VOLUME I OF V

U.S. DEEPWATER PORT STUDY

SUMMARY AND CONCLUSIONS

IWR

INSTITUTE FOR WATER RESOURCES

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

AUGUST 1972

IWR REPORT 72-8

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K B Cooper

K. B. COOPER
Brigadier General, USA
Director

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A report submitted to the

U.S. Army Engineer Institute for Water Resources
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Alexandria, Virginia

by

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Under Contract Number DACW 31-71-C-0045

Copies may be purchased from:

National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22151

August 1972

IWR Report 72-8

FOREWORD

Background and Purpose

Federal responsibility for the planning, construction, and maintenance of harbor and channel depths, and responsibility for reviewing and issuing permits for non-Federal developments in navigable waters of the United States, resides primarily with the Army Corps of Engineers. As a result, the Corps of Engineers is concerned with the recent and rapid increases in ship size and is seeking an assessment of the national requirements for and problems associated with accommodating supertankers and ore carriers in American ports and waters -- including economic, environmental, and physical aspects. In these matters, the Corps has the advice of many Federal agencies, including the Departments of Justice, Interior, Commerce and Transportation, as well as the Council on Environmental Quality and other elements of the Executive Office.

The Corps of Engineers is fundamentally concerned with the optimal pattern of harbor facility and channel investments for the handling of potential deep-draft shipping. Through research and related analysis it seeks to determine the most efficient (technically feasible and economically rewarding) configuration of deep-draft and related facilities to accommodate the future international and intranational waterborne commerce of the United States, and to protect important environmental and social interests of the nation.

As an important step toward achieving this objective, the Corps asked Robert R. Nathan Associates to carefully examine the need for deepwater ports and alternative solutions to deepwater port problems and requirements, and to estimate the benefits and cost of a range of alternative solutions in terms of engineering, environmental and economic characteristics. This required studies of (1) sources and markets of waterborne bulk commodities; (2) transportation and handling technologies and requirements (both "waterside" and "landside"); (3) physical, institutional, and environmental factors that may act as constraints or restrictions to port and harbor improvements; and (4) to a degree, analysis of the existing and resulting economic structure of the sectors and regions affected. The research contract stated the purpose as follows:

> The contract objective is to provide an overall appraisal of the U.S. deepwater port needs. It is not intended that the study concentrate on the specific needs of any port area but rather on the basic element of an overall plan and upon (1) identification (and whenever possible quantification) of the factors critical to the U.S. deepwater port decisions; (2) development of the criteria (engineering, economic, and environmental) appropriate to the evaluation of deepwater port needs policies; (3) analyses of the development options available at this time and the critical issues surrounding each; and (4) identification of the critical issues which need further analysis.

Findings

The findings are summarized in Volume I, Summary and Conclusions. The research shows that the savings in transportation costs which can be realized by the use of superships on long hauls is great and could fully justify in economic terms the cost of developing deepwater terminals. For the United States, these savings arise most importantly in the movement of crude oil from the Middle East, a trade which is growing rapidly to meet U.S. energy needs. Supersize vessels are also used for handling dry bulk, but the findings of the Nathan study are that the development of offshore deepwater ports for dry bulk is not economically justified even when such ports are combined with terminals handling petroleum. They are not justified because of the character of the dry bulk trades and the generally much shorter hauls from the port of origin or delivery.

The study does, however, suggest that there are needs in selected instances to deepen present harbors and channels for more effective dry bulk movements (for example, at the coal port in Norfolk, Virginia). The excess of benefits over measured cost for deepwater petroleum ports is great enough to support fully developed programs for protection of the environment and ecology of the sea and land components.

The Nathan investigation emphasizes the potential economies of adapting ship sizes to the channel conditions of the ports to be served by increasing capacity without increasing draft. Restricted-draft designs are, in numerous instances, the best solution to particular transportation problems both for oil and ore deliveries.

The report emphasizes the advantages and disadvantages of the several ways of accommodating deep-draft ships in U.S. trade. The benefit-cost ratios which are developed should not be interpreted as indicative of the advantage of one site over another but rather as showing the advantages and disadvantages of the various alternative approaches chosen for testing at selected sites.

It was hoped that the environmental protection aspects of deepwater port development could be treated as an integral part of the analysis and be reflected in the measured benefits and cost of alternative port and channel development plans. This objective was not accomplished, but each of the port development alternatives was reviewed from the environmental and ecological standpoint, and progress was made toward development of the data and analytic requirements for evaluation of environmental and ecological aspects of proposed deepwater port alternatives. Lack of knowledge concerning the environmental and ecological parameters prevented effective use of the procedural step toward the objective of quantification.

Status

This overview of U.S. deepwater port needs has suggested many topics which need further study. The more important are: (1) the legal, organizational, managerial and institutional aspects of deepwater port development; (2) an investigation of the systems relationship of very large tankers and proposed deepwater terminals to petroleum refineries, pipelines and product markets; (3) the effect which development of deepwater terminals will have on the ports which are not so developed; (4) further refinement of the economic costs and benefits of specific port alternatives; and (5) further refinement of the social, including ecological and environmental consequences, of alternative port developments.

