosion protection. Each of these cited reports has sections applicable to land-disturbing REMR activities.

10. Ground-disturbing construction activities also may adversely affect cultural resources. Even in areas that have been previously surveyed, new construction may reveal previously unknown cultural resources. The magnitude of the impact depends on the nature of the land disturbance, the characteristics of the site, and the importance of the data affected. Little generally applicable research had been done by the CE on cultural resources preservation prior to 1986. However, a large multiyear research effort was initiated in fiscal year (FY) 1986 that will investigate methods for locating, assessing the significance, and preserving cultural resources. Some results from this effort should be generated beginning in FY 1987.

Maintenance impacts

11. CE Civil Works projects are regularly inspected and maintained to ensure that they continue to perform their authorized purpose. A number of studies carried out under the EWQOS Program investigated the environmental aspects of various strategies for managing terrestrial vegetation that have application to general project maintenance and to some specific REMR activities.

12. Terrestrial vegetative maintenance is a regular requirement on many kinds of projects. Recreation areas must be maintained in a fashion compatible with anticipated use, including such actions as mowing of playing fields, campgrounds, and other areas of heavy use, and preventing growth of noxious plants such as poison ivy and thorny plants. Vegetation is managed on levees to facilitate levee inspection and to ensure that the structural integrity of the levee is not threatened by large trees. Hynson et al. (1985) describe

in detail vegetative management alternatives for levee projects, including recreational areas. Allen (1982b), Henderson and Shields (1984), and Nunnally and Shields (1985) discuss implications of vegetative management along stream corridors and streambanks and suggest environmentally beneficial modifications to traditional maintenance practices.

Impacts of Specific REMR Activities

13. The potential environmental consequences of individual REMR activities vary considerably, depending upon the types of actions required. Some activities involve multiple actions with many possible impacts while others are single actions with minimal impacts. Table 1, which was compiled from the "REMR Research Development Report" (Scanlon et al. 1983), available work unit documentation, and conversations with some REMR Problem Area Leaders, summarizes available information concerning REMR activities and associated actions and environmental consequences. Because the REMR Program is in its early stages, some work units have not yet begun, making it difficult to anticipate all actions and their consequences at this time. Tables 2 and 3 contain the same information on REMR activities and environmental consequences, followed by a listing of pertinent bibliographic references by number. This allows users to start either with environmental consequences or REMR actions, and locate those bibliographic entries which contain information useful in minimizing environmental impacts.

Impacts of Future REMR Activities

14. As work on the REMR Program proceeds, Problem Area Leaders and researchers will be faced with the problem of assessing environmental impacts of experiments and alternative treatments. A number of WES studies have generated products that may prove useful in these assessments. Henderson's (1982) "Handbook of Environmental Quality Measurement and Assessment: Methods and Techniques" should be especially helpful as a guide for measuring and predicting impacts. Lunz and Kendall (1982) describe a benthic resources assessment technique. Several water quality models are available for predicting water quality impacts of REMR actions in reservoirs (Collins and Wlosinski 1983, Environmental Laboratory 1982, Poore and Loftis 1983), rivers (Johnson,

Table 1

Potential Environmental Consequences of REMR Activities

REMR Activities	Actions	Potential Environmental Consequences
Rehabilitation of navigation locks.	Closure during low-water period.	Interference with recreational and commercial navigation during peak-use periods; interference with fish movements.
Rehabilitation of stilling basins.	Dewatering; removal of accumulated sediments.	Desiccation of substrate and disruption of aquatic ecosystems; disruption of fish movements; dredged material disposal impacts.
Rehabilitation to control levee underseepage; methods to control underseepage in embankment dams and previous foundations.	Construction or expansion of landside berms; pool reduction.	Vegetation removal; general construction impacts; land use impacts; borrow pits; recreation impacts; aesthetic impacts; alteration of aquatic habitat for invertebrates and fishes; cultural resource impacts.
Erosion control and slope stabilization (including unlined channels, streambanks, reservoir slopes, and recreation areas).	Regrading; seedbed preparation; selection and design of erosion control features; reservoir pool lowering.	Vegetation disruption; erosion and sedimentation; aesthetic impacts; biological effects of elevated turbidity and suspended sediment concentrations; alteration of streambank materials; stream access affected; cultural resource impacts.
Erosion control in cold regions.	Revegetation; selection and design of erosion control features.	Permafrost thawing; ecosystem disruption; cultural resource impacts

(Continued)

(Sheet 1 of 3)

Table 1 (Continued)

REMR Activities	Actions	Potential Environmental Consequences
Repair practices and quality control for rock slope protection.	Reengineering; armor replacement.	Loss or disturbance of rocky substrate; disturbance of riparian vegetation.
Repair or rehabilitation of rock channels and slopes.	Removal of damaged sections; debris disposal.	Debris disposal impacts; biological effects of elevated turbidity and suspended sediment concentrations.
Scour downstream of stilling basins.	Redesign, placement of stone, or other bank protection.	Altered substrate; aesthetic impacts.
Floating debris control systems.	Removal of floating debris.	Loss of large organic debris and consequent alteration of fish and invertebrate habitat.
Repair of scour around navigation training structures (including coastal).	Filling of scour holes with stone; modification of structures to reduce scour.	Substrate modification; alteration of fish habitat; biological effects of elevated turbidity and suspended sediment concentrations.
Techniques for repair of training structures (deep- and shallow-draft) including revetment.	Modification of structures; replacement of stone.	Effects on bank substrate and habitat; effects on dike field morphology and habitat; biological effects of elevated turbidity and suspended sediment concentrations.
Rehabilitation of rubble-mound structure toes.	Replacement of material; redesign of toe.	Effects on reef habitat; biological effects of elevated turbidity and suspended sediment concentrations.

(Continued)

(Sheet 2 of 3)

Table 1 (Concluded)

REMR Activities	Actions	Potential Environmental Consequences
Use of dissimilar armor for repair and rehabilitation of rubble-mound structure.	Rehabilitation or repair with different type or size of armor.	Altered marine habitat conditions.
Repair of localized damage to rubble-mound coastal structure.	Replacement of armor or repair with dissimilar material.	Effects on marine habitat.
Experimental testing of methods and materials for repair of rubble-mound structures.	Testing of various materials and methods.	Effects on marine habitat.
Development of methods to minimize maintenance requirements for coastal navigation channels.	New structure designs and placements; better dredging technology; dredged material disposal.	Marine habitat impacts; dredged material disposal impacts; interference with navigation.
Painting of submerged surfaces.	Painting.	Water quality impacts; toxicity to aquatic organisms.

(Sheet 3 of 3)

Table 2

REMR Activities and Applicable References

Actions*	Potential Applicability of References: High	Low
Closure of navigable waterways	--	
Construction or expansion of earthen berms	20,43	61,89
Dewatering of streams for repair of structures like stilling basins or locks	--	
Dikes (river training)	17,89	
Disposal of construction and demolition debris	61	
Dredged material disposal		
Beach nourishment	25,26,67,68,75,81,83,86	
Containment and treatment	10,27,32,35,74,99	
Contaminated sediments	10,32,72	74
Land disposal	61,72,90,93,98	91
Salt marsh habitat development	6,8,22,27,33,50,59,91, 102,103	5,18,29,54,57,76, 92
Upland habitat development	22,40,64,71,91,92	59,72
Wetland habitat development	27,64,91,96,101	33,92
Dredging		
Development of better technology	9,10,39,42,44,46,62,63,82	
Ecological effects	19,25,26,62,63,65,67,68, 75,81,83,85,86,87	32,95
Turbidity plumes	9,39,42,44,46,82	
Erosion control		
Coastal	1,5,6,11	8
Cold regions	7,12,13,14,15,20,21,34, 45,51,52,60,72,84	
General	70,72,84,88	20,38,72
New structure designs and placements for coastal navigation	31,55,85	48

(Continued)

* See Scanlon et al. (1983) for descriptions of these actions.

Table 2 (Concluded)

Actions	Potential Applicability of References: High	Potential Applicability of References: Low
Painting and treating underwater surfaces	--	
Removal and disposal of damaged materials such as stone or concrete from hydraulic structures	61	48,53
Removal of floating debris	70	88
Reservoir drawdown for repair or rehabilitation	4,77,78,79	16,23,30,47,49, 66,80
Revetment repair	38	88
Rock-lined channels, repair or replacement	--	
Rubble-mound structures	31,41,48,53,55,85,97	
Selection and design of erosion control and slope protection structures	34,38,45,70,72,84,101	20,21,88,89
Shoreline stabilization		
Lakes and reservoirs	1,36,56,57,101	2,4,89
Marine	1,5,6,11,56,57,58,69,76, 100,102,103	18,20,23,25,26
Streambank protection		29,44,54,67,71
Repair or replacement	38,70	1,2,3,88,89
Use of vegetation for	1,2,3,38,70,101	88,89

Table 3

Environmental Impacts of REMR Activities and Applicable References

Impacts	Potential Applicability of References: High	Potential Applicability of References: Low
Aesthetic	38,43,61,70,88	1,20,56,93
Aquatic ecosystem disruption	4,38,62,63,70,77,78,79	1,17,89
Aquatic habitat alteration	2,3,4,17,38,64,70,77,78, 79,88	1,19,43
Bank material alteration	1,2,3,4,36,38,57,70,88	56,89
Biological effects of elevated turbidity levels		
Aquatic	9,62,63,68	14,32,70
Marine	9,25,26,62,63,67,75,81, 86,87	
Borrow pits created	43	
Cultural resource impacts	43,70	
Debris disposal	61	90,93
Dike field morphology altered	17,89	
Dredged material disposal		
Ecological effects	19,62,63,65,87	17,25,67,68,72, 75,81,83
Landscape effects	70,88,90,93	72,89
Salt marsh habitat	6,8,22,27,33,50,59,91, 102,103	5,18,29,54,57,76, 92
Upland habitat	22,40,64,71,91,92	59,72
Wetland habitat (freshwater)	27,64,91,96,101	33,92
Erosion and sedimentation	7,12,13,14,15,21,38,43, 45,51,52,70,72,84,88,89	
Interference with fish movements	62,63,70,88	
Interference with navigation	--	
Land use impacts	43,90,93	70,89
Loss of large organic debris in streams	70,88	

(Continued)

Table 3 (Concluded)

Impacts	Potential Applicability of References: High	Potential Applicability of References: Low
Marine ecosystem impacts	25,26,31,41,48,53,55,65, 67,81,83,85,86,87,95, 97,102	1,5,6,62,63,76
Marine habitat change	25,26,41,48,55,65,75,83, 85,86,95,97,102,103	1,5,6,11,53,67,76 81,87
Permafrost thawing	7,12,13,14,15,21,34,45, 51,52,60	
Recreation impacts	24,38,43,61,70,88,89	4,41,93
Riparian vegetation disturbed	38,43,70,88,89	1,2,3,4
Stream access affected	38,43	
Substrate alteration		
Aquatic	1,2,3,17,38,70,88,89	4,56
Marine	1,25,41,48,55,67,68,75, 81,83,85,86,97	31,53,69,95,102
Toxicity effects on aquatic and marine organisms	10,32	
Tundra ecosystem disruption	7,12,13,14,15,21,45,50, 52,60	34,72
Vegetation removal	7,12,13,14,15,20,21,34, 38,43,45,51,52,60,70, 72,84,88,89	1,2,3
Water quality impacts	9,10,19,42,70,82,85,88, 89,99	62,63

Ford, and Robey 1981; McCutcheon 1983), and estuaries (Holliday, Johnson, and Thomas 1978). Although they were developed for other purposes, reservoir management models (Buchak and Edinger 1982; Edinger and Buchak 1983 (see reference 16); Fontane, Labadie, and Loftis 1982; Johnson 1981; Thompson and Bernard 1984) can be used to evaluate effects of drawdown for maintenance and rehabilitation purposes. Recreation carrying-capacity models (Coughlin, Berry, and Cohen 1978) might be useful for predicting impacts of some REMR actions on physical and human resources and for evaluating applications for reduced maintenance in recreational areas. Even though none of the models cited above are capable of providing precise answers, they do provide an objective basis for evaluating alternatives in a given situation if they are used by experienced personnel.

Summary and Conclusions

15. Much work has been done at WES and CERC within the last decade that has produced results useful to the REMR Program. A great deal of this research was conducted under the Dredged Material Research and EWQOS Programs. This is reflected in the large number of bibliographic listings in Tables 2 and 3 under topics such as dredged material disposal and biological effects of elevated turbidity levels.

16. Conversely, several categories of REMR actions and associated environmental impacts contain few or no references. REMR actions for which there has been little or no research are dewatering of streams, closure of navigable waterways, painting and treatment of underwater structures, repair or replacement of rock-lined channels or slopes, removal of damaged material, and debris disposal. Literature dealing with cultural resources impacts of REMR activities and the control of these impacts is also scanty. Many of the REMR actions in Table 1 potentially impact cultural resources, but CE literature in this area is virtually nonexistent. A search of non-CE literature should be conducted to determine if research has been conducted into the environmental consequences of the actions listed above, and future environmental research under REMR should be concentrated toward the actions for which little information is available.

PART III: ANNOTATED BIBLIOGRAPHY

1. Allen, H. H. 1978. "Role of Wetland Plants in Erosion Control of Riparian Shorelines," Wetland Functions and Values: The State of Our Understanding, American Water Resources Association, pp 403-414.

