US Army Corps
of Engineers
Waterways Experiment
Station

Wetlands Research Program Technical Report WRP-RE-4

Preliminary Feasibility Study: Transport and Distribution of Dredged Materials by Hovercraft for Wetland Nourishment and Restoration

by Trudy J. Olin, Michael R. Palermo, Anthony C. Gibson

June 1994 – Final Report

The following two letters used as part of the number designating technical reports of research published under the Wetlands Research Program identify the area under which the report was prepared:

	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

Technical Report WRP-RE-4
June 1994

Preliminary Feasibility Study: Transport and Distribution of Dredged Materials by Hovercraft for Wetland Nourishment and Restoration

by Trudy J. Olin, Michael R. Palermo, Anthony C. Gibson

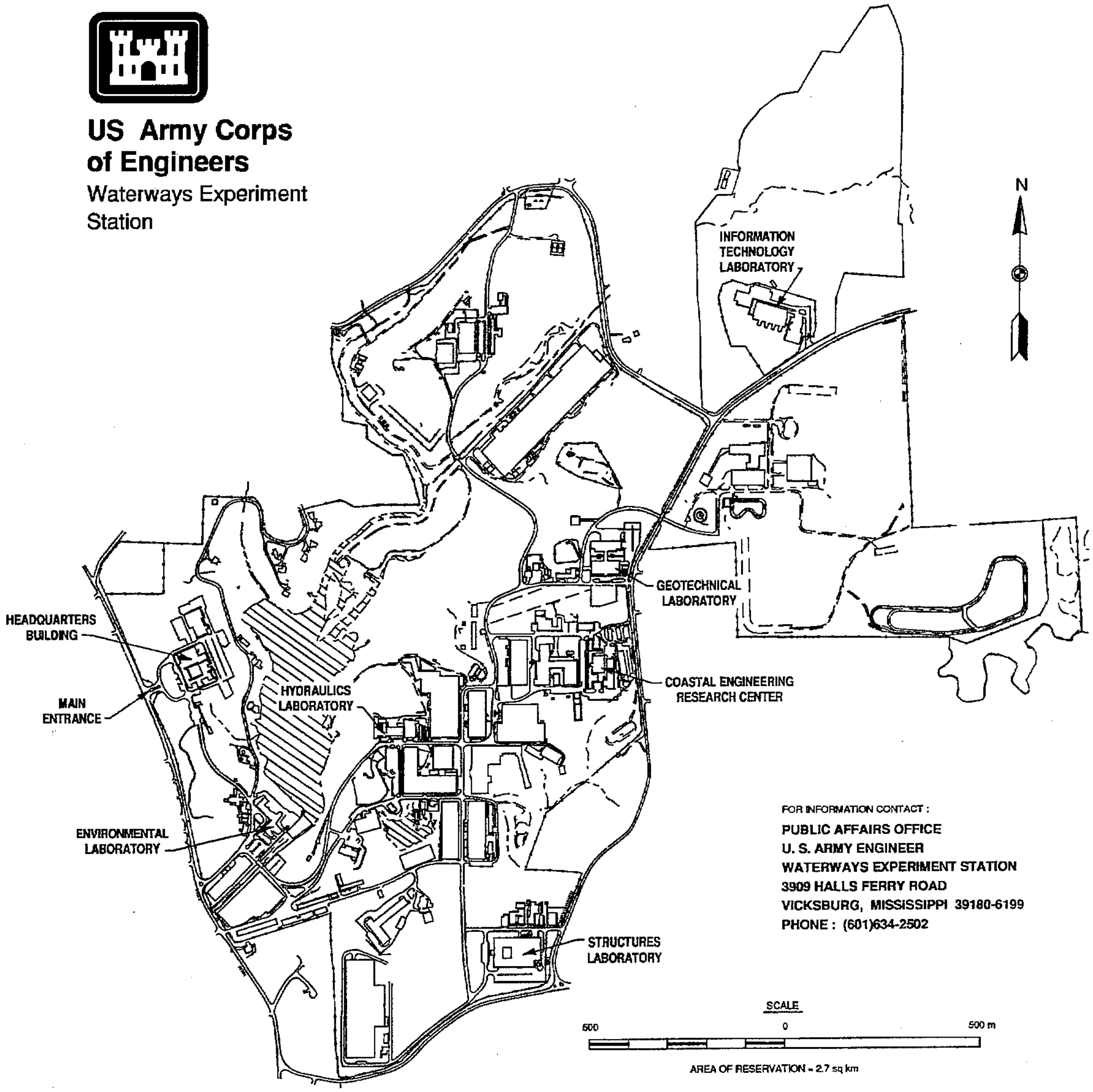
U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

US Army Corps of Engineers
Waterways Experiment Station



FOR INFORMATION CONTACT:
PUBLIC AFFAIRS OFFICE
U. S. ARMY ENGINEER
WATERWAYS EXPERIMENT STATION
3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199
PHONE: (601)634-2502

Waterways Experiment Station Cataloging-in-Publication Data

Olin, Trudy J.

Preliminary feasibility study: transport and distribution of dredged materials by hovercraft for wetland nourishment and restoration / by Trudy J. Olin, Michael R. Palermo, Anthony C. Gibson ; prepared for U.S. Army Corps of Engineers.

55 p. : ill. ; 28 cm. -- (Technical report ; WRP-RE-4) (Wetlands Research Program technical report ; WRP-RE-4)

Includes bibliographical references.

1. Wetland construction. 2. Shore protection. 3. Ground-effect machines. 4. Dredging spoil -- Environmental aspects. I. Palermo, Michael R. II. Gibson, Anthony C. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Wetlands Research Program (U.S.) VI. Title. VII. Title: Transport and distribution of dredged materials by hovercraft for wetland nourishment and restoration. VIII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; WRP-RE-4.

TA7 W34 no.WRP-RE-4

Corps of Engineers Research Report Summary, June 1994

Wetland Subsidence and Loss

Preliminary Feasibility Study: Transport and Distribution of Dredged Materials by Hovercraft for Wetland Nourishment and Restoration

ISSUE:

A variety of mechanisms have resulted in the loss of coastal wetlands. Thin-layer disposal of dredged material has been proposed to maintain and restore wetland areas. Transport of this material into wetlands areas is problematic due to the sensitivity of the wetland environment. Hovercraft transport and distribution of dredged material has been proposed as an environmentally acceptable alternative to conventional transport methods.

RESEARCH:

The objective of this study was preliminary evaluation of technical and economic feasibility of the use of hovercraft for dredged material transport and distribution in wetlands. Comparison was made to conventional transport alternatives.

SUMMARY:

Hovercraft transport and distribution of dredged material in wetlands appears to be technically feasible, although modification of hovercraft design would be required, and the method is as yet untried. Limited load capacity of hovercraft coupled with high capital, operating, and maintenance costs, results in high unit transport costs when compared with conventional transport methods. Environmental justification for this higher cost alternative was not evaluated because of the limited scope of this study.

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, telephone (601) 634-2355.

To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780. NTIS report numbers may also be requested from the WES librarians.

About the Authors:

Trudy J. Olin is a civil engineer and Dr. Michael R. Palermo is a research civil engineer for the USAEWES Environmental Laboratory. Mr. Anthony C. Gibson is a mathematician for the Environmental Laboratory. Point of contact is Trudy Olin at (601) 634-2125.

Please reproduce this page locally, as needed.

Contents

List of Figures

List of Tables

Preface

The study reported herein was conducted at the direction of the Energy and Water Development Appropriation Bill for FY 1993. Under this legislation, the U.S. Army Corps of Engineers (USACE) was directed to "assess the feasibility of using large hovercraft to transport and distribute dredged sediment in coastal wetlands." Due to the audiences inpacted by the results of the study, this report is published as part of the Wetlands Research Program Series, with Mr. Joe Wilson as the Technical Monitor at Headquarters, USACE.

This report was prepared with the assistance of the National Wetlands Research Center; Textron Marine Systems, New Orleans, LA; Department of the Army, 11th Transportation Battalion (TML), Fort Story, VA; Hover Systems, Inc., Eddystone, PA; U.S. Army Engineer District, New Orleans; U.S. Army Engineer District, Vicksburg; U.S. Army Engineer Division, Lower Mississippi Valley; U.S. Army Engineer District, Jacksonville; Dr. Walter B. Sikora, Center for Wetland Resources, Louisiana State University; Mr. Henry Shore, Gulf Coast Trailing; Mr. Rick Smith, T.L. James; Dr. Lindsay Nakashima, Woodward-Clyde Consultants, Baton Rouge, LA; and Drs. Pace Wilber and Thomas Wright, U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS.

This report was prepared by Ms. Trudy J. Olin, Dr. Michael R. Palermo, and Mr. Anthony C. Gibson, Environmental Engineering Division (EED), Environmental Laboratory (EL), WES. Technical review was provided by Ms. Linda Mathies, U.S. Army Engineer District, New Orleans; and Messrs. Thomas R. Patin, J. Craig Fischenich, and E. Clark McNair, Jr., WES.

The study was conducted under the general supervision of Dr. Raymond L. Montgomery, Chief, EED, and Dr. John Harrison, Director, EL. The study was supported by the Dredging Operations Technical Support Program, under Dr. Robert M. Engler, Program Manager of the Environmental Effects of Dredging Programs; and Dr. Russell F. Theriot, Director, Wetlands Research and Technology Center.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

This report should be cited as follows:

Olin, T. J., Palermo, M. R., and Gibson, A. C. (1994). "Preliminary feasibility study: Transport and distribution of dredged materials by hovercraft for wetland nourishment and restoration," Technical Report WRP-RE-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic yards	0.07645549	cubic meters
feet	0.3048	meters
inches	2.54	centimeters
knots (international)	0.5144444	meters per second
miles (U.S. statute)	1.609347	kilometers
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (force) per square inch	6.894757	kilopascals
square miles	2.589998	square kilometers
tons (force) per square foot	95.76052	kilopascals
tons (2,000 pounds, mass)	907.1847	kilograms

Summary

The loss of coastal wetlands has stirred interest in innovative methods of maintenance and restoration. Channelization of large river systems has inhibited the deposition of sediment and organics that naturally occurs during high water events, and artificial means of replacing wetland soils lost to subsidence and anthropogenic damage have been proposed.

Thin-layer dredged material disposal has been suggested as a potential source of sediments to counteract the loss mechanisms. It has been suggested that even wetlands that have reverted to open water could be reclaimed if sufficient volumes of dredged material were available.

The principal obstacles to implementation of a program to counteract wetlands loss are cost and environmental effect. Federal dredging projects are constrained by cost in selection of disposal alternatives. Further, wetlands are very sensitive areas, sustaining damage from traffic, which in itself exacerbates the problem. Adaptation of existing hovercraft technology to provide an environmentally sensitive means of transporting and distributing dredged material has been proposed. The relative capital and operating cost of the proposed "hoverbarge," the technical feasibility of the concept, and the expected environmental effects of thin-layer disposal and hoverbarge traffic are the principal areas of concern.

The purpose of this study is to examine the technical feasibility of the proposed hoverbarge concept, and to estimate the cost relative to other means of dredged material transport and distribution. Limited information is available concerning the effects of hoverbarge traffic over wetland areas. This study does not attempt to address environmental effects or potential environmental justification of the hoverbarge concept except to present the conclusions of previous, limited studies.

The technical feasibility analysis was based on consideration of standard dredging practices and engineering judgement. A prototype of the proposed hoverbarge has not been developed; capital, operating, and maintenance costs for such an operation can only be roughly estimated based on other hovercraft applications currently in use. Economic analysis then defines a range within which hovercraft transport costs could reasonably be expected to fall, but does not represent a definitive cost estimate. The

hoverbarge concept was compared with conventional barge transport and pipeline delivery in the economic analysis.

The outcome of this study indicates that from a technical perspective, hovercraft transport and distribution of dredged material appears to be feasible. Logistically, hovercraft suffer from certain constraints, the most significant being the limited load capacity. This has a direct bearing on the economics of the concept, which appears to be more expensive than other alternatives available for dredged material transport and distribution. A final consideration, the ultimate environmental cost of each alternative, was not addressed here because of lack of information and the constraints of the study.

1 Introduction

Background

Conditions in coastal Louisiana were utilized as the basis of this report. Information was readily available pertaining to wetlands losses for this area and dredging operations for the U.S. Army Engineer District, New Orleans. This historical data facilitated a "real world" analysis with respect to overall scale, volumes, and distances.

Significant losses of coastal wetlands have occurred in Louisiana, and the present rate of depletion is approximately 25 square miles[1] annually. The erosion and subsidence responsible for these losses are largely due to the combined effects of oilfield development and other human activities; the channelization of major rivers that were once a source of mineral sediments, organics, and freshwater; sea level rise and saltwater intrusion; and compaction of sediments (Louisiana Coastal Wetlands Conservation and Restoration Task Force 1993).

Introduction of sediments from dredging operations could counteract the mechanism of subsidence in existing wetlands and restore wetlands that have reverted to open water. The technical difficulties of this concept are fairly obvious. Wetlands are very sensitive to traffic, and existing technologies capable of delivering adequate amounts of sediment and water would themselves exert stresses on the wetland environment.