This report is not to be construed as necessarily representing the views of the Federal Government or of the Corps of Engineers.

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ACKNOWLEDGMENTS

This report would not be complete without some acknowledgment of the contributions made by staff members of Robert R. Nathan Associates, and of the assistance of a large number of other individuals, agencies of the Federal and state governments, private firms, and universities and other institutions.

Acknowledgment is due particularly to the Army Corps of Engineers, its District Offices, and the Institute for Water Resources, for their cooperation and assistance throughout the conduct of the study. Other Federal agencies which were helpful include the Office of Management and Budget, Department of Interior, Environmental Protection Agency, Council of Environmental Quality, Maritime Administration, Office of Business Economics, Bureau of the Census, and Department of Agriculture.

Project personnel traveled extensively to principal port areas and cities on the Atlantic, gulf, and Pacific coasts. Visits were made to all Corps of Engineers District and Divisional Offices, and to most port authorities, located in the cities visited. In addition, there were visits and interviews with a wide range of private firms in the shipping, petroleum, steel, aluminum, coal, grain, and phosphate rock industries; with representatives of research institutions, universities, and state, county, and local governments; and with scientific, environmental, engineering, and transport consultants.

Acknowledgment is due to all individuals, firms, agencies, and institutions, too numerous to mention, who gave so generously of their time and knowlege whenever and wherever requested to do so.

The Director of the project was Ralph L. Trisko. Other project principals were as follows:

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Jacobus de Rover - Deepwater Port Engineering and Cost Estimates
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INTRODUCTION

The U.S. Deepwater Port Study, of which this Summary is Volume I, consists of five volumes. The other volumes, the contents of which are listed below, contain the several underlying detailed studies.

<u>Volume II. Commodity Studies and Projections</u>

Annex A - Commodity Studies and Projections

<u>Volume III. Physical Coast and Port Characteristics, and Selected Deepwater Port Alternatives</u>

Annex B - Reconnaissance Survey of U.S. Coastal Areas, Ports, and Port Facilities

Annex C - Design Criteria, Engineering Requirements, and Cost Estimates of Deepwater Port Alternatives Selected for Detailed Analysis

<u>Volume IV. The Environmental and Ecological Aspects of Deepwater Ports</u>

Annex D - The Environmental and Ecological Aspects of Deepwater Ports

<u>Volume V. Transport of Bulk Commodities and Benefit-Cost Relationships</u>

Annex E - Transport of Bulk Commodities

Annex F - Transport Benefit-Cost Relationships for Selected Investment Alternatives

Annex G - Ocean Transport of Major Bulk Commodities in U.S. Foreign Trade, 1968 and 1969: Patterns of Geographic Linkage and Flows Through U.S. and Foreign Ports.

I. SUMMARY OF MAJOR CONCLUSIONS AND ISSUES

The United States faces the need to make important decisions with respect to the future development of its ports. Since the end of World War II there has been a significant growth in our foreign trade generally, and in the import and export of bulk commodities and other raw materials. We have become the world's principal export supplier of metallurgical coal and food grains, and our economy has become increasingly dependent upon imported raw materials, including iron ore, bauxite, and particularly crude petroleum. These trends are expected to continue and, in the case of crude petroleum, to be greatly intensified.

The maritime shipping industry has responded to the growth in world trade and in the movement of bulk commodities with the development of supertankers and dry cargo carriers with capacities in excess of 250,000 tons, and tankers are now under construction in Japan with capacities of approximately 1/2 million tons. The rapid growth in vessel size, capacity, and depth of draft requires consideration of related changes in port facilities and channel depths.

Few U.S. ports have naturally deep water and the capability of accommodating the larger vessels presently in the bulk carrier trades. Most of our principal ports have been deepened to 36 to 45+ feet by dredging. The accommodation of vessels requiring 70 feet or more of water requires a careful examination of new approaches to the loading and unloading of ocean vessels.

U.S. ports are a vital element in our foreign trade. Failure to adjust to the changing needs of foreign trade will impose a real cost upon our economy. The costs of imports and the delivered costs of exports will be higher, impairing our competitive position in world markets. Patterns of industrial location would be less responsive to changing needs. These costs must be weighed against the costs of further deepening of our ports and/or of building offshore facilities for bulk commodities.

The study provides a national overview of the deepwater port needs of the United States, of alternative means of satisfying those needs, and of the economic and environmental characteristics of selected alternatives. It is not the purpose of the study to select or recommend development of specific port areas or specific types of port development in those areas. Rather, the study is intended to throw light on the economic and social consequences of a range of possible port improvements and to present alternatives for the benefit of policy-makers, accompanied by preliminary judgment on the merits of the possible courses of action.

The principal conclusions and critical issues are summarized as follows.

1. FUTURE U.S. WATERBORNE IMPORTS OF HUGE VOLUMES OF CRUDE PETROLEUM APPEAR INEVITABLE.

The United States faces what appears to be an almost inevitable need to import nearly 300 million tons of crude petroleum annually from overseas sources by 1980, and perhaps 1 billion tons annually by 2000, delivered mostly to east and gulf coast ports from the Middle East and Africa. Avoidance of such import requirements would require greater development of indigenous energy resources, significant reduction of domestic demand for petroleum products, or both. However, these potential constraints on imports cannot reasonably be expected to assume major importance in the forseeable future.