The role of wetland vegetation in erosion abatement of lake, river, and stream shorelines and some of the work done by the US Army Engineer Waterways Experiment Station as related to the use of wetland vegetation for erosion control are described. Erosion control potential of both herbs and woody plant species is discussed, and various plants are identified that have special attributes for use in erosion control. Several factors are presented that influence the establishment of wetland vegetation along shorelines, such as plants' flood and desiccation tolerance and resistance to undermining, steepness in bank slope, amount and frequency of water-level fluctuation, degree of wave action, and speed of currents. Discussion is devoted to the artificial establishment and value of wetland vegetation. A method is presented of employing vegetation with an engineering structure such as a revetment to mutually abate erosion and provide other values such as a cover for wildlife and the improvement of aesthetics. In addition, several suggestions are made for future research and studies that could possibly enable optimum use of wetland plants in erosion control.

2. Allen, H. 1982a. "Non-structural Streambank Erosion Protection Measures - Planted Vegetation," Streambank Protection Course Notebook, Lecture F-3, US Army Engineer Division, Huntsville, Huntsville, Ala.

These notes, from a training course on streambank protection conducted at WES in October 1982, review the assets and limitations of planted vegetation for streambank control, discuss factors to be considered in designing vegetative protection, describe site preparation, discuss vegetation selection for different bank zones, describe revegetation techniques, and provide information on plant procurement and costs of vegetative protection.

3. Allen, H. 1982b. "Non-structural Streambank Erosion Protection Measures - Management of Native Vegetation," Streambank Protection Course Notebook, Lecture F-4, US Army Engineer District, Huntsville, Huntsville, Ala.

These notes, from a training course on streambank protection conducted at WES in October 1982, describe methods for managing planted and natural native vegetation for streambank protection.

4. Allen, H. H., and Aggus, L. R., eds., 1983. "Effects of Fluctuating Reservoir Water Levels on Fisheries, Wildlife, and Vegetation; Summary of a Workshop, 24-26 February 1981," Miscellaneous Paper E-83-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The seasonal fluctuations that occur on many lakes and flood control reservoirs and the daily fluctuations that are necessary on some hydroelectric projects often result in elimination of shoreline vegetation, which causes erosion, diminished water quality, and habitat loss or degradation. This report presents abstracts of papers presented at a workshop organized to identify the problems resource managers face and to present research results that might be applied to alleviate or moderate the adverse effects of reservoir fluctuation. Sessions were organized under the general topics of vegetation, wildlife, and fisheries.

Discussions of the results of the workshop sessions and possible means of resolving conflicts between the requirements of the reservoir biota and the principal operational goals of the reservoir projects are also presented. Addresses of the principal authors are provided to allow readers to seek further information regarding particular studies.

5. Allen, H. H., and Webb, J. W. 1983. "Erosion Control and Saltmarsh Vegetation," Proceedings of the Third Symposium on Coastal and Ocean Management, ASCE/San Diego, California, June 1-4, 1983, pp 735-748.

A salt marsh was established in a moderately high-energy wind-driven wave climate for the purpose of stabilizing a dredged material dike. The study site was located on a dredged material island in Mobile Bay, Alabama. About 1.7 ha of smooth cordgrass (*Spartina alterniflora*) sprigs was planted in May 1981 without wave protection. Significant washout of the sprigs occurred within 2 months. A second planting of two 0.15-ha areas was initiated in August 1981 with two different breakwater systems installed to protect the plants from wave action: a fixed breakwater made from wooden posts with metal planks bolted to them and rubber tires strapped to the planks, and a floating-tire breakwater (FTB). Plant establishment success behind each breakwater and in an area without breakwater protection is described, as well as marsh planting success behind a second FTB constructed in 1982. Degree of success and construction time and costs are given for each breakwater. Results indicated that salt marsh can be economically established in some moderately high wave-energy areas for erosion control or habitat development purposes if wave protection is provided during initial establishment.

6. Allen, H. H., Webb, J. W., and Shirley, S. O. 1984. "Wetlands Development in Moderate Wave-Energy Climates," Proceedings of the Conference Dredging '84, Waterway, Port, Coastal and Ocean Division ASCE/Nov. 14-16, 1984, Clearwater Beach, Fla., pp 943-955.

For 3 years, sprigs of *Spartina alterniflora* were planted on a portion of Theodore Island, a dredged material island in Mobile Bay, Alabama. The purpose of the planting was to stabilize the northwest side of the island and a small portion of the southwest side of the island, both of which are subject to moderate wave energies. Both the northwest and southwest sides of the island are dikes that form two of the three sides of a triangular disposal area.

This paper reports the degree of marsh grass establishment success at this island from 1981 to 1983 and discusses special marsh grass planting and protection techniques (including tire breakwaters) that are proving successful in stabilizing erodible areas. Some of the areas where these techniques were used had previously washed out due to wave action after two or three planting attempts using bare-rooted, single-stemmed sprigs. Results indicate that these special techniques are much more successful and cost effective in establishing marsh than repeated planting attempts using conventional methods. Successful wetlands development on dredged material may not only stabilize it, but also create valuable habitat that makes dredged material disposal more attractive to environmental agencies.

7. Andrews, M. 1977. "Selected Bibliography of Disturbance and Restoration of Soils and Vegetation in Permafrost Regions of the USSR (1970-1976)," SR 77-07, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

The literature is discussed in chronological fashion, with general statements followed by highlights of each year's contributions (with three tables and two appendixes for amplification). The years 1972 and 1973 produced the most publications, and by 1975 there was a noticeable lag in pickup of publications by the indexing services. A trend is apparent from a reconnaissance and description approach in earlier papers toward an integrated ecosystem approach in more recent publications. Increased consciousness of the effects of disturbance on the permafrost environment and the importance of restoration and preservation of these environments is reflected in the recent literature, particularly in symposium proceedings.

8. Barko, J. W., et al. 1977. "Establishment and Growth of Selected Freshwater and Coastal Marsh Plants in Relation to Characteristics of Dredged Sediments," Technical Report D-77-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The success of establishment and the growth of marsh plants on physically and chemically different dredged sediments were investigated under semi-controlled conditions in a greenhouse. Freshwater, brackish, and salt marsh environments were simulated for concurrent experimentation with various propagules of different species. Growth of individual marsh plant species was determined on the basis of stem density and total plant biomass. Growth of freshwater plants, affected by the availability of nitrogen, was significantly greater on fine-textured sediments than on sand. Growth of both brackish and salt marsh plants was relatively unrelated to nutrient availability and was affected most by the salinity of the sediment solution. Within the same period of growth, transplants produced plant populations having greater biomass and number of stems than did any of the other plant propagules. Rhizomes, rootstocks, and tubers responded similarly, but to a lesser extent, to sediment differences than transplant propagules of the same species. Recommendations relevant to marsh-creation projects are made on the basis of results of this investigation as well as a review of the pertinent literature.

9. Barnard, W. D. 1978. "Prediction and Control of Dredged Material Dispersion Around Dredging and Open-Water Pipeline Disposal Operations" (Synthesis Report), Technical Report DS-78-13, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Laboratory and field results of eight separate, but related, contract research studies performed within the Dredged Material Research Program are synthesized, and the available literature concerned with turbidity generation by different types of dredging operations is summarized. Water column turbidity generated by dredging operations is usually restricted to the vicinity of the operation and decreases rapidly with increasing distance from the operation due to settling and horizontal dispersion of the suspended material. Turbidity levels around dredging operations can be reduced by improving existing cutterhead dredging equipment and operational techniques, using watertight buckets, and eliminating hopper dredge overflow or using a submerged overflow system. During open-water pipeline disposal of fine-grained dredged material slurry, 97 to 99 percent of the material descends rapidly to the bottom of the disposal area where it forms a low-gradient fluid mud mound. One to three percent of the discharged slurry will remain suspended in the water column in the form of a turbidity plume. The relative degree of dredged material dispersion at open-water pipeline disposal operations can be controlled best by using different discharge configurations. By implementing the guidelines given in this report for selecting dredges, improving operational techniques, properly using silt curtains, and selecting appropriate pipeline discharge configurations, dredging or disposal operations can be conditioned to minimize environmental impacts. The appendix to this report describes the relationship of suspended solids concentration, bulk density, and percent solids by weight.

10. Barnard, W. D., and Hand, T. D. 1978. "Treatment of Contaminated Dredged Material" (Synthesis Report), Technical Report DS-78-14, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The report examines, in the context of both open-water and confined disposal, processes and techniques for treating dredged material or the effluent from confined areas to minimize the impact on receiving waters. Although generalizations are difficult to make, several findings have emerged from the various studies synthesized. For confined disposal operations, it has been concluded that: (a) sedimentation in a confined disposal area should be regarded as the primary treatment of the dredged material; (b) existing areas will function more efficiently as settling basins through dredge size reduction, intermittent pumping, increasing the weir length, and increasing the ponding depth by raising the weir; and (c) organic polymer flocculants can be used effectively to coagulate and clarify effluents from confined disposal areas containing unacceptably high solids concentrations.

11. Benner, C. S., et al. 1982. "Vegetative Erosion Control in an Oligohaline Environment, Currituck Sound, N.C.," Wetlands, The Journal of the Society of Wetland Scientists, Vol 2.

The Coastal Engineering Research Center (CERC) is engaged in research on erosion control with vegetation. This research has demonstrated that salt marsh plantings help dissipate wave energy, causing deposition of sediments. These processes can convert eroding environments into depositional environments producing shore advancement. In order to evaluate the impact of shoreline plantings in oligohaline coastal environments, a 30-m segment of a planting was monitored over an 8-year period. Within 5 years, the planting had halted shore erosion and at least 20 additional species of plants had invaded the study site.

12. Berg, R. L., and Smith, N. 1976. "Observations Along the Pipeline Haul Road Between Livengood and the Yukon River," SR 76-11, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

The TAPS Road has been evaluated periodically over a 6-year period with respect to construction and slope stabilization techniques in ice-rich roadway cuts and embankment subgrades. Lateral drainage ditches of sufficient width to handle construction excavation equipment, along with near-vertical slope cuts with hand-cleared tops equal in width to one and one-half times the height of the cuts, significantly enhance natural processes of slope stabilization. Rights-of-way clearing limited to the toe of embankment fill slopes minimizes subsidence of the roadway and its shoulder slopes. In extremely ice-rich soil cuts, the seeding of the slopes should not be attempted until late in the first thaw season for best results. Natural woody growth can be expected to have a substantial stabilizing effect after five or six thaw seasons but could be accomplished sooner by planting tree seedlings. Attempts to stabilize ice-rich cut slopes with applications of insulation are not very effective and seem to prolong the natural stabilization process.

13. Brown, J., ed. 1977. "Symposium: Geography of Polar Countries; Selected Papers and Summaries," SR 77-06, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

The symposium on Geography of Polar Countries held in Leningrad on 22-26 July 1976 as part of the XXIII International Geographical Congress consisted of three sessions: (a) polar environment, natural resources, their exploration and exploitation; (b) past, present, and future economic developments in the polar regions; and (c) polar environment protection. This report presents the full text or extended summaries of a number of the US papers, and English and Russian summaries of the Soviet contributions related to environmental protection. The papers and summaries presented in this report reflect the participation of members and of the joint US-USSR environmental protection agreement project, Protection of Northern Ecosystems. The US papers deal with land use planning to mitigate environmental impact; the impact of resource development on natives, fish and wildlife, and permafrost; the impacts of pipelines and roads on the environment; and computer modeling to simulate terrain modification due to man's activities. The Soviet summaries deal with the properties of and changes in arctic and subarctic flora, treeline, and permafrost, and methods of predicting changes in the environment.

14. Brown, J., ed. 1980. "Environmental Engineering and Ecological Baseline Investigations Along the Yukon River-Prudhoe Bay Haul Road," CR 80-19, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

During the period 1975 to 1978 the Federal Highway Administration sponsored a series of environmental engineering investigations along the Prudhoe Bay Haul Road. In 1976 the Department of Energy joined these investigations with a series of ecological projects which continue to the present. Both agencies' research efforts were conducted on a cooperative basis with CRREL's in-house research program. The objectives of the research focused on (a) an evaluation of the performance of the road, (b) an assessment of changes in the environment associated with the road, (c) documentation of flora and vegetation along the 577-km-long transect, (d) methodologies for revegetation and restoration, and (e) an assessment of biological parameters as indicators of environmental integrity. In support of these objectives, specific studies were undertaken that investigated the climate along the road, thaw and subsidence beneath and adjacent to the road, drainage and side slope performance, distribution and properties of road dust, vegetation distribution, vegetation disturbance and recovery, occurrence of weeds and weedy species, erosion and its control, revegetation and restoration, and construction of the fuel gas line. This report presents background information on the region; detailed results of the road thaw subsidence and dust investigations; and summaries of revegetation, fuel gas line, vegetation distribution, soil, and weed studies.

15. Brown, J., and Grave, N. A. 1979. "Physical and Thermal Disturbance and Protection of Permafrost," SR 79-05, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

This report is based on a review paper presented at the Third International Conference on Permafrost held in July 1978 at Edmonton, Canada. It reviews the literature from 1974 to 1978 and covers subjects related to natural and human-induced disturbance of terrain underlain by permafrost. Subjects include investigations undertaken in conjunction with oil and gas pipelines, terrain mapping methods for estimating terrain sensitivity, methods of protecting terrain, and the thermal effects of off-road transportation, oil spills, fire, removal of the surface soil layers, snow conditions, mining, and other construction practices. Methods of protecting and restoring permafrost in the USSR are presented in tabular form. An appendix summarizes results of modeling and microclimatic investigations, and the distribution and properties of subsea, land-based, and alpine permafrost.

16. Buchak, E. M., and Edinger, J. E. 1982. "User Guide for LARM2: A Longitudinal-Vertical, Time-Varying Hydrodynamic Reservoir Model," Instruction Report E-82-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A two-dimensional, laterally averaged reservoir hydrodynamic model, LARM, was modified to provide several enhancements. The two major enhancements made to the numerical model were the incorporation of a water quality transport module (WQTM) and the capability to add or delete upstream longitudinal segments during flooding or drawdown. WQTM is a general-purpose transport algorithm for which the user must specify the water quality constituent with sources and sinks and the associated reaction rates.