It has been proposed that hovercraft might successfully be adapted to this purpose, with less negative impact than more conventional methods of transport. Under the Energy and Water Development Appropriation Bill for FY 1993, the Corps of Engineers was directed to "assess the feasibility of using large hovercraft to transport and distribute dredged sediment in coastal wetlands." A multidisciplinary team was assembled to conduct an initial feasibility study and make recommendations regarding the direction and emphasis of future action.

---

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page x.

Purpose and Scope

The purpose of this report is to address the feasibility of the use of hovercraft for transportation and distribution of dredged material for wetland restoration. This initial feasibility study addresses two principal concerns: economics and technical feasibility. The current status of hovercraft technology was investigated through a review of literature, operational records of military hovercraft, industry records, and industry technical information. Conventional methods and costs of transporting and distributing fresh water and sediments were investigated. Potential hovercraft/dredging operation "interfaces" were examined and the relative costs of each alternative quantitatively evaluated.

2 Areas Affected and Requirements for Marsh Restoration

Geographic Areas Needing Restoration

Most of the coastal Louisiana wetlands in need of restoration are saline and brackish marshes within about 50 miles of the Gulf of Mexico. Figures 1 and 2 illustrate the relative areas of concern and the distribution of freshwater and saltwater marshes.

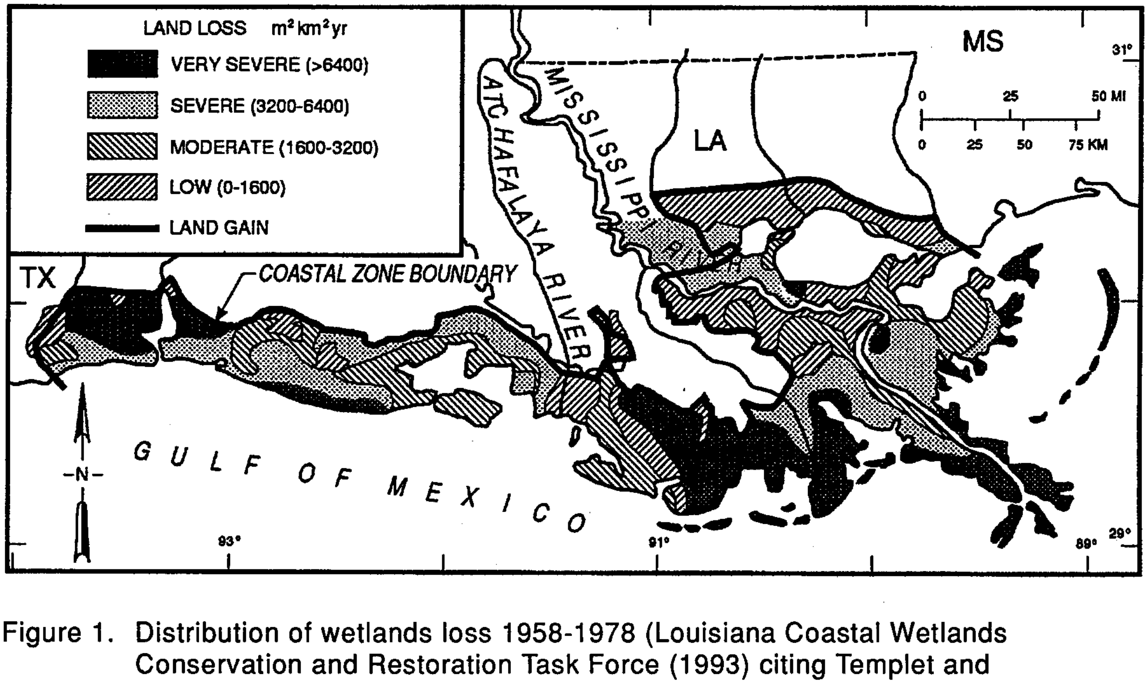


Figure 1. Distribution of wetlands loss 1958-1978 (Louisiana Coastal Wetlands Conservation and Restoration Task Force (1993) citing Templet and Meyer-Arendt (1988))

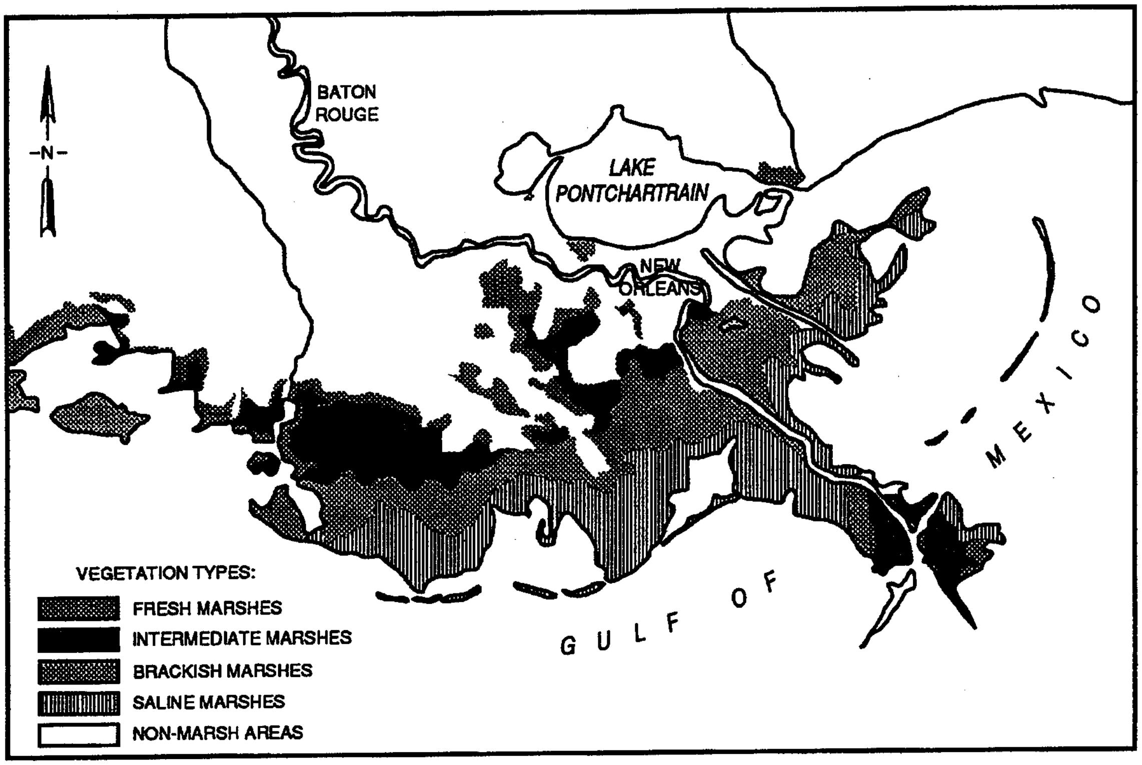


Figure 2. Distribution of freshwater and saltwater marshes (Louisiana Coastal Wetlands Conservation and Restoration Task Force (1993) citing Chabreck and Linscombe (1978))

Requirements of a Restoration Effort

Wetland development efforts can essentially be either stabilizing (nourishment) or restorative. In stabilizing a wetland, enough water, minerals (soil matrix), and organics are introduced, in a process called "thin-layer disposal," to counteract ongoing subsidence and maintain plant life. In restoration, significantly higher amounts of mineral sediment are introduced to convert wetland areas that have reverted to shallow open water to a substrate capable of supporting wetland plant life. The nature and amount of material needed will be site specific.

The initial effect of thin-layer disposal may be to kill all surface vegetation. This may be due to the large amounts of water required for slurrying, rather than the imposed burden of the dredged material itself. Two growing seasons are typically required for complete recovery (Wilbur, In Preparation). The degree of effect, however, will be a function of the depth of the layer applied, the subsequent change in elevation, resulting consolidation of substrate, changes in soil characteristics, and the type of vegetation initially present.

Studies of thin-layer disposal sites in North Carolina and Louisiana indicate that full recovery did occur for these sites, which received application of sediments at depths ranging from 1 to 20 cm (0.4 to 7.9 in.) (Wilbur 1992). Earlier studies also indicate that layers of up to 23 cm (9 in.) can be applied under appropriate conditions with little or no permanent adverse affect (Reimold et al. 1978). Depths in excess of this or the presence of high sulfide concentrations and hypoxic conditions can result in mortality of root mass and rhizomes from which the vegetative layer will not recover (Wilbur, In Preparation.)

The ultimate elevation of the marsh relative to tidal fluctuation is critical to the reestablishment of marsh vegetation. Elevations exceeding the upper range of tidal influence will typically recolonize with upland species. Elevations near or below marsh plant tolerances will have limited, probably temporary, benefits.[1] The optimum depth of sediment placement will therefore be a function of tidal elevations, consolidation expected in response to additional overburden, types of vegetation indiginous or to be established, and frequency of application. The response of other living organisms in the wetland must also be considered.

The rate of subsidence in coastal Louisiana wetlands varies with geographic location and the age, lithology, and thickness of geologic deposits. Subsidence rates range from 0.2 cm per year to approximately 1.0 cm per year.[1]

In the Louisiana delta areas, maintenance nourishment requires a minimum of 0.2 g sediment per square centimeter of subsiding marsh surface per year, assuming a worst case subsidence rate of 1 cm per year (0.2 g/cm^3 lost) (Woodward-Clyde Consultants (1991) citing DeLaune et al. (1979) and Penland and Ramsey (1990)). In English units, this would be 0.4 lb per square foot for a subsidence rate of .4 in. per year, or 12 lb per cubic foot lost. Assuming half of this amount is replenished naturally, 0.1 g/cm^2 (0.2 lb/ft^2) must be supplied artificially, which is equivalent to 10 metric tons dry sediment per hectare (9,000 lb dry weight per acre) (Woodward-Clyde Consultants 1991).

Restoration requires much more material. Significant material buildup may be required in areas along the edge of the marsh to restore elevations and allow plants to become reestablished. Areas with an average depth of 70 cm water (27.6 in.) would require a one-time input of approximately 7 million lb dry weight per acre (700 times that required for maintenance). The actual application rate varies, however, with depth of water and type and degree of consolidation of foundation materials underlying the area to be restored (Woodward-Clyde Consultants 1991).

---

[1] Personal Communication, January 13, 1994, Dr. Robert E. Stewart, Jr., Director, National Wetlands Research Center, Lafayette, LA.

Total annual sediment needs will depend upon the scope of the maintenance and restoration effort attempted. There are 2.5 million acres of coastal wetlands remaining in Louisiana. Based on the above assumptions, it is estimated that 10 million m^3 (approximately 13.1 million yd^3) of mineral sediments would be needed annually to maintain the existing wetlands and 70 million m^3 (91.6 million yd^3) to reclaim 10,000 ha (25,000 acres) per year (Woodward Clyde Consultants 1991). This would be a total annual requirement of 80 million m^3 (104.6 million yd^3) to achieve the ultimate goal of "no net loss of wetlands" for the coastal Louisiana region (over a period of approximately 20 years).

3 Dredging Operations in Southern Louisiana

Location and Volume

The U.S. Army Corps of Engineers New Orleans District maintains a number of navigation projects within coastal Louisiana, including the lower reaches of the Mississippi, Atchafalaya, and Calcasieu Rivers. Approximately 235 million yd^3 of sediment are dredged from Federal projects annually. Approximately 83 million yd^3 of this total volume is removed from various reaches of the navigation channels in coastal Louisiana (average annual volume, New Orleans District, 1983-1992, hopper and pipeline dredging).[1] This material is a potential resource for nourishment and restoration of the marsh. For purposes of this evaluation, it is assumed that both predominantly sandy and predominantly fine-grained dredged material from navigation channels could be effectively used for marsh nourishment. However, sandy material may not be able to sustain plant life.

Dredging operations in southern Louisiana are typically conducted in the spring and summer months, particularly April, May, and June. Dredges operate 22 to 24 hr per day during this time.

Equipment

Dredging in coastal Louisiana is usually accomplished using hydraulic pipeline dredges and hopper dredges. Agitation dredging also makes up a significant fraction of the total dredging volume.[2] There is little mechanical dredging associated with large navigation projects.

---

[1] Personal Communication, June 1993, Linda Mathies, U.S. Army Engineer District, New Orleans.

[2] Personal Communication, 10 May 1993, Cliff Dominey, U.S. Army Engineer District, New Orleans.

Pipeline dredges are essentially centrifugal pumps mounted on floating barges. These dredges hydraulically remove sediment from the channel bottom and pump sediment/water slurry through a pipeline to a disposal location. The production rate or volume dredged per time varies with the pump size, and these dredges are normally designated by their effluent pipeline diameter. Pipeline dredges used in larger navigation projects vary from about 18 to 28 in., with corresponding discharge flow rates from 26 to 64 cfs. The slurry produced by pipeline dredges has a solids concentration of 100 to 150 g/L.