This user's guide contains an overall view of LARM2, a summary of its theoretical basis, a description of its application procedure, and an example. The appendixes contain an input data description with examples and user notes for two auxiliary codes.

In addition to this guide, there is a more detailed description of the modified model entitled "Developments in LARM2: A Longitudinal-Vertical, Time-Varying Hydrodynamic Reservoir Model" (Edinger and Buchak 1983).

17. Burch, C. W., et al. 1984. "Environmental Guidelines for Dike Fields," Technical Report E-84-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The environmental guidelines for dike fields contained within this report consist of environmental objectives, design procedures, and river-specific examples of currently employed environmental features that can be used to maintain or increase fish and wildlife habitat diversity. Design, construction, and maintenance of dikes can alter the water depth, current velocity, and substrate composition to increase habitat diversity of US Army Corps of Engineer waterway projects.

Environmental features that can be incorporated into dike fields to increase diversity are notches, low-elevation dikes, rootless dikes, and minimum maintenance practices. Other potential techniques include dredging to remove sediment, disposing of dredged material within the dike field, relocating old notches, placing additional rock, adding artificial reefs, and building control structures in side channel closure dikes.

Two case studies--one on the Missouri River, one on the lower Mississippi River--of river response to dike field construction are presented. Aquatic habitat requirements of representative vertebrate species and of aquatic invertebrates are given in appendixes.

18. Cammen, L. M., Seneca, E. D., and Copeland, B. J. 1976. "Animal Colonization of Man-Initiated Salt Marshes on Dredged Spoil," TP 76-7, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

A research study to determine differences in fauna in disposal areas and natural marsh at Drum Inlet and Snow's Cut, North Carolina, is presented. A marked difference in faunal development was found at the sites. Research also showed that planting *Spartina* on dredged material led to the creation of salt marsh which resembled natural marsh.

19. Canter, L. W., et al. 1977. "An Assessment of Problems Associated with Evaluating the Physical, Chemical, and Biological Impacts of Discharging Fill Material," Technical Report D-77-29, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A multidisciplinary evaluation of the difficulties associated with determining environmental changes resulting from fill material discharges is presented. A literature survey was conducted to pinpoint technical deficiencies. A weighted rankings technique was employed to establish priorities for administrative/procedural and technical problems. While technical information does exist regarding the environmental impacts of various types of fill material used in a number of projects, there are major informational deficiencies relative to impact prediction, assessment, and mitigation. Among other areas, accompanying tables cover the following topics: (a) effects of construction projects on water quality; (b) water pollution from construction activities, cause/effect matrix; (c) administrative/procedural problems related to fill material discharge; (d) technical problems and needs related to fill material discharge; and (e) weighted-rankings of technical problems and needs. Appendixes to the report contain: (a) a legal and legislative history of Corps dredging; (b) regulations and guidelines relating to requirements for fill discharge; (c) informational contacts; (d) methodologies for environmental impact assessment; (e) case studies on discharging fill materials; (f) information on minimization of environmental impacts; and (g) engineering design considerations for fill material projects.

20. Clar, M., et al. 1983. "Restoration Techniques for Problem Soils at Corps of Engineers Construction Sites (Draft)," Instruction Report EL-83-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The report contains information on the planning and implementation of vegetative restoration for problem soils at Corps of Engineers construction sites. Problem soils described include acid soils, saline and alkaline soils, excessively drained soils, poorly drained soils, dispersive clays, and wind-erodible soils. Plant materials are listed for different regions of the United States, and seeding and planting procedures are described. The report should be a valuable resource document for planners and engineers who are required to control soil erosion and vegetate project sites that contain problem soils.

21. Clark, E. F., and Simoni, O. W. 1976. "Survey of Road Construction and Maintenance Problems in Central Alaska," SR 76-08, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

A survey of road construction and maintenance problems in central Alaska is presented. The problems of poor fill and foundation material, permafrost degradation under pavement and shoulders, slope instability, water erosion, road icing from subsurface seepage, and culvert icing are described. Possible solutions to road maintenance problems in central Alaska include the use of insulating materials in permafrost areas, MESL construction when nonfrost-susceptible soils are unavailable, and the use of improved drainage in areas where extensive icing occurs. Bridge damage, erosion of sidehill cuts, and embankment instability are also discussed, and potential solutions are given.

22. Coastal Zone Resources Corp. 1976. "Identification of Relevant Criteria and Survey of Potential Application Sites for Artificial Habitat Creation; Vol I: Relevant Criteria for Marsh-Island Site Selection and Their Application; Vol II: Survey of Potential Application Situations and Selection and Description of Optimum Project Areas," Contract Report D-76-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The first volume of this report, which develops a process for the selection of areas appropriate for marsh construction using dredged material, describes the biophysical and socioeconomic information needed to evaluate potential marsh creation sites and presents the rationale underlying the emphasis on these data. A two-scale approach is recommended for analyzing the information base typically available to the Engineer District. The first, a reconnaissance-scale evaluation, combines intuitive judgment and available data. A more rigorous application of criteria is presented for the second, detailed-scale evaluation. Specific kinds of potential problems and theoretical approaches to their solution are also discussed.

In the second volume, the selection rationale presented in Volume I is tested on 50 prime candidate project areas, 10 within each of five major coastal geographic regions. From this compilation, 10 optimum project areas, two in each geographic region, are selected and described further using data gathered in the project areas and from relevant Engineer Districts. The appendix presents the form letter used in the main survey.

23. Collins, C. D., and Wlosinski, J. H. 1983. "Coefficients for Use in the US Army Corps of Engineers Reservoir Model, CE-QUAL-R1," Technical Report E-83-15, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report supplies information about, and literature values for, many of the coefficients needed for the US Army Corps of Engineers Reservoir Model CE-QUAL-R1. Most of the information presented concerns biological processes of gross production, ingestion, respiration, mortality, and decomposition. Coefficients specified are suitable for the algorithms described in Instruction Report E-82-1, entitled "CE-QUAL-R1: A Numerical One-Dimensional Model of Reservoir Water Quality; User's Manual," available from the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, Miss. (see also reference 28).

24. Coughlin, R. E., Berry, D., and Cohen, P. 1978. "Modeling Recreation Use in Water-Related Parks," Technical Report R-78-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report examines procedures and techniques for use prediction, benefit estimation, and development of conceptual recreation plans. A thorough review of the literature was followed by a test of several models, including those already completed by the US Army Engineer District (USAED), Sacramento. For this test, data from 30 New York State Parks were used. The results were not as successful as those obtained by the USAED, Sacramento. This is attributed, in part, to the fact that the data were collected for another purpose and did not contain as many observations as would be desirable for a spatial analysis of this type.

25. Courtenay, W. R., Jr., et al. 1974. "Ecological Monitoring of Beach Erosion Control Projects, Broward County, Florida and Adjacent Areas," TM-417, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

Ecological monitoring of algae, invertebrates, and fishes was conducted along the southeastern Florida coast in connection with offshore dredging and beach nourishment projects. One area surveyed showed no adverse ecological effects, but reef damage by dredging equipment was found in another area. Ecological data have been recorded for three other areas proposed for dredge-and-fill operations.

26. Courtenay, W. R., Jr., Hartig, B. C., and Loisel, G. R. 1980. "Ecological Evaluation of a Beach Nourishment Project at Hallandale (Broward County), Florida; Vol I: Evaluation of Fish Populations Adjacent to Borrow Areas of Beach Nourishment Project at Hallandale (Broward County), Florida," MR-80-1 (I), US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

A study of the fish populations within the surf zone and over the first and second reefs off Hallandale (Broward County), Fla., was conducted 7 years after dredging for a beach restoration project. This study utilized an observational and recording technique to collect data. The data were compared with those of an earlier study conducted in 1971-1972.

In the 1971-1972 study, conducted during and after dredging activities, 42 species of fishes belonging to 24 families were found. The present study revealed the presence of 114 species of fishes belonging to 36 families. The dusky jawfish (*Opistognathus whitehursti*), common along the first reef platform in 1971-1972, was absent. The absence of this fish is attributed to an alteration of the substrate on the first reef by incursion of fine sediments. Damage to the second reef observed during 1971-1972 was not evident during this study.

27. Eckert, J. W., Giles, M. L., and Smith, G. M. 1978. "Design Concepts for In-Water Containment Structures for Marsh Habitat Development," Technical Report D-78-31, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

General guidance is provided for selecting, designing, and constructing structures for use in habitat development. Various types of structures are

reviewed based on the available literature. Steps to be followed in selecting an in-water confined disposal structure are enumerated, and case histories of structures in use are presented. An accompanying table lists known projects, their location, and their structural type. Structure selection problems also are examined. Appendixes to this report contain (a) cost data and (b) structure data sheets.

28. Environmental Laboratory. 1982. "CE-QUAL-R1: A Numerical One-Dimensional Model of Reservoir Water Quality; User's Manual," Instruction Report E-82-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This manual is organized into four major parts with several appendixes. In Part I, CE-QUAL-R1 is introduced to the reader by summarizing its major uses, attributes, and historical development.

Part II addresses model capabilities, assumptions and limitations, and basic equations. It supplies the necessary information to understand the model without getting into specific details.

Part III is concerned with specific constructs of CE-QUAL-R1. It describes each subroutine in detail. Part III can be skipped initially if the user is not interested in specific details and will not be modifying the program.

Part IV is the most important section of this manual. It describes how to determine the various coefficients, constants, and updates required by CE-QUAL-R1. It also describes how to calibrate the model and interpret output.

The appendixes include: (a) Appendix A, which is a listing of the program; (b) Appendix B, which is a glossary describing the variables and coefficients used in CE-QUAL-R1; (c) Appendix C, which shows card images; (d) Appendix D, which illustrates model output; (e) Appendix E, which describes the separate usage of the thermal analysis portion of CE-QUAL-R1; and (f) Appendix F, which details the preparation of meteorological data for use in CE-QUAL-R1.

29. Fonseca, M. S., et al. 1984. "Transplanting of the Seagrasses *Zostera marina* and *Halodule wrightii* for Sediment Stabilization and Habitat Development on the East Coast of the United States," Technical Report EL-85-9, prepared by National Marine Fisheries Service, Beaufort, N. C., for US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

There is little information on procedures for evaluating potential eelgrass (*Z. marina*) and shoalgrass (*H. wrightii*) planting sites. One major reason for the sparcity of information is that some critical environmental factors controlling eelgrass and shoalgrass growth are poorly documented for transplanting conditions. Study sites were selected which represent a wide range of environmental conditions under which eelgrass and shoalgrass locally occur. The environmental factors considered were temperature, salinity, light and depth, sediment characteristics, and hydraulic regime.

Growth of transplanted eelgrass can be predicted with a 25- to 50-percent variation by using age and site criteria (assuming all site evaluation criteria are met). Using these criteria, recovery of appropriate areas by transplanted eelgrass and shoalgrass can be accelerated dramatically, often by time measured in years. Successful seagrass transplants should display new shoot generation and coverage rates similar to natural populations.

30. Fontane, D. G., Labadie, J. W., and Loftis, B. 1982. "Optimal Control of Reservoir Discharge Quality Through Selective Withdrawal," Hydraulic Laboratory Investigation, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report presents a method combining simulation and optimization techniques to determine guidelines for operating selective withdrawal reservoir structures to meet downstream water temperature objectives. Optimal operation is achieved with successful application of operating rules that anticipate future critical temperature conditions.

In this study, a one-dimensional reservoir thermal simulation model developed by the US Army Engineer Waterways Experiment Station was used to simulate the thermal stratification cycle of a reservoir. The model was interfaced with a formulation called objective-space dynamic programming (OSDP) to develop the optimal operation strategy for each decision period. The OSDP formulation retains the integrity of the simulation model and minimizes an objective function related to deviations of predicted release temperature from downstream target temperature over a portion of the stratification cycle. Application to a case study shows the potential for using the dynamic programming technique, as compared to the normal period-by-period operation, to improve performance of the system.

31. Ford, J. C., Hurme, A. K., and Pullen, E. J. 1983. "An Annotated Bibliography on the Biological Effects of Construction Channels, Jetties, and Other Coastal Structures," MR 82-3, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This bibliography includes 199 historic and recently published research reports for use in evaluating the biological effects of construction channels, jetties, and other coastal structures on fish and shellfish migration.

32. Gambrell, R. P., Khalid, R. A., and Patrick, W. H., Jr. 1978. "Disposal Alternatives for Contaminated Dredged Material as a Management Tool to Minimize Adverse Environmental Effects" (Synthesis Report), Technical Report DS-78-8, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report synthesizes published research findings on the chemical mobility of sediment-bound contaminants under various conditions of dredged material disposal. The factors which should be evaluated to determine the environmental acceptability of a proposed disposal method for a contaminated sediment are examined. Brief reviews are included in the chemistry of contaminants in sediment/water systems, the properties of the dredged sediment that affect the fate of contaminants, and the short- and long-term physiochemical (acidity, oxidation-reduction conditions, and salinity) environments of the dredged material at the disposal site which influence processes enhancing or retarding contaminant mobility. Management practices that may be used to improve a marginally acceptable disposal method, especially where environmentally optimum methods are not feasible for technological or economic reasons, are also discussed.