Hopper dredges are essentially seagoing ships with dredge pumps and storage compartments or bins (hoppers). The sediment is hydraulically removed from the channel bottom using a trailing dragarm, and the material is pumped into the bins for storage. Once filled, the hopper dredge sails to a desired disposal location, and the material is usually released from the bins through a split-hull or bottom-dump mechanism. The slurry entering the bins is similar to that produced by a pipeline dredge. Filling is sometimes continued past the point of overflow to increase the density of material in the hopper prior to transport. Hopper dredges typically take about 30 min to fill and can release a load by opening the hoppers in a matter of a few minutes. The cycle time between loads depends on the distance from dredging area to disposal area. Hopper dredges are sometimes equipped with a pumpout capability to allow material from the hoppers to be hydraulically off-loaded to a desired disposal area. If the hopper has been overflowed during filling to increase the load density, water can be introduced back into the hopper by jets to allow the material to be pumped out. The time required for pumpout may be an hour or more.

In some channel reaches, agitation dredging is achieved by hopper dredges in an agitation mode. Sediments are resuspended and allowed to move downstream with the current.

Disposal Practices

Disposal practices vary by project and by specific reach of the project being dredged. Some of the material, especially that dredged from open Gulf reaches, is usually dredged by hopper and carried to open Gulf disposal sites adjacent to or near the channels. Material in the upper reaches of the channels is usually dredged by pipeline dredge. Some of the material is now placed on the marsh by pipeline for purposes of nourishment. Some of the fine-grained material from upper reaches is placed in confined (diked) disposal facilities (CDFs). In some reaches, material is merely dredged from the navigation channel and placed in adjacent areas of the river (within banks disposal). Disposal sites are typically within 2 to 3 miles from dredging locations for both hopper dredges and for pipeline disposal.

4 Hovercraft Technology

Existing Technology

The hovercraft, as the name suggests, is a vehicle that moves over the surface of land or water on a cushion of air, in effect, "hovering." It is also referred to as an air-cushion vehicle (ACV). A typical hovercraft is shown in Figure 3. Hovercrafts employ gas turbines or diesel engines driving fans to generate large volumes of air that are discharged beneath the craft for lift and behind the craft for thrust. The power split is typically one-third lift to two-thirds propulsion. The air cushion exerts fairly low pressures, typically less than 1 psi. Stability problems can occur if the cushion pressures exceed this value.[1]

The controlled release of air is governed by the type of skirt attached to the periphery of the craft between the deck and the water or ground. Hovercraft may be designed for aquatic use only (rigid skirt) or amphibious capability (soft skirt). Both types of craft will float and can have conventional props, water jets, or externally mounted fans to provide horizontal thrust in addition to, or in place of, air channeled from the lift turbines or fans.

The LACV-30 (Lighterage Air Cushion Vehicle) is a 30-ton capacity hovercraft. The Department of the Army, 11th Transportation Battalion (TML), Fort Story, VA, maintains a fleet of these vehicles. A larger hovercraft, the 75-ton capacity LCAC (Landing Craft Air Cushion vehicle), is currently in use by the United States Navy. The C7 is a 4-ton capacity light cargo/passenger hovercraft, proposed by Textron Marine Systems for use as a prime mover for a 100-ton capacity hoverbarge.

---

[1] Personal Communication, 27 April 1993, Textron Marine Systems, New Orleans, LA.

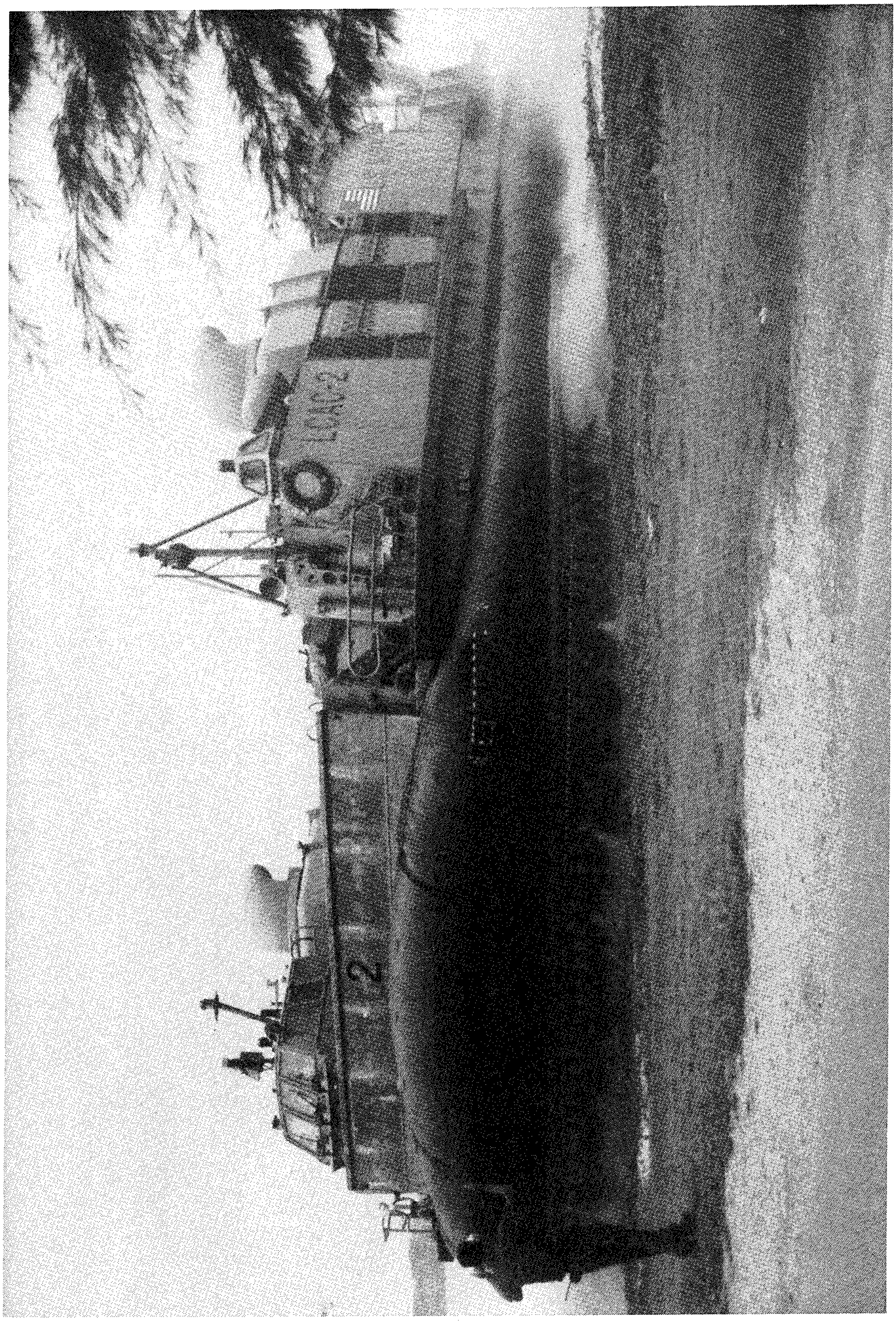


Figure 3. LCAC hovercraft (Courtesy Textron Marine Systems)

Utility for Dredged Material Transport

Modifications to current hovercraft design would be necessary for effective transport and handling of dredged material. Current designs have been oriented toward speed as well as payload capacity. Speed is not a major consideration for dredged material transport, and excessive speed during transport would be undesirable from the standpoint of load stability. The major consideration would be effective loading/unloading capability and efficient and stable transport of large payloads in a watertight compartment or bin.

It is unknown what effect bulk fluidized cargo may have on maneuverability and stability. Hovercraft are sensitive to the distribution of cargo, which must be loaded over the center of gravity. Baffling of the cargo compartment may satisfactorily address this issue. Fort Story personnel report some trim and balance problems when underway with certain load types. In addition, there is some concern that cargo composed of loose material might be ingested into the engine intakes, lift fan, or propellers. This could be addressed by cargo covers of some type if necessary.

Load Capacity

It is believed that the present maximum load capacity of hovercraft available domestically is that of the LCAC—approximately 75 tons. However, Sikora (1988) makes reference to an ACT-100, a 100-ton payload hovercraft that was developed for and utilized in oil and gas drilling operations in the Arctic in 1971. To date, the maximum load capability that has been developed worldwide is about 250 tons (Russian hovercraft). At the present state of the technology, 300 tons is thought to be the maximum feasible design load. Experience with LACV-30 hovercraft at Fort Story, VA, suggests that actual working capacity may be somewhat less than design capacity. The LACV-30 is rated to carry a working load of 30 tons. It has been successfully utilized at Fort Story to carry a maximum of about 21.5 tons, approximately 72 percent of design capacity.[1]

Potential Sources of Hovercraft

There are a number of companies listed domestically as suppliers of hovercraft. A partial listing can be found in Sikora (1988). An attempt was made to contact each of the companies listed therein. Only two viable contacts were made: Textron Marine Systems, New Orleans, LA,

---

[1] Personal Communication, 18 May 1993, 1st Lt. Joseph Corleto, 11th Transportation Battalion (TML), Fort Story, VA.

and Hover Systems, Inc., Eddystone, PA. Textron Marine Systems now actively manufactures hovercraft, with the capability of producing one craft approximately every 5 weeks. There are presently a number of LACV-30 and LCAC hovercraft in military (Army and Navy) inventory, and other models in commercial use.

5 Logistical Considerations in Hoverbarge Operation and Dredge/Hoverbarge Interface

Adaptation of present hovercraft design to a hoverbarge configuration would be required to accommodate large bulk payloads of dredged material. The hoverbarge proposed for use in wetlands nourishment would be an amphibious vehicle. It would float in the manner of a conventional boat or barge and move through the water under tow. It could also be equipped with a conventional screw drive, or air diverted from the cushion to produce horizontal thrust. However, it is anticipated that the most economical barge would have lift capability only (to maximize load capacity), and would be transported over water by a conventional tug (prime mover—tug), and over marsh or land by another ACV equipped for the purpose of towing (prime mover—ACV).

In applications where high speeds are not required, the power split could be optimized for the primary functions of the barge (lift) and prime mover (propulsion), respectively. Less power may be required for propulsion at lower speeds, with possible higher economy of operation realized, although high speed hovercraft achieve greatest fuel economy when operating in excess of hump speed (the speed at which the craft is moving ahead of its own wake).

To perform a feasibility analysis of the technical and economic aspects of hoverbarge operation, the logistical requirements of the hoverbarge must be evaluated. The manner in which the hoverbarge will be loaded (mechanically or hydraulically) and modifications to the cargo area must be considered. In addition, the potential "interface" with a conventional dredging operation must be defined. The respective capacities of the proposed hoverbarge and conventional dredging equipment must be examined, and the most feasible point of loading and use determined. Unloading alternatives must be addressed.

Hoverbarge Loading

For purposes of this evaluation, the only source of material for eventual transport to marsh interiors via hoverbarges is assumed to be limited to material generated by dredging operations from navigation channels. Because dredging in coastal Louisiana is by hydraulic equipment, hydraulic loading of hovercraft is assumed if the hoverbarge is to be loaded at the dredging site. Loading could be either hydraulic (pumps or portable dredge) or mechanical (loader and conveyor) if the hoverbarge is to be loaded from a remote sediment holding facility. However, to achieve sufficient dewatering of sediments to allow mechanical loading, a large storage area providing long retention times would be required. This would be feasible if sediments were to be taken from an existing CDF, and would eliminate uneconomical transport of water. The sediments could be reslurried for off-loading and distribution at the restoration site.

If the slurry delivered to the hoverbarges is primarily sand, the payload of solids loaded into hoverbarges could be increased by continuing to pump past the point of overflow. This is a common practice during dredging operations for both hopper dredges and for barges filled by hydraulic dredges. If the sediments being loaded are primarily fine-grained silts or clays, the increase in payload by overflowing the hoverbarges would be minimal, as the fines wash out with the overflow and little or no consolidation of the load is achieved. Water quality impacts associated with overflow must also be considered.

Another consideration regarding overflow is the desirability of densifying the load from the standpoint of ease of placement. Slurried materials transported in the hoverbarges at the same water content as hydraulically loaded might feasibly be released through a bottom opening and spread with the action of the air cushion. More densified loads, especially of sandy sediments, may be more difficult to release and spread. Additional water would have to be obtained at the off-loading area to reslurry densified loads if hydraulic off-loading were to be utilized.

Hoverbarge Bins

Since the dredged material loaded into the hoverbarges would be either a slurry or dry bulk sediment, the major required modification to current hovercraft design would involve a redesign of the cargo or payload area into a configuration similar to dry cargo or dredged material barges.

The cargo area would therefore have to be designed as a watertight containment bin, like a bathtub, with continuous sidewalls and bottom. Materials could be off-loaded hydraulically using pumpout machinery, through controllable openings in the sidewalls, or through controllable openings in the bottom.

The volumes of material required to nourish the marsh are large; therefore, the size of the payload for a hoverbarge should be as large as practicable. The limiting payload size is assumed to be 300 tons, based on discussions with manufacturers. Even though some of the payload requirements would be consumed by necessary features for handling or offloading, the 300-ton figure is used here for purposes of defining approximate size.

Dredged slurry is categorized according to specific gravity (unit weight of solids (W_s/V_s) divided by unit weight of water (W_w/V_w)), dry density (equivalent to weight of solids over total volume (W_s/V_t)), bulk density (the sum of the weight of solids plus the weight of water divided by the total volume), and concentration (weight of solids divided by total volume). Assuming a specific gravity of 2.65, dredged slurry hydraulically loaded into hoverbarges from a dredge discharge pipeline having a slurry concentration of 100 to 150 g/L will have a bulk density of 1,062 to 1,100 g/L (66 to 70 lb/ft^3). This is a fairly typical value for fine sediments. Sand slurries will typically have a concentration of 200 to 300 g/L. If the hoverbarge is overflowed during filling, the wet weight of the material may be increased, depending on the grain size and nature of the material.

A bulk density of 90 lb/ft^3 (1,442 g/L), representing a slurry concentration of approximately 700 g/L, is used here as an average value for sediment consolidated by overflow, for purposes of defining the approximate bin capacity required. A 300-ton payload at 90 lb/ft^3 corresponds to a payload volume of approximately 6,500 ft^3 (247 yd^3) of slurry. The volume of solids delivered in this load would be only 65.2 yd^3 (at 700 g/L, 0.264 yd^3 solids are delivered for every 1-yd^3 slurry). Assuming a final void ratio of 0.8, the consolidated (delivered and drained) volume (of 6,500 ft^3 or 247 yd^3) would be approximately 117 yd^3.

Freshly dewatered sediments contained in a holding area would still be too fluid to handle by mechanical means, and would be loaded by means of pumps or a portable dredge. Freshly dewatered sediments of mixed composition will have a concentration of approximately 700 g/L, which corresponds to the consolidated hydraulic loading assumptions stated above for volume and yield. Freshly dewatered fines at a concentration of 300 g/L will have a bulk density of approximately 1,187 g/L and will yield approximately 0.113 yd^3 solids per cubic yard slurry.

Sediments that could be mechanically loaded would have a concentration in the range of 1,000 g/L. For a 300-ton load, this would correspond to 220-yd^3 wet sediment, with a placed, consolidated volume of 149 yd^3, assuming a final void ratio of 0.8.

The relative volumes of slurry to consolidated, placed dredged material are given in Table 1 for the three load cases that will be considered in this document: 300 tons, 150 tons, and 100 tons.

Table 1
Relative Volumes of Slurry to Placed, Consolidated Dredged Material

	Hydraulically Loaded Material 700 g/L Concentration		Mechanically Loaded Material 1,000 g/L Concentration	
Payload Capacity	**Load Volume yd^3**	**Consolidated Volume, yd^3**	**Load Volume yd^3**	**Consolidated Volume, yd^3**
100 tons	82.3	39.1	73.3	49.7
150 tons	123.5	58.7	110	74.7
300 tons	246.9	117.4	220	149.2

The overall off-cushion (stationary or floating) size of the 75-ton capacity hovercraft now in production by Textron Marine (the LCAC) is 43.67 by 81 ft. The on-cushion dimensions are 47 by 87.92 ft. The payload area is roughly 25 by 70 ft. The light ship displacement is 205,318 lb. With a 300-ton payload (600,000 lb), the cushion pressure for this craft would exceed 1 psi. A larger cushion area (and consequently larger deck area) would be required to maintain cushion pressure at or below 1 psi for this payload.

For the purposes of this analysis, dimensions of 30 by 70 ft are assumed for the payload bay. The depth of filling for a 300-ton payload of dredged material with a density of 90 lb/ft^3 is then approximately 3 ft. The actual depth of the payload bay should be higher to allow for lighter density slurries and for shifting of the load during movement; say 6 ft.

Hoverbarge/Dredging Interface

The relative capacities of conventional sediment dredging and transport equipment utilized in this analysis are compared with the capacity of the proposed hoverbarge in Table 2 (based on the maximum estimated load capacity for the hoverbarge and the corresponding volumes for solids and slurry transport). The differences noted here will be a significant factor in the manner in which a hoverbarge might be interfaced with a conventional dredging operation.

Table 2
Relative Capacities of Sediment Dredging and Transport Equipment

Equipment Type	Volumetric Capacity	Production Rate
Conventional barge	4,000 yd^{3a}	N/A
Hopper dredge	4,000 to 8,000 yd^{3a}	500 to 2,000 yd^3/hr^a
Hydraulic dredge - pipeline discharge - 18 to 24 in. (26 to 64 cfs, 150 g/L sediment)	N/A	3,500 to 8,500 yd^3/hr (slurry) (198 to 486 yd^3/hr (solids))
300-ton hoverbarge	220 to 247 yd^3	N/A

[a] U.S. Army Corps of Engineers (1983).

Given the rate and volume of sediment typically dredged in the New Orleans District, it is apparent that a fleet of several hoverbarges would be unable to transport and distribute the entire production of a normal dredging operation. Other means of transport and disposal would also be required. The following alternatives exist:

- Divide the flow from the dredge between the hoverbarge and conventional transport equipment (barge or pipeline) at the dredging site.
- Utilize conventional barges, pipelines, or a hopper dredge to transport the sediments to a hovercraft loading site convenient to the restoration site, and load the hovercraft directly from these.
- Utilize conventional transport methods to deliver the sediments to an existing CDF, and transport by hovercraft from there to the project site.
- Utilize conventional transport methods to deliver the sediments to a strategically sited holding facility, constructed to provide a minimum operating reserve for the hovercraft, transporting by hovercraft from there to the project site.

The hovercraft could be loaded directly from the dredge discharge or from larger capacity conventional transport equipment used to "capture" the sediments as they are produced, but there are several disadvantages to this alternative. Direct loading of hovercraft from the dredge discharge, barge, or hopper dredge creates an uneconomic interdependence of the two operations, making one operation subject to delays in the other and introducing expense for standby time of transport or dredging equipment during unloading operations. If the dredging operation calls for open-water disposal, sediments that cannot be utilized by the hovercraft will be lost to beneficial use. Some type of interim storage is then indicated to allow dredging to proceed at a normal pace and to maintain an adequate supply of sediments for restoration activities. Use of existing CDFs or construction of a smaller holding facility would appear to be the most feasible alternatives.

For the purposes of the economic analysis, hydraulic or mechanical loading of sediments from an existing CDF or from a smaller, confined holding facility is assumed. Hydraulic loading of hovercraft from the dredge discharge will also be examined to establish the relative costs for the use of conventional equipment versus hovercraft for overwater transport. Hoverbarge transport over land or marsh will be compared with pipeline delivery costs.

Hoverbarge Unloading

Hydraulic offloading

The weight of pumps and attendant equipment must be considered in the payload and space requirements if hydraulic off-loading of slurry is pursued. There would also be a requirement to pump additional water from the off-loading site to "jet" and reslurry settled materials. A variation of this alternative would be to place pumpout equipment on board a dedicated hovercraft that could be used to service several transport craft that carry the material. The pumpout craft would be equipped with a snorkel-type arrangement similar to dredged material barge pumpout plants.

Sidewall opening requirements

Off-loading through sidewall openings would involve a controllable gate or gates. If the overall design of the hoverbarge is similar to existing self-propelled hovercraft, the gates would logically be in the front of the craft. If towed craft are used, location of the gates in the sides or rear may be possible. If the overall dimensions of the hoverbarge bin are 30 by 70 ft, these gate openings should be on the order of 10 to 15 ft wide to allow easy off-loading. The opening mechanism would require added machinery with payload requirements. With sidewall release, there would be no need for off-loading pumps, but there should be provisions for an onboard jet to wash out settled material. This would be a necessity if sandy material was transported.

Bottom opening requirements

Direct bottom release of material from the hoverbarge is also a possibility. This option would require a controllable bottom gate or gates that could be opened into an adjacent recess within the hull (like a pocket sliding door), or a hinged gate that could open downwards. The hull design and mobility requirements of the craft would have to be considered from the standpoint of available bottom hull space for the dump aperture or from the standpoint of required clearance. Considering overall dimensions of the hoverbarge, these bottom gate openings should be on the order of 10 to 15 ft square to allow easy off-loading. The opening mechanism would also require added machinery with payload requirements. There would be no need for off-loading pumps, but there should be provisions for an onboard jet to wash out settled material, similar to that mentioned for the sidewall release option.

Mechanical offloading

Mechanically loaded sediments will be too dry to off-load hydraulically without reslurrying. Another alternative would be to auger the sediments from the bin and mechanically broadcast them in thin layers from a moving hovercraft. Simple mechanical equipment such as this could potentially represent the most economic means of off-loading.

Considerations for hoverbarge spreading

Regardless of whether the material is off-loaded by hydraulic pumping, sidewall gates, or bottom gates, it can be assumed that material off-loaded as a slurry would tend to be deposited in relatively thin layers. It might also be effective for the hoverbarge to pass over the area of material release to allow the air cushion to assist in spreading the material in a thin layer. Dryer sediments could potentially be augered from the bin and mechanically broadcast.

Excessively thick sediment layers can have a permanent adverse effect on marsh vegetation. The exact thickness that the marsh will tolerate is dependent upon the type of vegetation present. The addition of overburden may also contribute to further subsidence due to consolidation of foundation materials. This will present a technical limitation in the feasibility of off-loading sediments by dumping.

6 Environmental Considerations of Hovercraft Operation

A serious concern is the effect of hovercraft traffic on the integrity of the marsh. Long-standing oilfield operations provide ample evidence of the detrimental effects of repeated passes from marsh buggies and other vehicles adapted to use in the wetland, as illustrated in Figure 4. It appears that the low cushion pressures of the ACVs would have potentially less damaging effects in moving in and out of the wetland and could eliminate the need for crews and equipment to place, move, and maintain pipelines for sediment distribution. The U.S. Navy conducted studies on the environmental impact of Amphibious Assault Landing Craft (AALC) (Planning Systems Incorporated 1984). Overwater operations resulted in generally minimal, temporary impacts. Overland operations involved "short term damage to vegetation, shearing of dune crests, and displacement of unconsolidated sand." Shearing of some vegetation did occur, but typically root systems were not damaged except where they existed on loose, unconsolidated soils.

Textron Marine Systems has maintained photographic records of marsh areas that have been repeatedly crossed during testing of newly manufactured hovercraft. An area such as this exists near the Textron manufacturing plant in New Orleans. Slight discoloration of marsh grasses and plants was noted, but obvious plant death and subsequent land subsidence was not evident by cursory inspection from the hovercraft. Table 3 and Figures 5-8 give corresponding photographic and archival records of marsh crossings (courtesy Textron Marine Systems) that reflect the effects of repeated hovercraft passes over time. This evidence is extremely limited, however, and does not represent a definitive study.

Distribution of the quantities of sediment discussed in this report will require a much higher magnitude of traffic, given the high density of dredged material and the limited volumetric capacity of the proposed hoverbarges. The potential effects of this must be further evaluated and consideration given to siting of loading and unloading operations so that

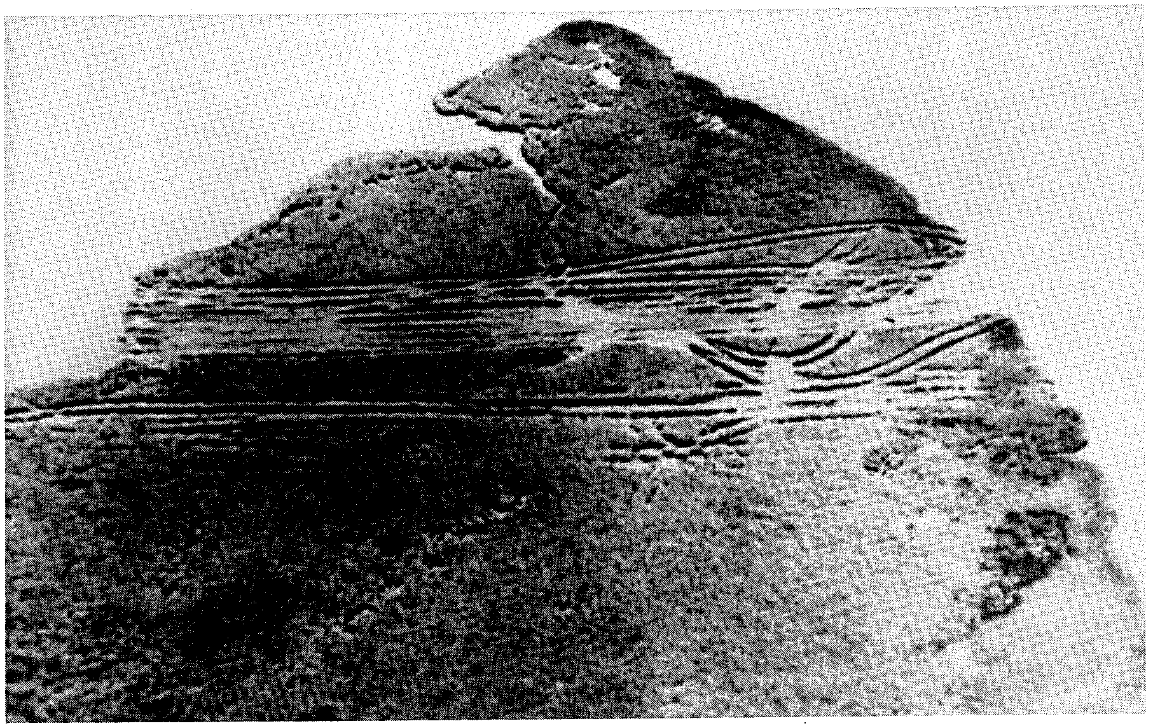


Figure 4. Marsh buggy tracks, Grand Bayou Blue, Lafourche Parish, LA (photo courtesy Dr. Walter B. Sikora, Sikora (1988))

traffic is minimized. Regeneration of travel corridors may be an attendant requirement of such an operation. In this case, the comparative benefits of utilizing hovercraft instead of dedicating a pipeline corridor may be minimal.