33. Garbisch, E. W., Jr. 1977. "Recent and Planned Marsh Establishment Work Throughout the Contiguous United States--A Survey and Basic Guidelines," Contract Report D-77-3, prepared by Environmental Concern, Inc., St. Michaels, Md., for US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report presents practical guidelines for marsh site preparation, marsh establishment, and site management and maintenance, developed on the basis of information received on deliberate marsh establishment work planned, under way, or completed throughout the contiguous United States within the period 1970 to 1976. Surface slopes and surface elevations are discussed as the two most important factors in preparing a site for marsh establishment.

Within the tidal zone, surface slopes should be developed so that they exhibit reasonable stabilities in the absence of vegetative cover. Surface elevations must be carefully considered in the design and planning of a project and tied in with the various zones of marsh types existing in the region. Considerations and actions to be included in marsh establishment at a given site are listed, and marshscape architecture, maintenance, and management are discussed. All aspects of marsh establishment must be an integral part of the design and planning of the total project. Information was identified through a literature review and interviews and by distributing information request forms. Appendixes to the report contain (a) the list of correspondents and (b) the marsh-creation research information request.

34. Gaskin, D. A., et al. 1977. "Utilization of Sewage Sludge for Terrain Stabilization in Cold Regions," SR 77-37, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

A terrain stabilization research/demonstration site was constructed in May 1974 at Hanover, N. H., to investigate various combinations of physical, chemical, and biological techniques for terrain stabilization in cold regions. Fourteen test plots (10 × 40 ft) (3 × 12 m) with individual 350-gal (1,325-cu dm) tanks to collect sediment were installed on a 16-deg slope to examine the effectiveness of sewage sludge and primary effluent on terrain stabilization in cold regions. In 13 of the 14 plots the variables studied were nutrient source (fertilizer, sludge, and primary wastewater), moisture (irrigated and nonirrigated), erosion control material (jute netting, straw tacked with a tacking compound), no erosion control material, and vegetation (three grasses and two legumes). The control plot was left bare of seed, fertilizer, and erosion control material for comparison. A 20,000-sq ft (1,858-sq m) area adjacent to the 14 plots was installed for general testing of various combinations of tacking chemicals, plastic netting, straw, and wood fiber mulch. In general, all treatments with the exception of two plots were effective in reducing soil loss in comparison with the control, which had a loss of 34,531 lb (15,663 kg) of soil (dry weight) on a per-acre basis.

35. Haliburton, T. A. 1978. "Guidelines for Dewatering/Densifying Confined Dredged Material" (Synthesis Report), Technical Report DS-78-11, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The results of Dredged Material Research Program Disposal Operations Project Task 5A, Dredged Material Densification, are presented in the form of guidelines for dewatering by progressive trenching, dewatering by underdrainage, and confined disposal area operation and management to facilitate dewatering. Use of progressive surface trenching concepts to remove disposal area ponded surface water and precipitation and to enhance evaporative dewatering of fine-grained dredged material is the most cost-effective dewatering alternative. When existing conditions make it impossible to implement a surface trenching dewatering program, surface trenching alone will not produce dewatering at necessary rates. Various concepts of either gravity- or vacuum-assisted underdrainage may be applied to obtain maximum possible dewatering effects. Implementation of any program of fine-grained dredged material dewatering and densification will be most effective when conducted as part of an overall confined disposal area management plan. The main technical unknown in application of concepts synthesized in the report is the exact rate at which dewatering will occur. State-of-the-art prediction methods given and referenced in the report are satisfactory for feasibility determinations and, in many instances, for use in final design. Monthly standard Class A pan evaporation data for the continental United States are given in the appendix.

36. Hall, V. L., and Ludwig, J. D. 1975. "Evaluation of Potential Use of Vegetation for Erosion Abatement Along the Great Lakes Shoreline," MP 7-75, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This study identifies and evaluates shoreline plants with potential, either alone or in combination with structures, to alter the erosion rate along shores of the Great Lakes. It was determined that plants alone are not suitable erosion controllers along most shores because of severe wave action.

37. Henderson, J. E. 1982. "Handbook of Environmental Quality Measurement and Assessment: Methods and Techniques," Instruction Report E-82-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Guidance is provided for the selection and use of environmental analysis techniques for environmental quality planning and evaluation. Uses of generic types of environmental analysis methods (such as environmental impact matrices for environmental planning) are explained. Technique profiles are given to support planning steps, and four performance matrices are given to assist the user. One section contains measurement and evaluation techniques for use in environmental quality evaluation procedures with (a) technique profiles that describe methods, techniques, and procedures for characterizing ecological, cultural, and aesthetic resources and (b) profile characteristics matrices. An extensive bibliography contains the references, reports, and citations considered in preparing the handbook.

38. Henderson, J. E., and Shields, F. D., Jr. 1984. "Environmental Features for Streambank Protection Projects," Technical Report E-84-11, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report provides guidance for incorporating environmental considerations into bank protection projects. Streambank stabilization to prevent or reduce bank erosion and failure may result in a wide range of environmental changes. Processes of stream erosion and failure and the effects of bank characteristics and human activities on these processes are reviewed. Environmental consequences of streambank protection are described in the first part of the report. The major portion of the report is devoted to detailed evaluations of environmental features (planning, design, construction, and maintenance practices that minimize adverse environmental impacts or enhance habitat values and aesthetic quality of land and water associated with streambank protection projects). Features evaluated included structural and nonstructural designs; environmentally compatible construction procedures; maintenance procedures; and institutional, planning, and management approaches for streambank protection projects. Each feature is evaluated in terms of concept, purpose or use, environmental considerations, limitations to use, performance history, and cost.

39. Holliday, B. W., Johnson, B. H., and Thomas, W. A. 1978. "Predicting and Monitoring Dredged Material Movement," Technical Report DS-78-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report summarizes the results from three work units (1B06, 1B07, and 1B09) of the Dredged Material Research Program concerned with predicting and monitoring dredged material movement. Work Unit 1B06 was an evaluation and calibration of the Tetra Tech disposal models using field data collected at several disposal sites, including the Duwamish, New York Bight, and Lake Ontario sites. The collection of these field data was performed under Work Unit 1B09 by Yale University. Work Unit 1B07 involved an evaluation of two two-dimensional finite element models for the long-term prediction of sediment transport in estuaries. The modifications of the Tetra Tech models made by the US Army Engineer Waterways Experiment Station are discussed, and calibration results are presented using field data from the Duwamish, New York Bight, and Lake Ontario disposal sites. A summary of observations from a field data collection program on the mechanics of the placement of dredged material at open-water disposal sites is provided. The factors involved in the long-term transport of sediment in estuaries, their treatment by finite element models, the limitations of the models, and their current status also are discussed.

40. Hunt, L. J., et al. 1978. "Upland Habitat Development with Dredged Material: Engineering and Plant Propagation" (Synthesis Report), Technical Report DS-78-17, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Pertinent literature and research on upland habitat development conducted by the Habitat Development Project, Task 4B of the Dredged Material Research Program, are synthesized. Guidelines are presented for developing existing or potential dredged material disposal sites into upland habitat. These involve: (a) planning and designing the project in relation to the proposed site and project goals; (b) constructing the site, including dredging and disposal operations, substrate modification, and vegetation establishment; (c) maintenance and management of the site as a habitat; (d) costs of proposed and sample projects; and (e) potential problems. Emphasis is placed on engineering and on plant propagation. Engineering aspects include data collection and analysis for site design, protective and retention structures, substrate characteristics, dredging and disposal operations, and specific requirements. The phase of plant propagation includes selecting plant species; selecting, collecting, and handling plant materials; planting; maintenance and management; and cost estimates. Tables of 360 selected plant species are given which show best propagules, occurrence by region and whether known to occur on dredged material, growth requirements and habits, propagule handling methods, soil tolerances, and other pertinent information. Appendixes to this report give: (a) a partial listing of commercial soil-testing facilities; (b) common and scientific names of animals and plants mentioned in the text and tables; and (c) sources of plant propagules.

41. Hurme, A. K. 1979. "Rubble-Mound Structures as Artificial Reefs," Proceedings of the Specialty Conference on Coastal Structures 79, American Society of Civil Engineers, Vol 2, US Army Corps of Engineers, Fort Belvoir, Va.

Structures armored with rubble can have a positive effect on coastal ecology by functioning as artificial reefs, particularly when they are placed in areas with a barren bottom. The desirable qualities of these reef structures are frequently overlooked. Many people think of rubble groins, jetties, and breakwaters as desirable places to fish, but do not realize that the structures themselves have a major influence on the success of their fishing.

Rubble-mound structures (constructed by the US Army Corps of Engineers) are ideal artificial reefs because they are built of natural stone and have many varying sized cracks and crevices exposed to the entire water column that can be colonized by a great diversity of reef dwellers. Most potential environmental problems can be overcome by careful planning and site selection. Although benefits appear great, quantifying them is a difficult task. Rubble-mound reefs are biologically highly productive both from the standpoint of biomass and sport-fishing success.

42. Huston, J. W., and Huston, W. C. 1976. "Techniques for Reducing Turbidity Associated with Present Dredging Procedures and Operations," Contract Report D-76-4, prepared by John Huston, Inc., Corpus Christi, Tex., for US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Operational techniques that can be used with existing technology and equipment to reduce turbidity created by a dredging plant are examined. The study focuses primarily on hydraulic dredging. Attention is paid to the cost and ease of implementation as well as to the effect on dredge operation and production rate. Techniques for reducing turbidity fall into the categories of the cutter, ladder, suction, hull, pipeline, connections, barges, tenders, personnel, inspection, contracts, plans, and specifications and consist principally of good dredging during periods of high background levels of turbidity and nationwide training for dredging operators, supervisors, and inspectors.

43. Hynson, J. R., et al. 1985. "Environmental Features for Streamside Levee Projects," Technical Report E-85-7, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This study provides designers of levee projects with guidance for incorporating environmental enhancement features into project design and maintenance. Forty-six environmental features that have potential to improve fish and wildlife habitat, recreational use, and aesthetic qualities of lands and water associated with levee projects are identified. Information was obtained from review of scientific literature and planning documents, as well as contact with US Army Corps of Engineer personnel and site visits to selected completed levee projects.

Features include general items for design and maintenance, as well as specific measures for fish and wildlife habitat, recreation, and aesthetic development. All features included in the main body of the report, plus a few that were rejected, were evaluated by an interdisciplinary team consisting of two civil engineers, a wildlife biologist, an aquatic biologist, and a landscape architect.

Each feature is discussed from a variety of perspectives: (a) its purpose is stated in order to give the reader a rapid means of determining environmental values that the feature would improve, protect, or enhance; (b) directions are provided for its implementation; (c) a summary of its past performance is given; (d) limitations, both general and site specific, are provided; and (e) information on construction, operations, and maintenance is discussed.

44. JBF Scientific Corp. 1978. "An Analysis of the Functional Capabilities and Performance of Silt Curtains," Technical Report D-78-39, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Analytical studies and field measurements were made during actual silt curtain operations to provide guidance on silt curtain usage. When silt curtains, or turbidity barriers, are used to enclose open-water pipeline disposal operations for fine-grained material, 95 percent or more of the dredged material slurry descends to the bottom of the disposal area where it forms a fluid mud layer. The remaining 5 percent or less of the dredged material slurry is responsible for the turbidity in the water column. A silt curtain that is properly deployed and maintained provides a mechanism for controlling the dispersion of turbid water by diverting its flow under the curtain. The effectiveness of the silt curtain depends on the nature of the operation; the characteristics of the material in suspension; the type, condition, and deployment of the silt curtain; the configuration of the enclosure; and the hydrodynamic regime present at the site. Under quiescent conditions, turbidity levels outside a curtain that is properly deployed and maintained may be reduced by 80 to 90 percent. An upper limiting current velocity for typical silt curtain usage appears to be approximately 1.5 ft/sec (0.5 m/sec). An alphabetical listing of companies who manufacture silt curtains and whose products were reviewed during this study is appended.

45. Johnson, A. J. 1981. "Revegetation and Selected Terrain Disturbances Along the Trans-Alaska Pipeline, 1975-1978," CR 81-12, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

Revegetation techniques used by Alyeska Pipeline Service Company along the trans-Alaska pipeline during the 1975-1978 summers were observed to determine treatment success, identify problem areas, and determine long-term implications. Observations and photographs at 60 sites along the trans-Alaska pipeline indicated frequent occurrence of successful revegetation as well as frequent problems, such as erosion, slope instability, poor scheduling of seed application, occurrence of weed species, failure to optimally reuse topsoil and fine-grained soil, and low rates of native species reinvasion. Alyeska's visual impact engineering was observed to be very successful, as shown by high first-season survival. However, a related program for establishing willow cuttings was unsuccessful in 1977 but appeared very promising in 1978 largely due to improved management and more favorable growing conditions. Terrain disturbances due to the construction of the fuel gas line, snowpads, and oil spills were examined to identify and describe related environmental impacts on natural vegetation. Proper construction and use of snowpads minimized the extent and severity of disturbance. Crude oil spills, although damaging to vegetation, did not cause total kill of vegetation, and certain types of spills may have only short-term effects. Results of restoration research by CRREL along the trans-Alaska pipeline are discussed.

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

Studies relevant to the development of mathematical models of ocean, estuarine, and riverine disposal of dredged material have been identified from the literature and from contacts with research groups. The identified studies are summarized in some detail, and their limitations are outlined. Recommendations are made for additional research needed in this area. The appendix gives the settling velocities of sediment particles in a water column.

47. Johnson, B. H. 1981. "A Review of Numerical Reservoir Hydrodynamic Modeling," Technical Report E-81-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Reservoir stratification occurs due to temperature variations as a result of surface heat exchange and plays an important role in determining the water quality of a reservoir. This role is determined through the influence of density variations on the movement of water in the reservoir. Therefore, the primary objective of predicting stratified flow hydrodynamics in reservoirs is to enable scientists to compute temperature distributions and water transports insofar as they affect various water quality parameters.