Table 3
LCAC Marsh Crossings, 1990-92 (courtesy Textron Marine Systems)

Period	No. of Crossings
1990	
July	0
August	0
September	0
October	11
November	4
December	7
1991	
January	0
February	4
March	1
April	6
May	4
June	7
July	7
August	6
September	3
October	6
No runs were conducted over the marsh between 31 October 1991 and 29 January 1992 because of hunting season.	
1992	
January	2
February	5
March	5
April	6
May	2
June	3
July	5
August	4
September	5
October	3

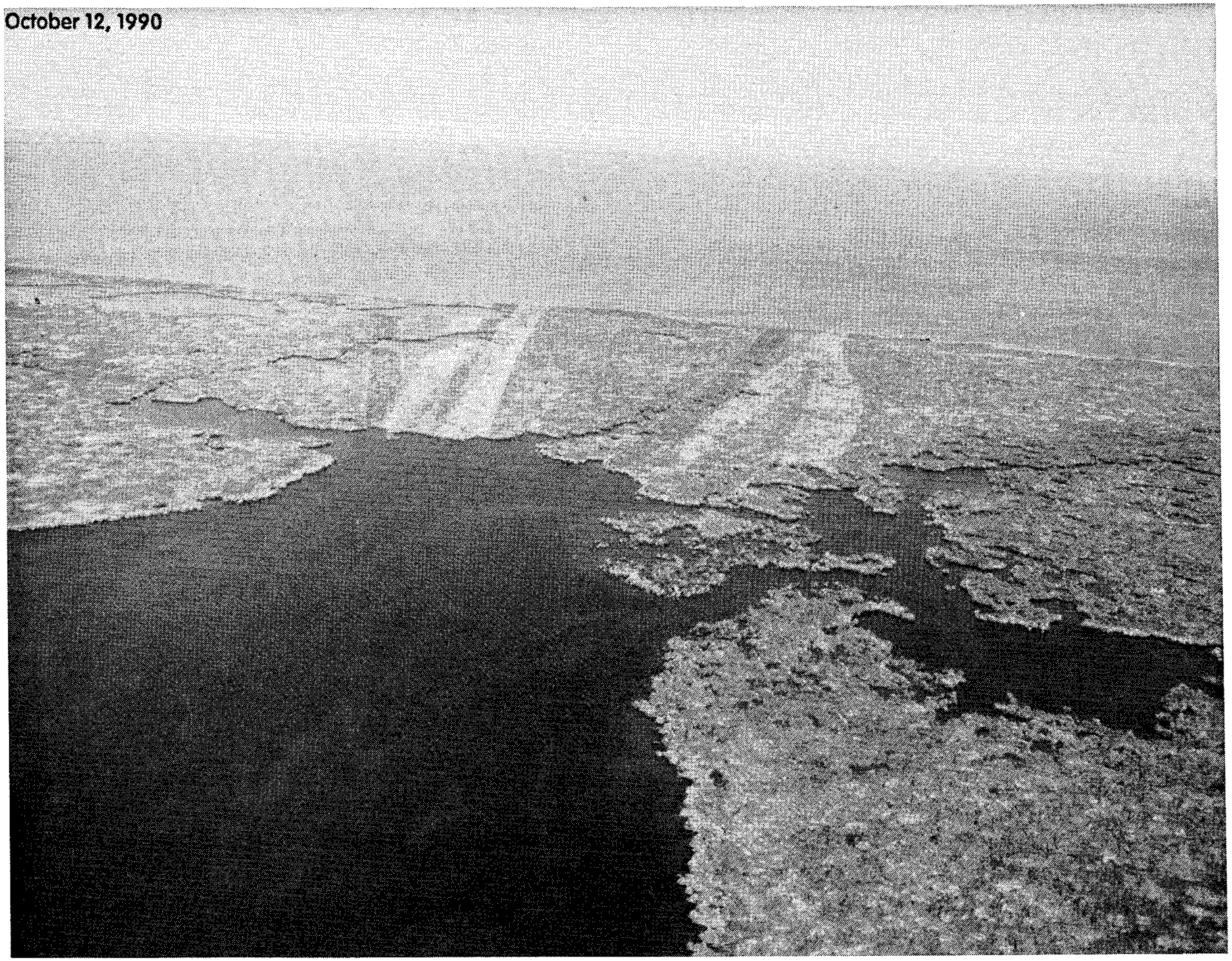


Figure 5. Hovercraft crossing, October 12, 1990 (Courtesy Textron Marine Systems)

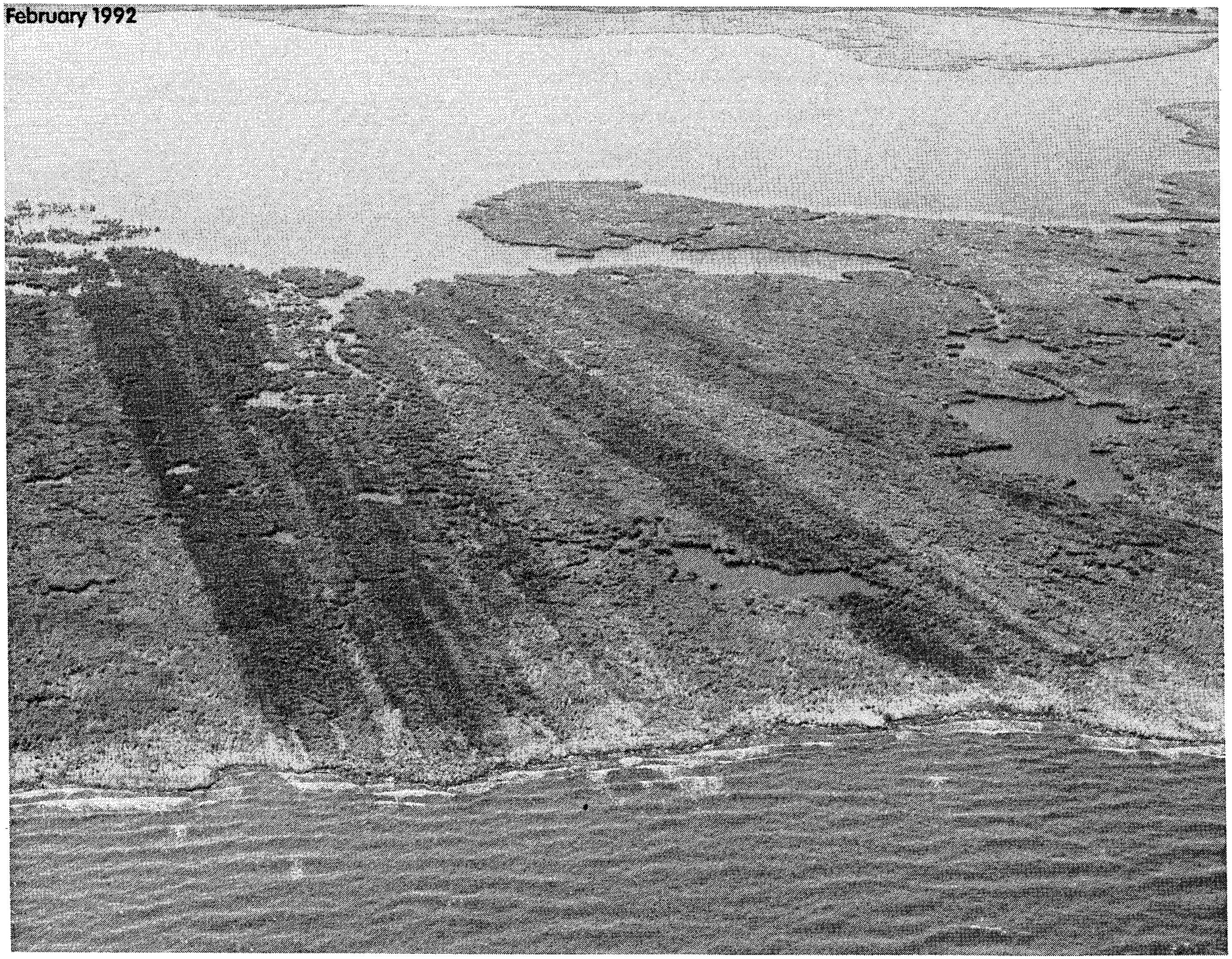


Figure 6. Hovercraft crossing, February 1992 (Courtesy Textron Marine Systems)

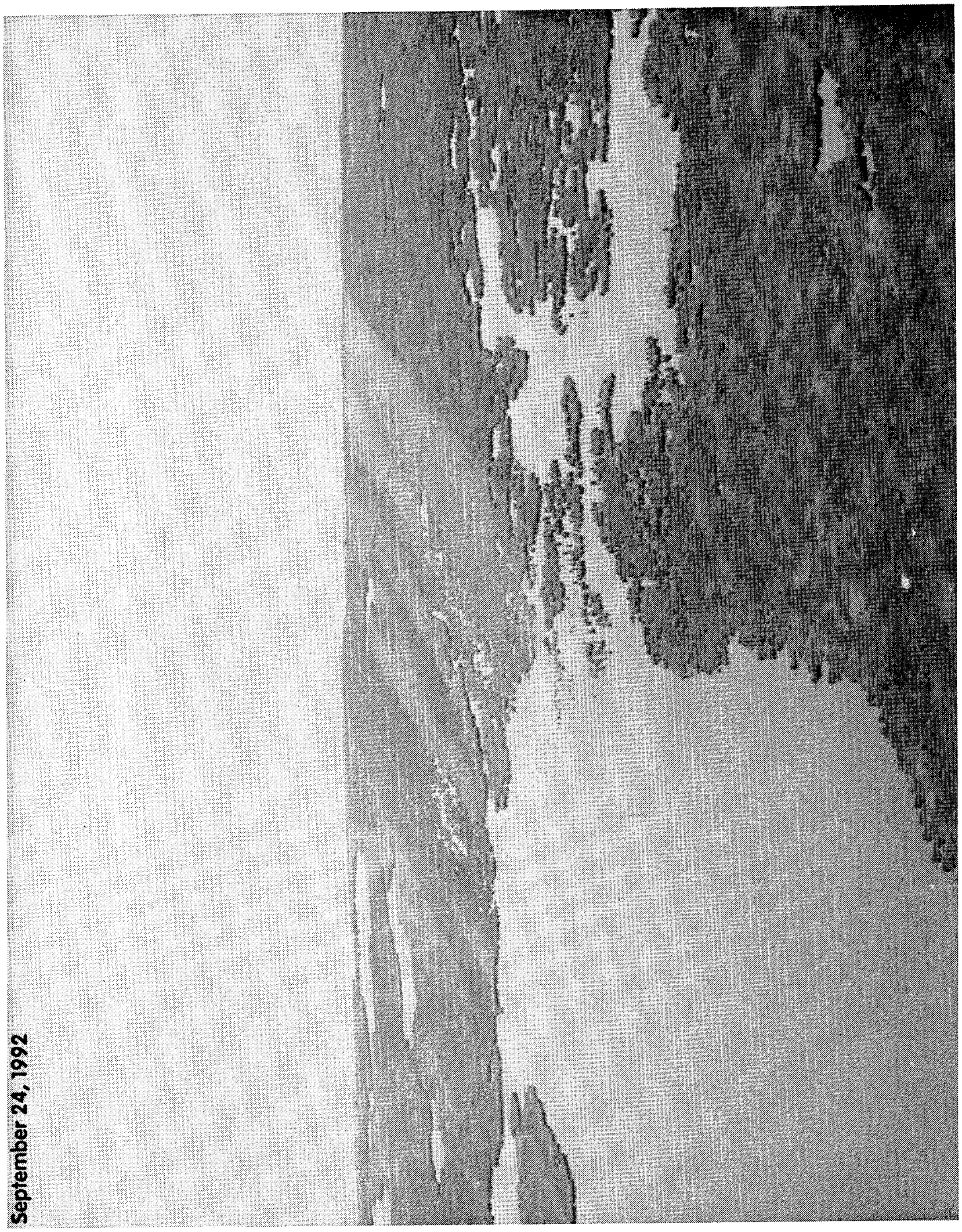


Figure 7. Hovercraft crossing, September 24, 1992 (Courtesy Textron Marine Systems)

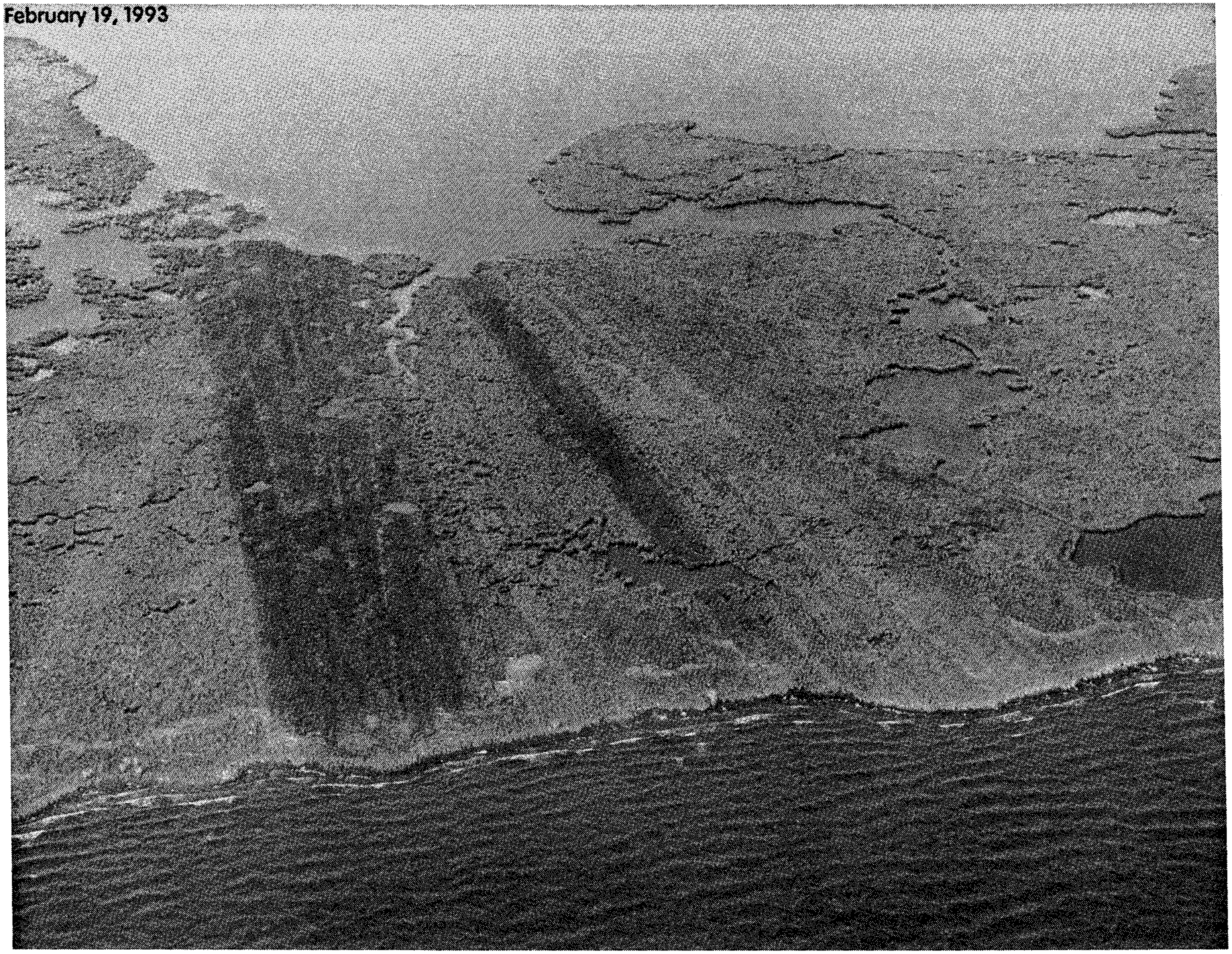


Figure 8. Hovercraft crossing, February 19, 1993 (Courtesy Textron Marine Systems)

7 Cost Analysis

Transport unit costs for dredged material are typically a function of the volumes of sediment being dredged, the density of the material being transported, the distances involved, the rate at which material is dredged, and the corresponding capacity of the transport equipment utilized. The cost of the transport component of a dredging operation is sometimes difficult to separate from the cost of the dredging activity, as in the case of hopper dredges in which the dredge serves both functions.

Conventional transport costs are well documented and can be developed with reasonable confidence for this analysis. Since a prototype of the hoverbarge has not yet been developed and tested, actual data for acquisition, operation, and maintenance costs of such a vehicle are not available. To perform a preliminary economic feasibility analysis, cost data from hovercraft developed for other applications were used to estimate expected costs for the proposed hoverbarge. A budgetary estimate for a 150-ton capacity hoverbarge was also obtained from Hover Systems, Inc. The results of the cost analysis that follow represent at best a range within which actual costs could reasonably fall, but do not necessarily represent a definitive cost estimate.

Dredging and transport equipment may be government owned and operated, government owned and contractor operated, or contractor owned and operated. This is largely influenced by two factors: the profit incentive for private industry to maintain capital equipment in a competitive, bid-based market and existing government policy to utilize contracted services whenever possible (Souder et al. 1978).

Usage costs for equipment will be based upon essentially the same factors, whether privately or government owned. Capital cost, useful life and salvage value of the equipment, cost of money, and annual months of active use will determine an effective monthly usage cost (ownership cost). Cost of labor to operate the equipment, maintenance, and fuel or energy usage are additional cost factors (operating expense). In addition, indirect costs or overhead will be factored in as will profit for contracted equipment or services.

Labor and ownership costs for pipelines and booster stations operated in conjunction with a dredging plant have been developed in the Corps of Engineers Dredge Estimating Program (CEDEP). Long distance transport costs for several transport alternatives were developed in Souder et al. (1978). Pipeline and barge transport of sediments from a CDF, including loading and unloading operations, are of primary interest here.

Hovercraft Specifications

Table 4 gives preliminary specifications for the proposed 300-ton hoverbarge. These are compared with specifications for the LCAC, the LACV-30, and the C7 hovercraft.

Table 4
Comparison of Hoverbarge Specifications to LCAC, LACV-30, and C7

Feature/Specification	LCAC	LACV-30	C7	Hoverbarge[1]
Maximum payload	60 to 75 tons	25 to 30 tons	4 tons	300 tons
Volumetric capacity[2]	49 to 62 yd^3	21 to 25 yd^3	3 yd^3	247 yd^3
Operating or cruise speed[3]	40 knots	40 knots	35 knots	8 knots

[1] Assumed values.
[2] For slurried dredged material with density of 90 lb/ft^3, based on maximum payload. Towing capacity could be higher.
[3] 1 knot = 1.151 mph.

Capital Costs

Projected capital costs for the 300-ton hoverbarge were unavailable. The initial capital cost for a C7, an LCAC, a LACV-30, and the budgetary cost estimate for a 150-ton hoverbarge are given in Table 5. Cost per ton capacity developed here is intended to roughly define a range within which hoverbarge costs would be expected to fall. Both the LCAC and the LACV-30 were developed for other high speed applications and incorporate sophisticated equipment not required for a hoverbarge. Load capacity of the LCAC and LACV-30, however, is less than that proposed for the hoverbarge.

Table 5
Capital Cost Comparison of C7, LCAC, LACV-30, and Budgetary Estimate for 150-Ton Hoverbarge

Equipment Description	Load Capacity, tons	Capital Cost 1993 Dollars in millions	Cost per Ton Capacity (to nearest hundred $)
Hoversystems Hoverbarge	150	3.30[1]	22,000
LCAC	60 to 75	16.5[2]	220,000 to 275,000
LACV-30	25 to 30	4.00[3]	133,300 to 160,000
C7	4	2.50[4]	625,000

[1] Budgetary estimate Hover Systems, Inc., June 1993.
[2] Personal communication, E. E. Shoults, Program Manager, Amphibious Warfare Program, Department of the Navy, Naval Sea Systems Command, Arlington, VA.
[3] Personal communication, CW3, Maxine L. Bond, 11th Transportation Battalion (TML), Fort Story, VA.
[4] Personal communication, August 27, 1993, S. L. Johnston, Director of Logistics and Support Services, Textron Marine Systems.

Maintenance

Hovercraft such as the LCAC are complex pieces of equipment. The flexible skirt of an amphibious craft requires ongoing maintenance. Figure 3 illustrates the construction of the skirt with modular units of "fingers," cones of rubber which release the air around the periphery of the craft to form the cushion. These come in contact with the surface being traversed and are subject to wear. Typical finger life is 15 to 30,000 miles, or > 1,000 hr for aquatic use exclusively and approximately 750 hr where the terrain involves concrete or other abrasive surfaces. When operated over abrasive surfaces, skirt maintenance may be a more significant expense than fuel consumption.[1] In addition, mechanical systems such as the diesel engines or gas turbines that power these craft can be high maintenance items, depending upon the conditions of operation.

Textron Marine Systems estimates an approximate cost of $\$2.74/m^3$ ($\$2.09/yd^3$) for fuel and for engine and finger maintenance for a hoverbarge equipped only with a lift module under the following limitations[2]:

- Capacity - 63 m^3 (82 yd^3, or 100.5 tons, assuming slurry density of 90 lb/ft^3).

---

[1] Personal Communication, 27 April 1993, Frank Higgins, Design and Product Support, Textron Marine Systems, New Orleans, LA.

[2] Personal Communication, 16 July 1993, S. L. Johnston, Director of Logistics and Support Services, Textron Marine Systems, New Orleans, LA.

- Operating an average of 1,200 hr per year.

- Operating at 8 knots (9.2 mph).

- Ten-mile round trip.

For the same scenario, Textron estimates the operating and maintenance costs for a C7 as prime mover for a 100-ton hoverbarge to be approximately \$5.13/m^3 (\$3.92/yd^3), including fuel consumption at 70 gal/hr, lube oil, filters, and total spares and parts for all primary equipment. This equates to approximately \$151/hr total operating cost, of which \$63/hr is maintenance.[1]

Fort Story reports an operating cost of approximately \$1,900/hr (under adverse conditions - erosive and corrosive environment) for the LACV-30, of which \$300/hr is for fuel.[2] Given the same speed and distance as stated for the Textron estimate, this would equate to a maintenance cost of \$90.99/m^3 (\$69.60/yd^3), based on a load capacity of 30 tons, hauling a slurry at a bulk density of 90 lb/ft^3.

The Naval Sea Systems Command reports operating costs of approximately \$3,080/hr for the LCAC. Of this, \$351/hr is for fuel. The remainder is for spares and maintenance. Because of corrosion problems, these craft are given a midlife overhaul (8 to 10 years into service) at an approximate cost of 1.1 million dollars.[3] For the above scenario, this corresponds to a maintenance cost of \$62.58/m^3 (\$47.84/yd^3), based on a load capacity of 75 tons and 90-lb/ft^3 bulk density slurry, exclusive of the midlife overhaul.

Table 6 summarizes these costs:

---

[1] Personal Communication, 2 August 1993, S. L. Johnston, Director of Logistics and Support Services, Textron Marine Systems, New Orleans, LA.

[2] Personal Communication, June 1993, Maxine L. Bond and 1st Lt. Joseph Corleto, 11th Transportation Battalion (TML), Fort Story, VA.

[3] Personal Communication, 22 July 1993, E. E. Shouts, Program Manager, Amphibious Warfare Program, Naval Sea Systems Command, Arlington, VA.

Table 6
Operating and Maintenance Cost Comparison Textron Marine Systems 100.5-Ton Hoverbarge, LACV-30, and LCAC

Vehicle Description	Load Capacity[1]	Fuel Cost	Maintenance Cost	Textron Cost Estimate Basis, Total Operating Cost/yd^3 Load Capacity[2]	Actual Operating Cost Basis, Total Operating Cost/yd^3 Load Capacity[3]
C7 Prime Mover 100.5-ton Hoverbarge	39.1 to 49.7 yd^3 combined	\$89/hr \$159/hr[4]	\$63/hr	\$7 to \$9/yd^3	N/A
LACV-30	11.7 to 16.8 yd^3	\$300/hr	\$1,600/hr	N/A	\$123 to \$177/yd^3
LCAC	29.3 to 41.9 yd^3	\$351/hr	\$2,729/hr[5]	N/A	\$80 to \$114/yd^3

[1] Based on slurry bulk density of 90 to 101 lb/ft^3 in transit, and void ratio of 0.8 after placement and consolidation.
[2] Based on speed of 8 knots, 10-mile round trip.
[3] Assuming use as self-propelled hoverbarge. Use as tow vehicle to higher capacity hoverbarge could result in lower unit costs.
[4] Fuel and maintenance costs combined.
[5] Exclusive of midlife overhaul.

Cost Comparisons and Basis

Souder et al. (1978) indicates that for annual volumes of 1 million yd^3, hydraulic pipeline transport is the most economical (conventional) transport mode available, up to distances of approximately 50 miles. Beyond this distance, barge transport is most economical. Rail and truck transport are probably inapplicable to transport and distribution of sediments along or within a marsh unless transportation routes coincidentally exist where restoration is needed, and both are more costly than pipeline or barge for the distances considered in this analysis.