Two- and three-dimensional, unsteady, variable-density, heat-conducting models were investigated under an EWQOS work unit. The investigation centered around an analysis of both the mathematical and numerical bases of individual models as well as their ability to simulate a density underflow in the Generalized Reservoir Hydrodynamics (GRH) flume located at the US Army Engineer Waterways Experiment Station. A discussion of the limitations and relative advantages of the various models is presented along with results of the GRH flume applications.

The general conclusion is that a two-dimensional laterally averaged model developed by Edinger and Buchak offers the most promise of providing the Corps with a computationally efficient and accurate multidimensional reservoir hydrodynamic model. It does not appear that any three-dimensional models that allow for economical long-term simulations have been developed.

48. Johnson, G. F., and deWit, L. A. 1978. "Ecological Effects of An Artificial Island," MR 78-3, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This study documents marine ecological conditions at Rincon Island, located approximately 0.5 mile (0.8 km) offshore between Ventura and Santa Barbara, Calif., in a depth of 45 ft (14 m). The island, which was constructed between 1954 and 1959 to serve as a permanent platform for oil and gas production, is particularly suitable for ecological study. Habitat features associated with the armor rock and concrete tetrapods surrounding the island support a "microecosystem" which differs in biotic composition from surrounding natural bottom areas. A major part of the study was devoted to analysis of seasonal dynamics in biotic composition. All macrobiota were established normal to each of the four cardinal sides of the island. The macrobiota were censused in duplicate 1-sq m quadrants along cardinal transects during each of the four seasons. Other studies included a gill net survey of fish fauna, mapping of mussel "talus" beds at the base of the island, and a survey of biota along a natural bottom transect between the island and the shore.

49. Johnson, L. S., Ford, D. E., and Robey, D. L. 1981. "Workshop on Riverine Water Quality Modeling," Miscellaneous Paper E-81-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A Riverine Water Quality Modeling Workshop was held at the US Army Engineer Waterways Experiment Station (WES) on 9-10 April 1980 to address three objectives: (a) define environmental/water quality problems in large rivers encountered by Corps of Engineers (CE) offices; (b) determine if state-of-the-art riverine models are able to address these problems; and (c) identify areas of inadequacy in the state-of-the-art models for future study and development in the Environmental and Water Quality Operational Studies Program. To address these objectives, representatives from CE District and Division offices, other Federal agencies, and the consulting community were invited to participate in the Workshop.

Problems were identified in two main areas: (a) water quality problems and (b) problems associated with water quality models. Major water quality problems dealt with reservoir releases and sedimentation. The modeling-related problems included the entire spectrum, from new model development to model application problems (i.e., coefficient selection).

Workshop recommendations included collecting data sets for a one-dimensional unsteady flow water quality model and for a two-dimensional vertically averaged model. The development and verification of a mathematical algorithm for the transport of fine suspended sediment were also recommended.

50. Johnson, L. E., and McGuinness, W. V., Jr. 1975. "Guidelines for Material Placement in Marsh Creation," Contract Report D-75-2, prepared by The Center for the Environment and Man, Inc., Hartford, Conn., for US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A set of seven procedural guidelines is presented for creating new marshes from dredged material under a variety of situations and constraints. The guidelines are as follows: (a) determine if marsh creation warrants significant consideration, (b) define the dredging situation and determine the most likely types of marshes, (c) make preliminary comparison with other disposal alternatives, (d) refine basic properties, (e) focus on special characteristics, (f) recommend the best disposal alternative, and (g) design and construct the new marsh. New marshes are classified based upon dredging frequency, confinement requirements, and surcharging requirements. The report presents the important aspects of the physical environment, dredging operations, and engineering properties of dredged material as related to marsh creation, then incorporates these aspects into the guidelines. Appendixes to the report contain: (a) sites visit summaries; (b) weight and volume balance relations used in dredging; (c) a probability analysis of the likelihood of each type of marsh analysis; (d) examples of guideline application; and (e) examples of containment area layout, construction, incremental fill placement, and drainage.

51. Johnson, L. A., Quinn, W. F., and Brown, J. 1977. "Revegetation and Erosion Control Observations Along the Trans-Alaska Pipeline - 1975 Summer Construction Season," SR 77-08, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

Procedures for revegetation and erosion control of the Trans-Alaska Pipeline System during the initial construction phase are reviewed. Fertilizer and seed rates and schedules of application by major areas (sections) are presented. During the field season of 1975, CRREL personnel observed revegetation and erosion control practices along the entire length of the pipeline route. The types of problems and early successes are discussed. Thirty-eight photographs are presented of characteristic areas on which revegetation was initiated. A list of sites for follow-up observations is presented.

52. Johnson, L. A., and Van Cleve, K. 1976. "Revegetation in Arctic and Subarctic North America - A Literature Review," CR 76-15, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

A literature review of revegetation and biological aspects of restoration research was completed for arctic and subarctic North America. Although there is a great deal of climatic variation in this region, it is generally characterized by extreme conditions, such as a short growing season and permafrost. Most of the revegetation research has been undertaken in the last 6 years as a result of increased natural resource development. The primary goal has been erosion control, with aesthetics, minimization of thermokarst, and production of browse as other objectives. Revegetation and long-term restoration methods depend upon such variables as the site conditions, nutrient regime (especially as this is influenced by the climatic conditions in the Arctic and Subarctic), plant adaptations, and the selection of native or introduced species. Technologies which have been developed to meet these conditions primarily include seedbed preparation, use of seed mixes, and fertilization and seeding methods. Most of the research has focused on the use of agronomic grasses and legumes. These are selected on the basis of a number of factors, such as cold hardiness and growth form prior to evaluation in the laboratory and the field. The most successful species to date have been Arctared fescue and Nugget bluegrass in the Arctic, while these two and creeping red fescue, meadow foxtail, Frontier reed canarygrass, Durar hard fescue, slender wheatgrass, and Icelandic poa did well in the Subarctic. Similar methods have been attempted to a more limited extent with evaluation of native herbaceous and woody species which seem promising on the basis of natural succession studies. There are a number of continuing research needs for arctic and subarctic revegetation. These include fertilization strategies, development of specialized techniques (such as sprigging) for native species, and longer term studies. It is particularly important to integrate short-term revegetation methods with long-term restoration goals.

53. Keith, J. M., and Skjei, R. E. 1974. "Engineering and Ecological Evaluation of Artificial-Island Design, Rincon Island, Punta Gorda, California," TM-43, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

Rincon Island is a man-made offshore island composed of armor rock and tetrapod revetments enclosing a sand core. An evaluation after 14 years shows: no damage by waves; littoral transport has been unaffected; little subsidence has occurred; and a thriving community of marine organisms has developed.

54. Knight, D. B., Knutson, P. L., and Pullen, E. J. 1980. "An Annotated Bibliography of Seagrasses with Emphasis on Planting and Propagation Techniques," MR 80-7, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This bibliography includes abstracts on 145 historic and recently published research reports on seagrasses, with emphasis on *Halodule*, *Ruppia*, *Thalassia*, and *Zostera*. The compilation of reports emphasizes planting and propagation techniques for seagrasses and important environmental parameters for successful transplanting. The bibliography is published to aid coastal engineers and scientists in planning, designing, and transplanting seagrasses to rehabilitate areas affected by coastal engineering projects and to stabilize substrates adjacent to navigation channels.

55. Knott, D. M., Vandolah, R. F., and Calder, D. R. 1984. "Ecological Effects of Rubble Weir Jetty Construction at Murrells Inlet, South Carolina; Vol II: Changes in Macrobenthic Communities of Sandy Beach and Nearshore Environments," Technical Report EL-84-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Beach and nearshore areas were sampled at Murrells Inlet, South Carolina, to evaluate the effects of jetty construction on the benthic macroinvertebrate communities in those habitats. Quantitative samples were collected seasonally during jetty construction (1977-1978) and again 5 years later along transects located adjacent to and distant from the jetties. Polychaetes, amphipods, and pelecypods were the dominant organisms in both the intertidal and subtidal zones during jetty construction. Although differences were noted in the community structure between these zones, several of the dominant species were abundant in both habitats. Five years later, some of these species were not commonly observed, and oligochaetes and nematodes were abundant in the area. Many of these differences were attributed to normal seasonal and yearly variations. Changes resulting from jetty construction included increased species diversity in a wave-sheltered area, as well as changes in abundance and species composition near the jetties. Many of the observed changes were short term or limited to the area between the jetties where sediment characteristics were altered. Beach and nearshore areas south of the jetties were also changed by extensive shoaling, which presumably altered community structure in that vicinity. Similar modifications in the beach profile were not observed north of the jetties.

56. Knutson, P. L. 1976. "Summary of CERC Research on Uses of Vegetation for Erosion Control," Proceedings of Great Lakes Vegetation Workshop, Great Lakes Basin Commission and USDA Soil Conservation Service, pp 31-36.

The US Army Engineer Coastal Engineering Research Center and its predecessor, the Beach Erosion Board, have been investigating uses of vegetation for erosion control for nearly two decades. Early research focused upon dune formation and stabilization with beach grasses. More recently, marsh grasses have been studied as means of controlling bank erosion. This presentation summarizes important research findings concerning: (a) the use of vegetation for the stabilization and formation of dunes, (b) the use of vegetation for bank stabilization, and (c) the use of vegetation in combination with coastal structures. Potential application of these findings in the Great Lakes region is also discussed.

57. Knutson, P. L. 1978. "Designing for Bank Erosion Control with Vegetation," Proceedings of Fifth Symposium of Waterway, Port, Coastal and Ocean Division, American Society of Civil Engineers, pp 716-733 (also Reprint 78-2, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.).

Marsh plants are effective in stabilizing eroding banks in sheltered coastal areas. Exceptional results have been achieved in a variety of intertidal environments at a fraction of the cost required for comparable structural protection. Techniques are available for the efficient propagation of several marsh plants for use in bank stabilization. This paper provides design criteria for: (a) determining site suitability, (b) selecting plant materials and planting methods, and (c) estimating labor requirements on a project-by-project basis.

58. Knutson, P. L., and Woodhouse, W. W., Jr. 1983. "Shore Stabilization with Salt Marsh Vegetation," SR-9, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This report is published to provide engineers and scientists with guidelines on using coastal marsh vegetation as a shore erosion control measure in coastal regions of the United States. This erosion control alternative is suitable for relatively sheltered shorelines such as those found on bays, sounds, and estuaries. For various reasons this alternative has not been found to be effective in the Great Lakes, Alaska, or Hawaii. Criteria are provided on (a) determining site suitability, (b) selecting plant materials, (c) planting procedures and specifications, (d) estimating projects costs, and (e) assessing impact.

59. Landin, M. C. 1978. "Annotated Tables of Vegetation Growing on Dredged Material Throughout the United States," Miscellaneous Paper D-78-7, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Tabular data are presented on vegetation growing on dredged material islands and sites throughout the United States. More than 1,000 dredged material islands and sites built in the last 100 years were surveyed aerially to determine wildlife use, and 202 of these were sampled intensively and had all vegetation recorded, identified, and/or collected as voucher specimens. With the exception of the marsh plant species tables, the tables are presented by growth habitat groups: ferns and their allies, grasses, aquatic and low marsh plants not included elsewhere, herbs, vines, shrubs and small trees, and large trees. Table 1 provides an annotated listing by common name for easy reference to 1,120 plant species occurring on dredged material; frequency and occurrence are briefly noted.

Table 2 presents a selection of 361 upland and high marsh plant species that may be planted on dredged material for wildlife habitat enhancement and substrate stabilization. Table 3 gives a matrix of upland plants based on the same 361 species. Data include: (a) best propagule types and propagule collection periods, temporary storage requirements, and planting periods; (b) species range, heights, growth habits, wildlife value, salinity tolerances, and pertinent remarks on cultivation value, pest species, and habitat occupation; (c) and species occurring on dredged material and their availability from commercial sources. Tables 4 and 5 present pertinent information beneficial to site planners of wetland habitats, including: recommended propagules, planting and storage techniques, ranges, soil tolerances, moisture requirements, wildlife value, nuisance potential, soil stabilization abilities, and pertinent remarks on individual values and benefits to be derived from each species. A total of 115 species, selected for their ability to grow on wetlands sites, are listed. Table 6 gives an alphabetical, grouped listing (by scientific name and authority) of the 1,120 species occurring on dredged material.

60. Lawson, D. E., et al. 1978. "Tundra Disturbances and Recovery Following the 1949 Exploratory Drilling, Fish Creek, Northern Alaska," CR 78-28, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

A 1949 drill site in the Naval Petroleum Reserve Number 4, Alaska, the Fish Creek Test Well 1, was examined in August 1977 to determine the disturbance caused by drilling activities and to analyze the response and recovery of the vegetation, soils, permafrost, and surficial materials to that disturbance. Man-made disturbances include bladed and unbladed vehicular trails, a winter runway, excavations, pilings, remains of camp structures, steel drums and other solid waste, and hydrocarbon spills. The most intense and lasting disturbance to the vegetation, soils, and permafrost resulted from bulldozing of surface materials, diesel fuel spills, and trails developed by multiple passes of vehicles. Thermokarst subsidence and thermal erosion, caused by increased thaw of permafrost due to disturbance, resulted in the development of a hummocky topography and water-filled depressions at the drill site. Some ice wedges disturbed in 1949 are still melting. Soil disturbance ranges from minor modification to complete destruction of the soil morphology. The effects of hydrocarbon spills are still detectable in the soils. Little of the original vegetation remains in the intensely disturbed area, such as around the drill pad where a grass-dominated community prevails. After 28 years, the vegetation cover is closed over most mesic sites, shallow wet sites are well vegetated, and xeric sites, areas of diesel fuel spills, and areas of severe erosion remain mostly bare. Pioneering plant species on bare, disturbed areas are members of mature vegetation assemblages from the undisturbed tundra which have high reproductive and dispersal capacities. A hypothetical model of natural revegetation and vegetation recovery is proposed. Recommendations on cleanup and restoration of sites are presented.