Dry material is significantly more economical to transport than slurry (by means other than pipeline transport) (Souder et al. 1978). However, because dredging operations in the New Orleans District are principally hydraulic, hydraulic loading of conventional barges or hoverbarges might be considered to "capture" sediments that would otherwise be lost to open-water disposal. Costs estimates for transport of slurried sediments are therefore included here. The cost per cubic yard "yield" (volume of dredged material delivered after placement and consolidation) is then an important parameter in determining the economic feasibility of an alternative, as distinct from the cost per cubic yard of volumetric capacity. This is particularly important in the case of the hoverbarge, in which volumetric capacity is directly related to ton load capacity.

Table 7 compares the relative capital and contract costs for hopper barges and hoverbarges and the relative unit costs for barge transport based on volumetric capacity, labor, and operating expense, exclusive of tug costs.

Hoverbarge capital and operating costs are estimated based on military purchase, maintenance and operating records for the LACV-30 and the LCAC, and on industry cost estimates. For purposes of estimating operating costs, the 100-ton and 150-ton hoverbarges were equated to the LACV-30, and the 300-ton to the LCAC. This approach offeres only a rough approximation of expected costs, as the LACV-30 and LCAC are sophisticated military craft not closely comparable to the proposed hoverbarges. Cost figures for the LACV-30 and the LCAC represent the only capital and operating data available, however, upon which to base this analysis. Industry estimates of operating costs for the 100-ton hoverbarge were extrapolated to the 150-ton and 300-ton hoverbarges as well, for comparison. The cost comparisons contained in Table 7 then define a range of estimated capital and operating costs for hoverbarges. A more rigorous economic analysis is not possible with the limited information available.

The cost to transport dredge material with a hopper dredge was estimated using the daily lease rate of the dredge, exclusive of oilers, yard costs, standby time, and other expenses not specifically associated with the transport component. Costs for this alternative were higher than for barge transport and were therefore excluded from the cost comparison above.

Although sediment can be transported at a lower unit cost in large capacity conventional barges, there could be instances where a hoverbarge would still be utilized. When the overwater transport component is very short, the additional time and cost associated with rehandling the sediments may not be justified. Hoverbarges could be used for the overwater transport component in this case.

Hoverbarges could be towed overwater singly by an ACV or in a fleet using a conventional tug. Conventional barges are assumed to be towed by conventional tugs. A comparison of estimated ownership and operating costs for a LACV-30 utilized as a prime mover, contract costs for two conventional tugs, and ownership and operating estimates for a C7 hovercraft are given in Table 8.

The operating costs for a hoverbarge under tow must also be considered and are given in Table 7. It is assumed that the hoverbarge can be towed overwater off-cushion, as a conventional barge is towed, for both the ACV prime mover and the conventional tug. If it must be operated on-cushion to be towed by an ACV, additional expenses for the overwater

Table 7
Ownership and Operating or Contract Cost Comparison, Hopper and Hoverbarges (exclusive of loading and tug costs)

Description	Capital Cost	Total Ownership and Operating Cost or Contract Cost	Volumetric Capacity (cubic yards of dredged material after placement and consolidation)	Cost/1,000 yd^3/ mile[1], Hydraulically loaded sediments (700 g/L slurry)	Cost/1,000 yd^3/ mile[1], Mechanically loaded sediments (1,000 g/L slurry)
1,500-yd^3 Dump Scow	\$5.01 million[2]	\$100/hr[3,4]	712 yd^3 (for 700 g/L slurry) 1,018 yd^3 (for 1,000 g/L slurry)	\$15.3	\$10.7
4,000-yd^3 Hopper Barge	\$4.0 million[5]	\$42/hr[6]	1,900 yd^3 (for 700 g/L slurry) 2,714 yd^3 (for 1,000 g/L slurry)	\$2.4	\$1.7
100-ton Hoverbarge	\$3.0 million[7]	\$1,984/hr - On-cushion - Fort Story Cost Basis \$199/hr -[3,10] On-cushion - Textron Cost Basis \$60/hr -[3,11] Off-cushion[3,12]	39.1 yd^3 (for 700 g/L slurry) 49.7 yd^3 (for 1,000 g/L slurry)	On-cushion: \$5,515 - Fort Story Basis \$553 - Textron Basis Off-cushion: \$167	On-cushion: \$4,339 - Fort Story Basis \$435 - Textron Basis Off-cushion: \$131
150-ton Self-propelled Hoverbarge[8]	\$3.3 million[9]	\$1,992/hr - On-cushion - Fort Story Cost Basis[3,10] \$207/hr - On-cushion - Textron Cost Basis[3,11]	59 yd^3 (for 700 g/L slurry) 74.7 yd^3 (for 1,000 g/L slurry)	On-cushion: \$3,670 - Fort Story Basis \$381 - Textron Basis	On-cushion: \$2,899 - Fort Story Basis \$301 - Textron Basis
300-ton Hoverbarge	\$4.0 million[7]	\$3,192/hr - On-cushion - Naval Sea Systems Command Cost Basis[3,13] \$227/hr - On-cushion - Textron Cost Basis[3,11] \$80/hr - Off-cushion[3,12]	117 yd^3 (for 700 g/L slurry) 149 yd^3 (for 1,000 g/L slurry)	On-cushion: \$2,965 - Naval Sea Systems Command Basis \$211 - Textron Basis Off-cushion: \$74	On-cushion: \$2,329 - Naval Sea Systems Command Basis \$166 - Textron Basis Off-cushion: \$58

[1] Assumes operating speed of 8 knots (9.2 mph).
[2] Souder et al. 1978 adjusted to March 1993.
[3] Assumes 5-percent depreciation, 6.5-percent facilities capital cost of money, 8-months operation per year, 24-hr operation/day.
[4] No labor component associated with dump scow.
[5] Herbich (1992).
[6] Personal communication, June 8, 1993, Mr. Rick Smith, T. L. James, hourly rate assumes 24-hr operation/day.
[7] Estimated capital cost based on LACV-30 capital cost and Hover Systems, Inc., budgetary estimates for 150-ton self-propelled hoverbarge.
[8] No additional cost for tug would be incurred for self-propelled hoverbarge.
[9] Hover Systems, Inc., budgetary estimate June 1993.
[10] For on-cushion operation - includes estimated labor, fuel, and maintenance costs - based on LACV-30 operating costs (personal communication, Lt. Corleto, 11th Transportation Battalion, Fort Story, VA).
[11] For on-cushion operation - based on Textron Marine Systems operating and maintenance estimates for 100-ton hoverbarge.
[12] For off-cushion operation - no labor or operating costs associated with this operational mode.
[13] For on-cushion operation - includes estimated labor, fuel, and maintenance costs - based on LCAC operating costs (personal communication, July 22, 1993, E. E. Shouts, Program Manager, Amphibious Warfare Program, Naval Sea Systems Command, Arlington, VA.

transport component would be incurred. The hoverbarge is operated on-cushion overland.

On the basis of the data presented in Table 8, it appears that it is most economical to utilize conventional tugs for transport of hoverbarges overwater. Use of conventional tugs overwater will be assumed in the economic analysis.

Based on available cost information, it is clear that overwater transport is most economically effected with conventional equipment where its use is feasible. The remaining component of a transport and distribution system is overland or over marsh. Based on previous studies of transportation systems, the most economical conventional delivery system for the distances involved here is a pipeline system (Souder et al. 1978). This

Table 8
Prime Mover Cost Comparison

Vehicle	Capital Cost	Total Ownership and Operating Cost or Contract Cost	Towing Capacity	Cost/1,000 yd^3/mile[1] Hydraulically Loaded Sediment	Cost/1,000 yd^3/mile[1] Mechanically Loaded Sediment
250-HP Tug	$326,200[2]	$75/hr[2]	One 300-ton capacity hoverbarge 117-yd^3 consolidated sediment yield (for 700 g/L slurry) 149-yd^3 consolidated sediment yield (for 1,000 g/L slurry)	$69.7	$54.7
1,500- to 2,000-HP Tug	unknown	$100 to $135/hr[3]	One 4,000-yd^3 conventional barge 1,900-yd^3 consolidated sediment yield (for 700 g/L slurry) 2,714-yd^3 consolidated sediment yield (for 1,000 g/L slurry)	$5.7 to $7.7	$4.0 to $5.4
C7	$2.5 million[4]	$222/hr	One 100-ton capacity hoverbarge 39-yd^3 consolidated sediment yield (for 700 g/L slurry) 50-yd^3 consolidated sediment yield (for 1,000 g/L slurry)	$618.7	$482.6
LACV-30	$4.0 million[5]	$2,012/hr[6,7]	One 300-ton capacity hoverbarge 117-yd^3 consolidated sediment yield (for 700 g/L slurry) 149-yd^3 consolidated sediment yield (for 1,000 g/L slurry)	$1,869.2	$1,467.8

[1] Assumes operating speed of 8 knots.
[2] Capital cost, ownership and operating cost based on CEDEP 1993. Labor estimated at 40 percent of ownership cost (based on personal communication, 8 June 1993, Mr. Rick Smith, T. L. James. Assuming a net multiplier of 3 for profit and overhead.
[3] Personal communication, June 8, 1993, Mr. Rick Smith, T. L. James.
[4] Personal communication, August 1993, S. L. Johnston, Director of Logistics and Support Services, Textron Marine Systems.
[5] Personal communication CW3, June 1993, Maxine L. Bond, 11th Transportation Battalion (TML), Fort Story, VA.
[6] Ownership costs based on 5-percent annual depreciation, 20-year life, 0-salvage value, 6.5-percent facilities capital cost of money, 8 months operation per year, labor estimated at 40 percent of ownership cost.
[7] Operating expense based on $1,900/hr (personal communication, May 1993, Lt. Corleto, 11th Transportation Battalion, Fort Story, VA.

will be compared with a hovercraft/barge delivery system. The following scenarios will be considered:

Scenario 1: Hoverbarge (300-ton) transport and distribution over marsh, with LACV-30 prime mover, hydraulic loading from CDF or confined holding facility.

Scenario 2: Hoverbarge (300-ton) transport and distribution over marsh, with LACV-30 prime mover, mechanical loading from CDF or confined holding facility.

Scenario 3: Self-propelled (150-ton) hoverbarge transport and distribution over marsh, hydraulic loading from CDF or confined holding facility.

Scenario 4: Self-propelled (150-ton) hoverbarge transport and distribution over marsh, mechanical loading from CDF or confined holding facility.

Scenario 5: Hoverbarge (100-ton) transport and distribution over marsh, C7 prime mover, hydraulic loading from CDF or confined holding facility.

Scenario 6: Hoverbarge (100-ton) transport and distribution over marsh, C7 prime mover, mechanical loading from CDF or confined holding facility.

Scenario 7: Pipeline transport and distribution of sediment from CDF or confined holding facility.

Hoverbarge volumetric capacity and yield will be based on previously stated assumptions (see Table 1). Transport of fines would entail the movement of higher volumes of water and greater expense per unit volume solids delivered.

In Scenarios 1 and 2, capital and operating costs were based on Naval Sea Systems purchase and operational records for the LCAC (considered to be the basis for the 300-ton barge), and Fort Story purchase and operational records for the LACV-30 (considered to be the basis for the ACV prime mover).

In Scenarios 3 and 4, capital costs for the 150-ton self-propelled hoverbarge were based on the Hover Systems Budgetary Estimate. Operational costs were based on Fort Story records for the LACV-30 and Textron Marine Systems estimates for the operation of a 100-ton hoverbarge.

Scenarios 5 and 6 were based on Textron Marine Systems estimates for operation of a 100-ton hoverbarge and C7 (as prime mover).

Scenario 7 was based on cost estimates for pipeline transport with reslurrying from a CDF given in Souder et al. (1978). Included in these costs are booster pumps, pipe, rehandling dredge, energy, and labor costs. Optimum conditions are assumed. The effect of marsh terrain on pipe laying costs is not specifically addressed in this reference, but it appears that seriously adverse conditions could result in an increase of up to 50 percent for this element. This would result in an increase in the overall cost of the pipeline system of approximately 12 percent over base for the worst case. Real estate and pipeline rights of way costs are not included.

Sediment distribution using hovercraft will entail the use of a mobile pumping station to reslurry and discharge sediment from a stationary hovercraft, discharge directly from the mobile hovercraft (dumping or augering), or pumping equipment installed on either the prime mover or the hoverbarge for unloading from a stationary position. A mobile pumping station on a dedicated hovercraft would impose lease and operating costs for the station, as well as periodic relocation expense. Discharge from a moving hovercraft would entail operating expense similar to that for transport by this method. If the sediment is discharged by pumping, additional capital and operating costs for pumps would be required. Discharge is assumed to be from a moving hovercraft for purposes of this analysis. Unloading time is considered to be negligible relative to transport time.