61. Lee, C. R., Engler, R. M., and Mahloch, J. L. 1976. "Land Application of Waste Materials from Dredging, Construction, and Demolition Processes," Miscellaneous Paper D-76-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The paper is divided into two sections: (a) waste materials generated by the dredging process and (b) those generated by the construction and demolition processes. Quantities and the general physical and chemical characteristics of the waste materials for each process are described. The potential use of these materials for land application for agricultural production is discussed, and other potential uses such as land improvement, wildlife habitat development, recreational facilities, and industrial and residential landfill are examined. The environmental impacts of using these materials are described, with emphasis on the legal restrictions and social/psychological concerns to be considered.

62. Lunz, J. D., Clarke, D. G., and Fredette, T. 1984a. "Seasonal Restrictions on Dredging Operations; A Critical Review of the Arguments for Seasonal Restrictions with Suggested Criteria and a Method to Determine the Need for Seasonal Restrictions on Federal and Permit Dredging Projects," report prepared by the Environmental Laboratory, WES, for the US Army Engineer District, New York, through the Dredging Operations Technical Support Program.

After reviewing the occurrence and types of seasonal restrictions imposed on bucket dredging operations, the authors (a) discuss physical and chemical environmental alterations caused by bucket dredging operations, (b) propose a method for determining the need for seasonal restrictions, and (c) summarize technical literature pertinent to the principal biological issues most often given for seasonal restrictions on dredging operations. The appendix contains

habitat and life history information on selected important aquatic biological resources within the jurisdiction of the USAED, New York.

63. Lunz, J. D., Clarke, D. G., and Fredette, T. J. 1984b. "Seasonal Restrictions on Bucket Dredging Operations, A Critical Analysis with Recommendations," Proceedings of Dredging '84, ASCE Specialty Conference on Dredging and Dredged Material Disposal, Clearwater Beach, Fla., pp 371-383.

Seasonal restrictions are sometimes imposed on bucket dredging operations in response to concerns for potential impacts of sediment resuspension on various biological resources. Five broad categories of biological concern are identifiable: (a) survival and development of egg and larval stages of fishes, (b) survival and development of egg and larval stages of shellfishes, (c) survival and movements of subjuvenile fishes and shellfishes, (d) survival and movements of subadult and adult shellfishes, and (e) survival and movements of subadult and adult fishes. Resource managers, handicapped by inconsistencies within the technical data base, often resort to establishment of rigid dredging windows. Sufficient evidence exists, however, to suggest that most life history stages of target biological resources are very tolerant of elevated suspended sediment concentrations and that rigid dredging windows are not justified. In place of dredging windows it is suggested that a standardized list of questions be used to solicit specific information about the project and location. This information can be used to guide discussions and, consequently, decisions about the need for restrictions. The questions require information about contaminant and physical properties of the sediment at the dredging location, the size and shape of the water body to be dredged, prevalent local hydrodynamic conditions, the occurrence of nearby important benthic and planktonic resources, proximity to a natural or dredged channel, and the natural turbidity characteristics of the water body.

64. Lunz, J. D., Diaz, R. J., and Cole, R. A. 1978. "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations," Technical Report DS-78-15, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Guidance on providing an ecological framework is presented for environmental planners and managers considering the habitat development option of dredged material disposal. The report (a) identifies the historical

precedents for habitat development, (b) describes an ecological management philosophy relevant to habitat development decisions, (c) briefly summarizes current ecological theories and observations on natural plant habitat and animal habitat interactions, (d) presents some general design considerations for habitat development, and (e) considers special conditions (habitat displacement and chemical mobilization) that modify dredged material disposal operations designed for habitat development. The four types of habitats discussed are upland mainlands and peninsulas, upland islands, wetlands, and aquatic habitats.

65. Lunz, J. D., and Kendall, D. R. 1982. "Benthic Resources Assessment Technique, A Method for Quantifying the Effects of Benthic Community Changes on Fish Resources," Proceedings of Marine Pollution Sessions of Oceans '82, Washington, DC.

The US Army Engineer Waterways Experiment Station is developing and field testing a technique called Benthic Resources Assessment Technique. This technique facilitates the development of a quantitative impact statement using data on changes in the benthos related to project activities. Additionally, it allows quantitative comparisons to be made between areas being considered for disposal and/or other modification during project planning and uses a measure with social significance (i.e., the potential productivity of the demersal fishery).

66. McCutcheon, S. C. 1983. "Evaluation of Selected One-Dimensional Stream Water-Quality Models with Field Data," Technical Report E-83-11, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Evaluation of the US Geological Survey One-Dimensional Steady-State Stream Water-Quality Model (a modified Streeter-Phelps model), the QUAL II model (Southeast Michigan Council of Governments version), and the US Army Hydrologic Engineering Center's Water Quality for River-Reservoir Systems model indicated that these readily available models for simulating water quality downstream of reservoirs were of comparable accuracy and performed according to their documentation. The evaluation was based on a wide range of accurate steady-state data collected on the Chattahoochee River in Georgia, the Willamette River in Oregon, and the Arkansas River in Colorado.

A number of differences exist among these three models; however, each model has the flexibility to make these differences relatively unimportant for typical water quality studies. Each model had minor coding errors which have been corrected.

Modeling capabilities are summarized in tabular form to facilitate comparison and selection. Although the modified Streeter-Phelps and QUAL II models are equally valid, different modeling options may make one preferable depending on the specific modeling application. The Water Quality for River-Reservoir Systems model is best limited to dynamic flow and water quality modeling because the data coding it requires is tedious and involved. However, the wide range of components in that model may be needed for steady-state modeling under special conditions.

67. Naovi, S. M., and Pullen, E. J. 1982. "Effects of Beach Nourishment and Borrowing on Marine Organisms," MR 82-14, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This report summarizes the latest research on the effects of beach nourishment and borrowing on the coastal environment. Guidelines are formulated for sampling the beach and nearshore, and recommendations are provided for minimizing the impact of beach nourishment and borrowing.

68. Nester, R. T., and Poe, T. P. 1982. "Effects of Beach Nourishment on the Nearshore Environment in Lake Huron at Lexington Harbor (Michigan)," MR 82-13, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

In October 1980 the US Army Corps of Engineers conducted a beach nourishment project at the Lexington (Michigan) Harbor on the southwest shore of Lake Huron, a project designed to mitigate beach erosion attributable to the installation of the harbor. In response to a request from the Coastal Engineering Research Center, the US Fish and Wildlife Service's Great Lakes Fishery Laboratory conducted a Corps-funded study from June 1980 to October 1981 along a 8.4-km segment of shoreline adjacent to the harbor to determine the effect of the Corp's beach nourishment project on the nearshore aquatic environment. The study performed by the service included aerial photographic surveys of the study area; measurements of dissolved oxygen, turbidity, and suspended particulate matter levels; and collection of lake bottom sediment, macrozoobenthos, and fish.

69. Newcombe, C. L., et al. 1979. "Bank Erosion Control with Vegetation, San-Francisco Bay, California," MR 79-2, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

During 1975 to 1978, an intertidal shoreline stabilization study was conducted to determine biological means of controlling erosion. California cordgrass (*Spartina foliosa*) and mussels (*Ischadium demissum*) were used in San Pablo Bay and South San Francisco Bay, California.

The study indicated that establishing cordgrass with seeds is not a practical method for controlling erosion. Cordgrass plugs are more useful than sprigs while the cordgrass-mussel plugs, termed bioconstructs, are the most tolerant to erosion by waves. The cordgrass-mussel community bioconstructs survived exceptionally well during the 13-month observation at Alameda Creek, a high-energy site. Once established, they are highly resistant to waves, will survive transplanting, and can be established in an area with up to a 7-km fetch without wave-stilling devices.

The biomass of the aerial parts of 23 natural California cordgrass marshes averaged 1,062 g/sq m. The value is similar to those previously reported for smooth cordgrass (*Spartina alterniflora*) on the Atlantic coast.

70. Nunnally, N. R., and Shields, F. D. 1985. "Incorporation of Environmental Features in Flood Control Channel Projects," Technical Report E-85-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Channels modified for flood control often experience severe environmental degradation due to erosion and sedimentation, loss of vegetative cover, reduction in amount and value of habitat, and decline in aesthetic value. Many negative environmental impacts can be avoided by designing flood channels that are in harmony with other fluvial and biological systems and by incorporating environmental features into flood channel design. Environmental features are defined as any structures or actions employed in the planning, design, construction, or maintenance of flood control channels that produce environmental benefits. Environmental features may include modifications of standard techniques, such as selective clearing and snagging or single-bank construction; modified channel designs, such as low flow channels, pools and riffles, and meandering alignments; structures for erosion and sediment control, water level management, and instream habitat; inclusion of recreational features in project design; and special designs and treatments for aesthetic purposes. Procedures are presented for the design of environmental features. These procedures are based largely on prior experience with the use of environmental features on modified channels and on fluvial processes and natural stream geometry. Tables are provided to help select the best environmental features based on environmental objectives and stream and watershed conditions.

71. Ocean Data System, Inc. 1978. Handbook for Terrestrial Wildlife Habitat Development on Dredged Material," Technical Report D-78-37, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The results of a study of terrestrial wildlife habitat development on dredged material within the contiguous United States are compiled in a user-oriented handbook. A general list of 250 plant species (including trees, shrubs, vines, herbs, and grasses) with food cover value for wildlife is indexed by life form and state; a synopsis is given for each of 100 plant species chosen from the general list on the basis of their importance to wildlife, ease of establishment, and geographic distribution. Each synopsis includes a description and discussion of habitat, soil requirements, establishment and maintenance, disease and insect problems, and wildlife value. A range map and illustration are given along with appropriate miscellaneous comments. The handbook also outlines a suggested approach for developing terrestrial wildlife habitat on dredged material; discusses wildlife species inhabiting dredged material areas; and recommends techniques for propagation, establishment, and maintenance of plantings. Appendixes to this report contain: (a) the list of 250 plants with food or cover value for wildlife, indexed by state and life form; (b) rare, endangered, or threatened species references; and (c) addresses for soil conservation service plant materials specialists, plant materials centers, and regional biologists.

72. Palazzo, A. J. 1977. "Reclamation of Acidic Dredge Soils with Sewage Sludge and Lime at the Chesapeake and Delaware Canal," SR 77-19, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

A field study was conducted to assess the effects of sewage sludge and lime on the revegetation and reclamation of acidic (pH 3.0) and infertile dredge soils. Sewage sludge at 100 metric tons/ha and lime at 25 metric tons/ha were applied during the summer of 1974 on a 7-ha site and plowed into the soil to a depth of 20 cm. Soils were sampled 20 months after sludge incorporation at three depths (0 to 20, 20 to 40, and 40 to 60 cm) within the sludged and control areas. A total of 29 grass treatments, containing grasses seeded alone or in combinations, were also evaluated, and seven grass types were analyzed for mineral composition. Comparisons between the sludged and control areas in the layers from 0 to 20 cm and below 20 cm were made in terms of changes in soil and plant chemistry, plant utilization of soil minerals, plant adaptability and vigor, and eventual resulting vegetative cover.

73. Palazzo, A. J., Rindge, S. D., and Gaskin, D. A. 1980. "Revegetation at Two Construction Sites in New Hampshire and Alaska," CR 80-03, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

Revegetation techniques were investigated for gravel soils in cold regions. Two gravel soil test sites were established in Hanover, N. H., and and Fairbanks, Alaska. During three growing seasons, the applicability and cost effectiveness of various nutrient sources and mulch materials were studied. The nutrient sources included sewage sludge (40, 60, and 80 tons/acre)(approximately 90, 140, and 180 metric tons/ha) and commercial fertilizer (at 200, 400 and 600 lb/acre)(approximately 22, 45, and 67 g/sq m). The mulching materials were wood-fiber mulch with various types of tackifiers, peat moss, and sewage sludge. The effects of refertilization during the second growing season were also studied.

74. Palermo, M. R., Montgomery, R. L., and Poindexter, M. E. 1978. "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas" (Synthesis Report), Technical Report DS-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Dredged Material Research Program results pertinent to designing, operating, and managing dredged material confined disposal areas to meet required effluent solids standards and to provide adequate storage volume are summarized. The guidelines are equally applicable to design of new confined disposal areas and to evaluation of existing sites. Field investigations necessary to provide data for confined disposal area design are described. Sample type and location, sampling equipment, and sample preservation techniques are included. Laboratory testing procedures required to obtain data for sediment characterization, disposal area design, and estimates of long-term storage capacity are given, and procedures are described for confined disposal area design for retention of suspended solids based on solids removal through gravity sedimentation. Guidelines are presented for estimating gains in long-term storage capacity due to settlement within the confined disposal area. Design and operational procedures for weirs are presented based on the assumption that the capability for selective withdrawal of the clarified upper layer of ponded water will be provided. Confined disposal area management activities are described which may be considered as possibilities for improving efficiency and prolonging the service life of confined disposal areas. Appendixes to this report present: (a) detailed test procedures; (b) a summary of design data requirements; (c) example design calculations; and (d) summaries of research pertinent to designing, operating, and managing dredged material confined disposal areas.

75. Parr, T. D. D., and Lacy, S. 1978. "Effects of Beach Replenishment on the Nearshore Sand Fauna at Imperial Beach, California," MR 78-4, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This study evaluates the changes in intertidal and shallow subtidal sand-bottom infaunal populations in response to the addition of approximately 765,000 cu m of dredged material added to an eroded beach at Imperial Beach, California.

The dredged material had a high proportion of fine materials with lesser amounts of shell fragments. Fine sediments were rapidly transported offshore while shells persisted on the beach. Measured beach effects were short term (5 weeks or less), involving increases in abundance, mostly of motile crustacean species which brood their young. Planktonic recruitment of polychaetes was evident during this period.

As the fine sediments worked offshore, silt and fine sand fractions increased in the bottom sediments. At subtidal depths, there was a positive correlation between the silt-clay fraction and number of species and abundance. Overall abundance and diversity of the benthos were not adversely affected by beach replenishment. In response to an unpredictable, changing environment (erosion-deposition), most of the resident biota are short-lived, opportunistic species which are typically patchy in distribution both temporally and spatially. Possible longer term effects upon populations of longer lived species, such as the sand dollar, were not determined.

76. Phillips, R. C. 1980. "Planting Guidelines for Seagrasses," CETA 80-2, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

An intensive review was made of the historical and present work on transplanting seagrasses, including eelgrass, turtle grass, shoalgrass, manatee grass, and ditch grass. The best seasons, recommended methods of transplanting, and propagules to use for each species are listed for the coasts of the United States. Some of the more important environmental parameters which directly influence successful transplanting are reviewed.

77. Ploskey, G. R. 1982. "Fluctuating Water Levels in Reservoirs; An Annotated Bibliography on Environmental Effects and Management for Fisheries," Technical Report E-82-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report contains 367 annotations describing the effects of fluctuating reservoir water levels on fish. Citations on phytoplankton, zooplankton, and water quality that pertain to reservoir fisheries are also included. An index to facilitate location of references dealing with specific topic areas is included as an appendix.

78. Ploskey, G. R. 1983. "A Review of the Effects of Water-Level Changes on Reservoir Fisheries and Recommendations for Improved Management," Technical Report E-83-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report synthesizes and summarizes information gathered from available sources about the physicochemical and biological effects of water-level changes on reservoir ecosystems. It describes how variations in both the physical environment (i.e., basin morphometry, bottom substrates and structures, erosion, turbidity, temperature, and water-retention time) and the chemical environment (i.e., nutrients and dissolved oxygen) caused by water-level changes can directly influence a reservoir's production of fish. It also describes the complex ways in which water-level changes affect aquatic plants, zooplankton, and the benthos and how these trophic variations can eventually affect the growth, reproduction, and harvest of fish.

The final part of the report summarizes the effects of drawdown and flooding on reservoir fish populations and recommends ways to manage reservoir fluctuation zones by making controllable variables as favorable as possible for fish survival, spawning, and feeding.

79. Ploskey, G. R., Nestler, J. M., and Aggus, L. R. 1984. "Effects of Water Levels and Hydrology on Fisheries in Hydropower Storage, Hydropower Mainstream, and Flood Control Reservoirs," Technical Report E-84-8, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report is a case-history evaluation of the effects of fluctuating reservoir water levels on the density and biomass of individual fish species or groups of fish species in hydropower storage, hydropower mainstream, and flood control reservoirs using correlation analysis and stepwise multiple regression. Correlation analysis was used to rank seasonal hydrologic variables according to their importance in predicting the abundance of reservoir fish. Stepwise multiple regression was used to generate regression equations describing the relationship between easily obtained hydrologic data and fish for 11 study reservoirs. In many cases, these equations can be used either to predict the effects of altering seasonal water levels in existing Corps of Engineers reservoirs or to predict which of several reservoir operation alternatives for a new reservoir will have the least negative effect on the reservoir fishery.

80. Poore, A. B., and Loftis, B. 1983. "Water Quality Optimization Through Selective Withdrawal," Technical Report E-83-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report discusses the problem of operating a multipurpose reservoir through regulation of a multilevel outlet works for a number of water quality objectives. Operation of a reservoir to meet downstream goals for multiple water quality parameters often results in conflict. A problem formulation and solution are presented as an attempt to resolve these conflicts. The multiparameter reservoir regulation problem is formulated in terms of a scalar objective function, which indicates the relative value of any specified operational strategy, and a linear constraint set. These constraints include the hydraulic characteristics of the outlet works and any specified bounds on the release concentrations of the water quality parameters. Two different problem formulations are addressed. The target-concentration problem is formulated to achieve specific downstream target concentrations without actual constraints on the release concentrations. The constrained-concentration problem is formulated to allow the specification of upper and lower bounds for all or some of the water quality constituents. Both formulations can accurately deal with the hydraulic complexity of a multilevel outlet works.

The algorithms presented herein can be used to regulate a reservoir in a real-time mode in which the state of the system is known by actual measurements. The algorithms can also be used with an ecosystem simulation model in which the state of the system is predicted.

81. Pullen, E. J., and Yancey, R. M. 1979. "Beach Nourishment: Its Effect on Coastal Ecology," Proceedings of the 23rd Annual Meeting of the Florida Shore and Beach Preservation Association, Florida Sea Grant Marine Advisory Program, pp 51-64.

Results of studies by the US Army Engineer Coastal Engineering Research Center (CERC) on the ecological effects of beach nourishment, from 1971 to the present, are presented. The studies indicate that the area impacted by nourishment and dredging should be considered as three zones for quantitative sampling because of the physical and biological conditions of the beach and nearshore areas. Based on CERC's results, nourishment operations (if properly planned) have only minor impacts on coastal resources, unless especially sensitive resources are involved (coral reefs, turtle habitat, shellfish beds, etc.). Nearshore organisms are better adapted to being covered with sediment than offshore organisms.

82. Raymond, G. L. 1984. "Techniques to Reduce the Sediment Resuspension Caused by Dredging," Miscellaneous Paper HL-84-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The US Army Engineer Waterways Experiment Station's Water Resources Engineering Group is conducting field studies to evaluate new and existing dredging methods. Different dredge types produce different amounts of suspended sediment in different parts of the water column. Resuspension caused by cutterhead and hopper dredges tends to remain in the lower water column, while bucket dredges increase resuspensions throughout the water columns. The amount of resuspension caused by a given dredge type also depends on the operating techniques used with the dredge. Sediment resuspension can be lessened by changing operating techniques, as in the case of the cutterhead, or by modifying the equipment, such as enclosing a clamshell bucket. Special-purchase dredges can also be used to reduce sediment resuspension, but their lower production rates limit their application.

83. Reilly, F. J., and Bellis, V. J. 1983. "The Ecological Impact of Beach Nourishment with Dredged Material in the Intertidal Zone at Bogue Banks, North Carolina," MR 83-3, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

During the winter and spring of 1977-1978 approximately 1,600 m of high-energy sandy ocean beach at Fort Macon State Park was nourished with sediments dredged from Morehead City State Port Harbor. This report is the result of a 20-month study of the nourished beach and a comparable unnourished beach. There was a reduction in species diversity and abundance on the nourished beach while the unnourished beach remained stable, except for seasonal variations. It was found that a speedy recovery depended on recruitment from pelagic larvae stocks, and the turbidities associated with nourishment can prevent this recruitment. After nourishment, the intertidal species on the Fort Macon beach were mostly young of the year and therefore small in size, causing lower densities of important migrating consumers. The beach showed signs of recovery. Only *Emerita talpoids* returned in near-normal densities; all other numerically important species returned, but in significantly lower density.

84. Rindge, S. D., Gaskin, D. A., and Palazzo, A. J. 1979. "Utilization of Sewage Sludge for Terrain Stabilization in Cold Regions; Part 3," SR 79-34, US Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, N. H.

The authors conducted a 2-year revegetation study to assess the ability of sewage sludge applications with or without supplemental fertilizer to promote plant growth and stabilize sloping soils. The study site was a west-facing, 16-deg slope at CRREL in Hanover, N. H. Eight revegetation treatments and one control were replicated three times. Treatments involved applications of dewatered, anaerobically digested sewage sludge at two rates (20 and 40 tons/acre)(approximately 44 and 89 metric tons/ha). The sludge was applied alone or in combination with commercial fertilizers which supplied nitrogen, phosphorus, and potassium. The seed mixture in the treatments contained four grasses and one legume. The effects of the various treatments were determined through soil loss yields, visual grass ratings, and plant yields.

85. Rounsefell, G. A. 1972. "Ecological Effects of Offshore Construction," Journal of Marine Science, Vol 2, No. 1 (89 pp and appendixes).

An evaluation of current knowledge of the probable ecological effects of various types of offshore construction reveals slight danger from the majority of construction programs. Two dangers include the placement of artificial islands within or too close to estuaries, where they can significantly affect water exchange, and the proliferation of water-cooled nuclear power plants.

86. Saloman, C. H., Naughton, S. P. and Taylor, J. L. 1982. "Benthic Community Response to Dredging Borrow Pits, Panama City Beach, Florida," MR 82-3, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This report gives biological and physical oceanographic data from baseline work and studies of dredged and undredged sediments before and after dredging (9-m contour) for beach nourishment at Panama City Beach, Florida. These studies were designed to show major short-term environmental effects of offshore dredging and included analysis of hydrology, sediments, and benthos. The study showed that recovery began soon after dredging and was complete, or nearly so, within 1 year. These results were similar in most respects to those from study of offshore dredging elsewhere in comparable geographic settings. Even so, the need for close association between ecological research and coastal engineering programs is emphasized.

87. Sherk, J. A., Jr., et al. 1974. "Effects of Suspended and Deposited Sediments on Estuarine Organisms," Chesapeake Biological Laboratory Reference No. 74-20, Final Report, Natural Resources Institute, University of Maryland, College Park, Md.

A 3-year laboratory study identified the biological effects of (a) 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 (b) natural sediments. Generally, bottom-dwelling fish species were most tolerant to suspended solids; filter-feeders were most sensitive. Early life stages were more sensitive to suspended solids than adults. Carbon assimilation by four species of phytoplankton was significantly reduced by the light-attenuating properties of fine silicon dioxide suspensions. Ingestion of radioactive food cells by two species of calanid copepods was significantly reduced during exposure to suspensions of fuller's earth, fine silicon dioxide, and natural Patuxent River silt.

88. Shields, F. D., Jr. 1982. "Environmental Features for Flood-Control Channels," Technical Report E-82-7, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report presents and documents preliminary findings of an information review performed to develop environmental guidance for flood control projects that involve modification of natural stream channels by clearing and snagging, alignment, enlargement, and lining. The response of the fluvial system to modification sometimes results in unintentional or unforeseen environmental impacts.

The adverse environmental impacts of channel enlargement can be reduced by following the existing channel alignment and excavating from one side only. Floodways may be used to preserve portions of the existing channel and its associated aquatic habitat. Low-flow channels may be constructed inside a larger channel, or the existing channel may be preserved as a low-flow channel. Pools and riffles may be constructed. Water control structures may be placed in the channel to maintain water levels for aquatic habitat and aesthetics and to prevent invasion and blockage. Meander loops may be maintained as small ponds or wetlands.

Many of the adverse impacts of channel work can be avoided by preservation of existing valuable vegetation and by prompt revegetation with appropriate species. Aquatic habitat diversity may be restored to a modified channel by placing simple habitat structures in the channel to create vertical relief, nonuniform flow patterns, and stable substrate. Biological recovery of some modified streams may be improved by armoring the new channel with biologically desirable coarse bed material. Adverse impacts of channel lining or paving may be addressed by incorporating natural materials such as boulders in the lining, by ponding water in the lined channel, and by constructing low-flow channels, fishways, pools, and spawning channels.

89. Shields, F. D., Jr., and Palermo, M. R. 1982. "Assessment of Environmental Considerations in the Design and Construction of Waterway Projects," Technical Report E-82-8, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report identifies factors and constraints in design and construction of waterway projects affecting environmental quality. Waterway projects covered in this report include channel modifications for flood control and navigation, dikes, streambank protection, and levees. Locks and dams and flood control dams are not addressed. Flood control channel modifications include clearing and snagging; channel enlargement, alignment, and relocation; and channel stabilization using grade control structures or streambank protection.

Adverse environmental impacts of flood control channel modification include loss of valuable habitats and habitat diversity, channel instability, reduction of aesthetic value, water quality degradation, and undesirable hydrologic changes. The severity and nature of environmental impact vary considerably from project to project. Methods to reduce adverse impacts include stream restoration, artificial instream structures, modified channel cross sections, and management of cutoff meanders.

Immediate and eventual losses of backwater habitat are a major impact of navigation channel modification projects. The major environmental impact associated with dikes is the reduction in water surface area and loss of habitat diversity due to sediment accretion in the dike field. In some situations, the rate of sediment accretion may be reduced by constructing notches or gaps in the dikes.

Major adverse effects of streambank protection include loss of riparian vegetation and reduction in the rate of channel migration. Innovative streambank protection designs that reduce adverse impacts feature vegetation and combinations of structures and vegetation.

The major environmental impact of levees is land use changes triggered by the creation of drier conditions on the landside. Recent efforts to incorporate environmental considerations in levee projects include management of vegetation on and around levees for wildlife and aesthetics and recreational features.

90. Skjei, S. S. 1976. "Socioeconomic Aspects of Dredged Material Disposal: The Creation of Recreation Land in Urban Areas," Contract Report D-76-6, University of Virginia, Charlottesville, Va.