The purpose of this analysis is to establish relative costs of the transport alternatives. The analysis can be simplified by excluding associated costs that are common to all alternatives. This includes the cost of construction of CDFs or confined holding facilities, which may or may not be an additional cost to the project. Dredging costs will be the same for all scenarios and are, therefore, excluded from this analysis. Capital and operating costs for a portable dredge associated with reloading operations are incorporated in unit costs for pipeline transport (Souder et al. 1978). Rehandling costs estimates are, therefore, also included for the hovercraft transport alternative.

Results of the cost comparisons reflected in Table 9 indicated that greatest economy for the marsh transport component is obtained with a pipeline system. Distribution costs are not reflected here, however, and in the case of pipeline distribution, would be a significant addition. A distribution header would be required at the terminus of the supply pipeline and would require periodic relocation to deliver sediments to the needed areas. The main supply pipeline could be permanent to serve annual maintenance restoration efforts. The effect of this factor on overall project cost can best be illustrated by an example problem, which follows this section.

Table 9 contains the results of the economic analysis of the transport component for the seven scenarios.

Table 9
Cost Comparison Marsh Transport Scenarios[1]

Basis	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Naval Sea Systems Command Operational Records	Transport: $4,834 Rehandling: $3,790	Transport: $3,797 Rehandling: $567	N/A	N/A	N/A	N/A	N/A
Fort Story Operational Records	N/A	N/A	Transport: $3,670 Rehandling: $7,580	Transport: $2,899 Rehandling: $633	N/A	N/A	N/A
Textron Marine Systems Estimates	N/A	N/A	Transport: $381 Rehandling: $7,580	Transport: $301 Rehandling: $633	Transport: $1,121 Rehandling: $11,420	Transport: $880 Rehandling: $700	N/A
Souder et al. (1978)	N/A	N/A	N/A	N/A	N/A	N/A	Transport: $169 Rehandling: Included

[1] Transport costs in units of $/1,000-yd^3 yield*mile. Rehandling costs in units of $/1,000-yd^3 yield. Rehandling costs are in addition to transport costs. This was estimated based on the assumption of 18 loads delivered per day for an operating period of 24 hr per day.

Cost Example

An example problem was developed to compare costs of pipeline and hoverbarge systems for overland transport and distribution of a given quantity of sediment. This was based on the cost assumptions previously described and the following:

- Overland transport distance - 6 miles.
- Project area - 100 acres.
- Sediment application thickness - 3 in.
- Dredged material volume required at consolidated void ratio of 0.8 - 40,000 yd^3.

Approximately 85,000 yd^3 slurry at a concentration of 700 g/L will be required to yield 40,000 yd^3 placed, consolidated material at a void ratio of 0.8. Approximately 183,000 yd^3 slurry will be required at a concentration of 325 g/L. Mechanically loaded sediments have a somewhat higher yield, requiring approximately 60,000 yd^3 at a concentration of 1,000 g/L. Pipeline costs are already adjusted for the additional quantity that must be pumped for a slurry with a solids concentration of 325 g/L (slurry bulk density of 1,200 g/L).

Sediment delivery by pipeline assumes a straight line manifold 1,000 ft in length that will distribute sediments over an area 1,000 by 250 ft via spray nozzles (Woodward-Clyde Consultants 1991). It is assumed that the in-line booster pumps provide sufficient head for operation. No additional capital costs for the manifold were considered; ownership costs for this pipe segment were assumed to be the same as for the remainder of the pipeline, although some additional costs would be incurred for valves and nozzles. Mobilization/demobilization costs for the header are estimated at \$10/lineal foot combined.

One ACV prime mover is assumed to be operating with one hoverbarge at a speed of 8 knots. Off-loading operations are considered to represent negligible additional cost.

Table 10 reflects the following comparative costs for delivery of 40,000 yd^3 placed, consolidated dredged material to a 100-acre plot, by pipeline and by hoverbarge.

Table 10
Comparative Costs for Pipeline Versus Hoverbarge Transport Alternatives—100-Acre Example Problem

Transport/ Distribution Alternative, 100-Acre Example	Textron Marine Systems Cost Estimate Basis	Fort Story LACV-30 and Naval Sea Systems Command LCAC Operational Cost Basis	Souder et al. (1978) Transport Analysis Cost Basis
Centrifugal Pump Pipeline Delivery System (Souder et al. 1978)	N/A	N/A	\$5/yd^3
300-ton Hoverbarge w/LACV-30 Prime Mover - Hydraulic Loading	N/A	\$62/yd^3	
300-ton Hoverbarge w/LACV-30 Prime Mover - Mechanical Loading	N/A	\$46/yd^3	
100-ton Hoverbarge w/C7 Prime Mover - Hydraulic Loading	\$25/yd^3	N/A	N/A
100-ton Hoverbarge w/C7 Prime Mover - Mechanical Loading	\$11/yd^3	N/A	N/A

Note: Low cost range represents operating costs based on Textron Marine Systems estimates; high range represents operating costs based on Fort Story, VA, operational records for the LACV-30 and Naval Sea Systems Command operational records for the LCAC (see scenario cost basis description in previous section).

Low end unit costs in Table 10 for the 100-ton hoverbarge alternative with mechanically loaded sediments reflect the most potentially competitive cost range when compared with hydraulic delivery by either pipeline or hoverbarge. These costs are based on industry estimates for fuel and maintenance costs, while the high end costs in Table 10 are based on actual operational cost data for the LCAC and the LACV-30. Critical elements in the outcome of this economic analysis are as follows: the accuracy of the industry cost estimates, the accuracy of rehandling cost estimates, and the characteristics of the sediment to be transported. If the main supply pipeline is considered to be permanent, however, unit costs for repeated use would drop significantly as capital costs were distributed over a longer time period and larger volumes of sediment distributed. In addition, pipeline delivery directly from a dredge, in connection with a dredging operation, could be significantly less expensive than a permanent pipeline supplied from a CDF with associated rehandling costs. This alternative was not examined because of logistical concerns regarding interdependence of the distribution system with the dredging operation.

8 Conclusions and Recommendations

Assessment of the economic and technical feasibility of dredged sediment transport and placement using hovercraft is limited by the fact that the use of hovercraft in this capacity is conceptual only. Actual design, performance, and cost data for this application were not available.

From a technical perspective, the hoverbarge concept appears to be viable, although subject to a number of physical limitations. The load capacity of hovercraft is limited, and the volume of sediments that can be transported is small relative to conventional means of transport. Hovercraft are sensitive to load distribution, and it is not known how successfully a slurry can be transported by this means. Hovercraft have been traditionally designed for high-speed applications, and operating parameters for low-speed operation and for towing may differ significantly.

Estimates of sediment requirements for "no net loss" wetlands maintenance and restoration in coastal Louisiana (Woodward Clyde Consultants 1991) closely match the total average volume of sediment dredged annually by the New Orleans District. For all of these sediments to be utilized for wetlands restoration, adequate means for transporting and storing or distributing the sediments as they are produced must be available. Hovercraft capacity is limited and is unable to keep up with and fully utilize the sediments produced by a normal dredging operation. Therefore, additional storage or alternate means of transporting and distributing the sediments would be required in conjunction with a hovercraft operation.

To perform a preliminary economic analysis, cost data from other hovercraft applications were used to define a potential cost range for this application. Cost comparisons to conventional transport methods were based on these assumptions. In most cases, the costs developed on this basis are thought to represent the least cost scenario, and actual costs could be higher. The validity of these assumptions cannot be demonstrated, however, without supporting cost and performance data.

Estimates indicate that because of high capital and operating costs, the use of hovercraft to transport and distribute slurried sediments will be significantly more expensive than other methods available. The economic analysis indicates that the most potentially economic hovercraft application is for transport of dryer, mechanically loaded sediments, which are less expensive to handle and transport than slurried sediments. However, low end hoverbarge cost ranges are based upon industry estimates for operating and maintenance costs, rather than performance data. Cost estimates based upon operational cost records from Fort Story, VA, for the LACV-30 and the Navy Sea Systems Command for the LCAC are much higher for both mechanically and hydraulically loaded sediments. If the main supply line of a pipeline distribution system is permanent, unit costs for sediment distribution will drop as the first costs are distributed over a longer time period and larger volumes of sediment, further widening the economic gap. Distribution of sediments directly from a dredge discharge pipeline is another potentially cost-effective alternative.

Even the most optimistic cost estimates for hoverbarge operation do not support the use of hoverbarges over water on an economic basis. (Logistically, this could be necessary in some instances.) In this application, conventional means of transport are available that are significantly less expensive. It seems likely that the most feasible application of the hoverbarge concept is transport and distribution of sediments to otherwise inaccessible interior sites. Marsh areas that can be effectively replenished by high pressure or hydraulic sediment distribution adjacent to existing canals can more economically be served by conventional equipment.

The Federal Standard requires that the Corps of Engineers select the dredged material disposal alternative that is "the least costly alternative, consistent with sound engineering and scientific practices and meeting applicable Federal environmental statutes" (U.S. Army Corps of Engineers 1988). This limitation has direct bearing on the selection of innovative dredged material disposal alternatives.

Because the economics of the hoverbarge concept are uncertain, emphasis of any further research should first be placed on studying the effects of high intensity hovercraft traffic over a single glide path. This should be compared with the impact of pipeline installation and movement in determining if an environmental justification for the hoverbarge concept exists. Mitigation costs of both alternatives must also be considered.

Within the United States, hovercraft manufacturing appears to be limited to a few companies. Development of this concept would therefore benefit a limited number of commercial entities. Because of the potential economic benefit to private sector industry, additional research in this area would most appropriately be funded under Construction Productivity Advancement Research, with technical input from the dredging and wetlands research components.

References

Herbich, J. B. (1992). *Handbook of dredging engineering.* McGraw Hill, Inc., New York.

Louisiana Coastal Wetlands Conservation and Restoration Task Force. (1993). "Louisiana Coastal Wetlands Restoration Plan."

Planning Systems Incorporated. (1984). "Environmental assessment (EA) for Landing Craft Air Cushion (LCAC) Program at NCSC, Panama City, Florida," PSI Job No. 1293, NCSC Contract No. N61331-84-M-0127, Naval Coastal Systems Center, Panama City, FL.

Reimold, R. J., Hardisky, M. A., Adams, P. C. (1978). "The effects of smothering a spartina alterniflora salt marsh with dredged material," Technical Report D-78-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sikora, W. B. (1988). "Air cushion vehicles for the transport of drilling rigs, supplies, and oil field exploration operations in the coastal marshes of Louisiana," Center for Wetland Resources, Louisiana State University, Baton Rouge, LA.

Souder, P. S., Tobias, L., Imperial, J. F., Mushal, F. C. (1978). "Dredged material transport systems for inland disposal and/or productive use concepts," Technical Report D-78-28, General Research Corporation, McLean, VA.

U.S. Army Corps of Engineers. (1983). "Engineering and design, dredging and dredged material disposal," Engineer Manual, EM 1110-2-5025, March 25, 1983.

__________. (1988). "Discharge of dredged material into waters of the U.S. or ocean waters: Operation and maintenance; Final rule," 33 CFR Parts 335 and 338, Federal Register, Tuesday, April 26, 1988.

Wilbur, P. (1992). "Thin-layer dredged material disposal in coastal marshes - Case studies." *Ports 92, Proceedings of the Conference, July 20-22, 1992, Seattle, WA.*

__________. "Managing dredged material via thin-layer disposal in coastal marshes," Technical Note in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Woodward-Clyde Consultants. (1991). "Feasibility of using pipelines and dredged sediments to restore wetlands in Terrebonne Parish," Baton Rouge, LA.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
June 1994

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Preliminary Feasibility Study: Transport and Distribution of Dredged Materials by Hovercraft for Wetland Nourishment and Restoration

5. FUNDING NUMBERS

6. AUTHOR(S)
Trudy J. Olin, Michael R. Palermo, Anthony C. Gibson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report WRP-RE-4

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Loss of coastal wetlands because of subsidence and anthropogenic activity has prompted interest in the use of dredged material to reclaim and maintain these areas. The adaptation of hovercraft for the transport and distribution of dredged material in coastal wetland areas has been proposed as an environmentally sensitive alternative to conventional transport methods. A preliminary analysis was conducted regarding the economic and technical feasibility of hoverbarge transport of dredged material. The results of this analysis indicate that hovercraft (hoverbarge) transport of dredged material may be technically feasible. Limited load capacity, however, and high operating and maintenance costs result in logistical problems and high unit transport costs in comparison with other transport methods. The production rate of a typical dredging operation exceeds the potential utilization rate of hovercraft. Interim storage and rehandling would therefore be required.

The environmental impact of repetitive hovercraft traffic in wetland areas has not been studied in depth. Environmental justification for this higher cost transport alternative would be contingent upon demonstrating fewer adverse impacts than for conventional transport methods after mitigation. Costs of mitigation would also be considered in a full-scale economic analysis. These elements were beyond the scope of this report.

14. SUBJECT TERMS

Coastal wetlands	Hovercraft technology
Dredged material transport	Reclamation and nourishment
Hoverbarge concept	Thin-layer disposal

15. NUMBER OF PAGES
55

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
UNCLASSIFIED	UNCLASSIFIED		

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102