The legal, institutional, sociological, and economic factors affecting the recreational use of dredged material disposal sites are presented, with emphasis placed on the factors which would constrain the creation of shoreline or offshore recreational land. Factors influencing supply of and demand for outdoor recreational facilities are discussed. The National Environmental Policy Act of 1969, the Fish and Wildlife Coordination Act, and the Coastal Zone Management Act are reviewed in detail to determine what effect they would have on the recreational use of dredged material sites. The activity-specific (market-demand) approach, used to estimate benefits for recreational facilities which could be created from dredged material, is described and applied to proposed recreational uses of dredged material disposal sites in Baltimore, the New York region, and the Los Angeles Harbor. Findings indicate that dredged material can be used in an economically feasible manner, that derived benefits would be substantial, and that environmental concerns are not insurmountable. However, financial resources available to local communities could be an important constraint. Appendixes to this report present (a) a summary of the problems and practices associated with dredged material disposal for selected Corps of Engineer Districts and (b) the procedures used to estimate benefits from the recreational use of dredged material.

91. Smith, H. K. 1978. "An Introduction to Habitat Development on Dredged Material" (Synthesis Report), Technical Report DS-78-19, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Four general habitat types are suitable for establishment on dredged material: marsh, upland, island, and aquatic. Conditions favoring habitat development are described, and a general habitat selection procedure is outlined. The rest of the report deals with more specific aspects of marsh, upland, island, and aquatic development. The advantages and disadvantages of each alternative are considered, and procedural guidelines are provided. Factors considered include characterization of the dredged material, site selection, engineering, cost of alternatives, sociopolitical implications, and environmental impacts. Techniques for actual construction and development of a specific habitat are not discussed. A selected bibliography of Dredged Material Research Program reports pertinent to habitat development is appended.

92. Soots, R. F., Jr., and Landin, M. C. 1978. "Development and Management of Avian Habitat on Dredged Material Islands" (Synthesis Report), Technical Report DS-78-18, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Seven regional studies were conducted throughout Corps of Engineers-maintained waterways to determine dredged material island use by nesting water birds and the succession of vegetation on these islands as affected by bird use, to compare diked and undiked islands and natural and man-made islands and sites, and to study migratory and year-round use of dredged material islands. These data and pertinent management information are synthesized in this report. Recommendations and guidelines for management of existing dredged material islands and creation of new islands are presented. Five major factors determining selection for water bird colony sites on dredged material islands are set forth: isolation from predators and humans, habitat diversity, nesting substrate stability, species behavioral characteristics, and species feeding and foraging habits. Management for water bird colonies has been proven feasible and may be accomplished through incorporation of management plans into routine dredging operations, interagency cooperation, and public education and cooperation. Dredged material islands often are crucial habitat for colonial water birds and should be maintained and managed as such. Appendixes to this report present (a) scientific and common names of flora and fauna mentioned in the text, (b) a bibliography of pertinent

research on colonial water birds and their management, and (c) an example of a management plan.

93. Spaine, P. A., Llopis, J. L., and Perrier, E. R. 1978. "Guidance for Land Improvement Using Dredged Material" (Synthesis Report), Technical Report DS-78-21, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Concepts and guidelines for planning and implementing land improvement projects using dredged material are provided. Information is drawn from Dredged Material Research Program research reports, literature surveys, field demonstrations, and greenhouse studies. Environmental, technical, economic, social, and legal aspects of projects are presented as well as outlines of project planning procedures and dredged material transport systems. Three dredged material land improvement techniques are detailed: surface mine reclamation, sanitary landfill, and agricultural use. Planning, construction, and equipment considerations are presented for each technique. Local, State, and Federal government sources which have jurisdiction or expertise in the various aspects of land improvement projects are included. The report describes techniques for land improvement which utilize dredged material productively as alternatives to conventional disposal methods in regions where land acquisition is difficult and open-water disposal infeasible. The Appendixes provide (a) summaries of research pertinent to this study, (b) the Interim Report on Surface Mine Reclamation Demonstration, and (c) three tables on potential vegetative covers for land improvement projects using dredged material.

94. Thompson, J. F. and Bernard, R. S. 1984. "Numerical Modeling of Two-Dimensional Width-Averaged Flows Using Boundary-Fitted Coordinate Systems," Technical Report E-85-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Finite-difference solution of two-dimensional (2D), time-dependent width-averaged Navier-Stokes equations, including an algebraic turbulence model, based on a numerically generated boundary-fitted coordinate system, is discussed. This solution, implemented by the WESSEL computer code, is applicable to 2D regions of arbitrary shape, with multiple inlets and outlets, and with obstacles in the interior. A choice of central, upwind, or ZIP differencing

of the convective terms is provided. One-sided differencing is used for the continuity equation. The density is taken to be a function of the temperature, and the system of equations forming the model consists of the continuity equation, the two momentum equations, and the energy equation. Arbitrary distribution of velocity and temperature (or density) can be specified on the inlets and outlets. The solution is implicit in time, with the difference equations being solved simultaneously by SOR (successive over-relaxation) iteration at each time step. Pressure is calculated via Chorin's method. This solution is designed specifically to include the modeling of the water quality in selective withdrawal from reservoirs, and results for one configuration related to the application are given.

95. Turbeville, D. B., and Marsh, G. A. 1982. "Benthic Fauna of an Offshore Borrow Area in Broward County, Florida," MR 82-1, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

Benthic fauna from two stations within a 5-year-old borrow area and two control stations off Hillsboro Beach (Broward County), Florida, were sampled quarterly from June 1977 to March 1978 to evaluate the long-term impact of offshore dredging.

96. US Army Engineer Waterways Experiment Station, Environmental Laboratory. 1978. "Wetland Habitat Development with Dredged Material; Engineering and Plant Propagation" (Synthesis Report), Technical Report DS-78-16, Vicksburg, Miss.

Pertinent literature and research of the Dredged Material Research Program (DMRP), including six major marsh development field sites, are synthesized. Guidelines for developing marsh habitat are presented: (a) planning the project in relation to the proposed site and project goals; (b) engineering construction of the site including dredging operations; (c) propagation, maintenance, and monitoring of the site as habitat, including potential problems that may be encountered; and (d) costs. Emphasis is placed on engineering and plant propagation. Engineering aspects and design of potential sites are discussed and include protective and retention structures, substrate and foundation characteristics, dredging operations, and elevation and drainage requirements. Phases of plant propagation are detailed in the text and tables: selecting plant species for the site, collecting and storing plant materials, selecting a propagule type, planting the site, maintaining and monitoring the site, pilot studies, costing the work, and allowing natural colonization. Tables of 115 selected plant species showing best propagules; occurrence by region and whether now occurring on dredged material; growth requirements; propagule handling methods; soil, salinity, and inundation tolerances; and other pertinent information are given. Appendixes to this report contain (a) a list of DMRP reports pertinent to marsh development; (b) common and scientific names of plants and animals mentioned in the text, appendixes, and tables; and (c) a synopsis of 28 plant species discussing their characteristics, value, and potential use on dredged material.

97. Van Dolah, R. F., Knott, D. M., and Calder, D. R. 1984. "Ecological Effects of Rubble Weir Jetty Construction at Murrells Inlet, South Carolina; Volume I: Colonization and Community Development on New Jetties," Technical Report EL-84-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Quarrystone jetties constructed at Murrells Inlet, South Carolina, were studied over a 4-year period to evaluate community development patterns of biota colonizing the rocks. Sessile macroinvertebrates and algae were quantitatively assessed using line-transect and photographed-quadrat censusing techniques. Motile epifauna were also quantitatively sampled using a suction device, and fishes were qualitatively assessed using gill nets, hook and line, traps, and seine net, and through visual observations while scuba diving.

The results documented that both jetties were rapidly colonized by sessile and motile biota. Within 1 year after construction, faunal and floral coverage of the rock was equivalent to subsequent sampling periods, as were estimates of species diversity and abundance. Distinct vertical zonation of sessile biota was also observed within 1 year, with distribution patterns generally remaining similar throughout the study period. Vertical gradients in the distribution of motile fauna were noted intertidally versus subtidally. Community composition, on the other hand, changed both seasonally and yearly. Community structure appeared to change less over time in intertidal areas than in subtidal areas, where marked changes in dominant sessile taxa were observed between sampling periods. No stable or "climax" jetty community was apparent subtidally after 3 to 4 years, and other studies suggest that such a community is not likely to occur. Fish found around the jetties were abundant and included several recreationally important species. Stomach content analysis indicated that the jetty biota was an important food resource for several fishes. In addition, at least one species, black sea bass, was using the rocks as a nursery area.

98. Walsh, M. R., and Malkasian, M. D. 1978. "Productive Land Use of Dredged Material Containment Areas: Planning and Implementation Considerations" (Synthesis Report), Technical Report DS-78-20, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

General guidance is provided for planning and implementing the land use of dredged material confined disposal areas. Seven productive land use categories are defined based on functional use: recreational (commercial and noncommercial), industrial/commercial (including horticulture and mariculture), institutional (including public transportation), material transfer, waterway-related, and multiple purpose. Engineering, environmental, socioeconomic, and legal and institutional considerations that are important with regard to disposal-productive land use projects are reviewed. A land value methodology is included which provides estimates of (a) the direct market value of the created land and (b) related community benefits and adverse impacts from the productive land use. Planning and implementation factors for disposal-productive use projects are examined, and policy and planning issues affecting the land use of dredged material confined disposal areas are discussed. Appendixes to this report present (a) Task 5D research report abstracts and (b) an example of State law matrix.

99. Walski, T. M., and Schroeder, P. R. 1978. "Weir Design to Maintain Effluent Quality from Dredged Material Containment Areas," Technical Report D-78-18, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A procedure is developed for designing and operating weirs to maintain good effluent quality, given a flow and dredged material type. Stratified-flow and sediment-transport models were investigated to describe the depth of withdrawal, velocity profile, and effluent suspended solids concentration, given a concentration profile and flow. Field data on these parameters were collected at three sites--Yazoo River, Mississippi, and Flow River and Oyster

Bay, Alabama. The WES selective withdrawal model developed by Bohan and Grace, modified to fit observed data, was selected as the basis of the design procedure. Using this model, nomograms were developed for the design procedure for silt and saltwater clays and for freshwater clays. The nomogram relates the flow, weir length, ponding depth, and effluent suspended solids concentration. The designer manipulates these four variables until a satisfactory balance is reached between weir length and ponding depth, based on his design flow and effluent goal. Modified versions of these nomograms are presented in final guidelines contained in Technical Report DS-78-10. Sharp-crested rectangular or shaft-type weirs are recommended. Guidance for operation of the weir for special applications also is presented. Appendixes to the report give (a) equations to relate density and solids concentration and (b) withdrawal depth and velocity profile models.

100. Webb, J. W., and Dodd, J. D. 1978. "Shoreline Plant Establishment and Use of a Wave-Stilling Device," MR 78-1, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

The establishment and development of smooth cordgrass transplants on a 2-percent slope behind a wave-stilling device constructed of two tiers of tires strung on a cable were monitored along the north of East Bay in Texas. Two previous plantings on the sloped area, the first without wave protection and the second behind one tier of tires, were unsuccessful. After a second tier of tires was placed on top of the original tier, enough protection was provided from waves to allow successful planting. A 0.15-m buildup of sediment occurred directly behind the barrier.

Smooth cordgrass survival was approximately 50 percent, and more than 100 stems/sq m were counted in some areas 1 year after planting. Density and height of smooth cordgrass increased with increasing hours of inundation. Gulf cordgrass, marshhay cordgrass, and saltgrass survived better than smooth cordgrass above mean high water (MHW). At the highest elevation (0.6 m above MHW), survival was limited, regardless of species. Needlegrass rush transplants failed to survive in significant numbers. With adequate wave protection, smooth cordgrass can be established below MHW in estuarine areas. Gulf cordgrass, marshhay cordgrass, and saltgrass can be used above MHW for shoreline protection.

101. Whitlow, T. H., and Harris, R. W. 1979. "Flood Tolerance in Plants: A State-of-the-Art Review," Technical Report E-79-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Basic aspects of flood tolerance in plants and the applied aspects of establishing vegetation on reservoir shorelines are discussed through a comprehensive literature review. Flooding imposes complex stresses on many vascular plants, most of which arise from the depletion of oxygen in the flooded soil. Plants avoid or mitigate oxygen depletion stresses by either transferring oxygen into their roots via anatomical modifications in the shoot and/or by utilizing anaerobic respiration pathways in their roots.

In addition to a plant's ability to withstand soil anaerobiosis, plant age, plant size, flood depth, flood duration, flood timing, substrate composition, wave action, and other factors determine survivorship when plants are flooded. Studies are reviewed that correlate these factors with species tolerances. A detailed summary of research relating directly to reservoir revegetation is provided, and species tolerances are assessed for each US Army Engineer Division. Techniques for the establishment of vegetation around reservoirs are discussed, as are examples of species mortality prediction and impact assessment.

102. Woodhouse, W. W., Jr. 1979. "Building Salt Marshes Along the Coasts of the Continental United States," SR-4, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This is the first comprehensive report on coastal marsh creation in the continental United States. This report provides potential users an analysis and interpretation of the available information on this subject. The role of marshes, the feasibility of marsh creation, and the effects of elevation, salinity, slope, exposure, and soils on marsh establishment are discussed. Plants suitable for marsh building are described by the major regions. Plant propagation, planting, fertilization, and management of the major plants are discussed. Labor and material requirements for marsh creation are summarized.

103. Woodhouse, W. W., Jr., Seneca, E. D., and Broome, S. W. 1974. "Propagation of *Spartina alterniflora* for Substrate Stabilization and Salt Marsh Development," TM-46, US Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

This report describes techniques developed for the propagation of *Spartina alterniflora* (smooth cordgrass) in the intertidal zone of dredged material and eroding shorelines. Both seeding and transplanting methods were successful. The relationship of mineral nutrition to productivity of *S. alterniflora* was also determined.