These large volumes of imports compare with actual imports of about 50 million tons in 1969, mostly from Caribbean sources. They pose the central issues for future U.S. deepwater port development. The magnitude of the physical volumes, the practically certain demand for maximum-size supercarriers with associated economic costs and benefits, and the potential environmental and ecological impact make these issues of overwhelming importance and complexity relative to those raised by prospective imports and exports of dry bulk commodities.

2. MOST U.S. CRUDE PETROLEUM IMPORT NEEDS WILL PROBABLY MOVE TO THE WESTERN HEMISPHERE IN SUPERCARRIERS WHETHER OR NOT THE UNITED STATES PROVIDES DEEPWATER PORT FACILITIES.

Potential economic savings from the use of supercarriers are of a scale that will effectively compel the use of such tankers for the ocean transport of crude petroleum imports, particularly from Far East, Middle East, and African sources. If deepwater port facilities are not available in the United States, some form of transshipment, with delivery of crude petroleum or petroleum products to U.S. ports in smaller vessels, will be used. This includes the lightering of deep-draft oceangoing vessels by transfer to barges at locations where naturally deep water is available; the transshipment of crude petroleum from deepwater ports in the Maritime Provinces of Canada and in Caribbean islands; and the refining of petroleum products for shipment to the United States at Canadian and Caribbean locations. These alternative solutions will involve higher economic, and possibly environmental, costs.

3. CHANNEL AND HARBOR DEPTHS ARE SUBSTANTIALLY BELOW THE DEPTHS REQUIRED FOR SUPERCARRIERS IN MOST AREAS WHERE PETROLEUM IMPORT NEEDS ARE CONCENTRATED.

The bulk of U.S. petroleum refining capacity is located along the heavily populated and industrialized Atlantic and gulf coastal areas. Ports, harbors, and entrance channels serving existing refineries do not have sufficient depths to accommodate supertankers. These depths must be somewhat greater than actual vessel draft by an amount that varies with specific physical conditions. Maximum permissible vessel drafts are typically in the 36-foot range, whereas supertankers require drafts of 60 feet or more. Comparable draft constraints apply in the San Francisco Bay area, to a much lesser extent in the Los Angeles-Long Beach area, and not at all in the Puget Sound area of the Pacific Northwest.

4. CHANNEL DREDGING TO REQUIRED DEPTHS AT EXISTING PETROLEUM TERMINALS WOULD POSE MAJOR ECONOMIC AND ENVIRONMENTAL ISSUES.

Most east coast petroleum refineries are located on the New Jersey side of the Arthur Kill across from Staten Island, where controlling channel depths are 35 feet, and along the Delaware Bay and River in New Jersey, Pennsylvania, and Delaware, where the controlling depths are 40 feet. Most gulf coast refining capacity is located along the Lower Mississippi and in the Texas port areas of Beaumont-Port Arthur and Galveston-Houston, where controlling depths are 40 feet or less.

Limited existing studies of dredging in New York Harbor and Delaware Bay and River indicate that the economic and environmental costs of required dredging and spoil disposal are higher than other possible solutions to deepwater port needs.

Similar conclusions are indicated at relevant gulf coast and Mississippi River ports, and in the San Francisco Bay area.

5. THE MOST PRACTICABLE PETROLEUM DEEPWATER PORT ALTERNATIVES ARE GENERALLY OFFSHORE FACILITIES LOCATED AS ADVANTAGEOUSLY AS POSSIBLE TO EXISTING OR POSSIBLE NEW REFINERY AREAS.

Offshore facilities for discharging crude petroleum would permit direct delivery to the United States in oceangoing supercarriers, obviating all or most of the economic and environmental costs of dredging channels with direct access to existing refinery locations. They also offer a greater degree of flexibility in the location of ports and new refinery capacity, as well as a range of design and engineering concepts with varying economic and environmental characteristics.

6. OFFSHORE SITES WHICH COMBINE ADVANTAGEOUS LOCATION WITH NATURALLY DEEP WATER ARE A SCARCE RESOURCE, AND SHOULD BE TREATED AS SUCH.

Offshore sites in relatively protected waters, such as those in Lower New York and Delaware Bays, which combine deepwater port potential with relatively small requirements for dredging and maintenance, and with comparatively short distances to existing refinery locations, are limited in number. Because of their importance to the regional and national economy, they should be treated as a scarce national resource. The right to develop these valuable resources for offshore port purposes should be treated in a manner similar to the allocation of other limited and important resources.

To a lesser degree, similar considerations would apply to favorably located deepwater sites in exposed locations off the Atlantic, Gulf of Mexico, and Pacific coasts.

7. UNCERTAINTIES REGARDING THE LOCATION OF REQUIRED ADDITIONS TO REFINERY CAPACITY POSE A MAJOR PROBLEM IN DETERMINING LOCATIONS AND CAPACITY REQUIREMENTS FOR DEEPWATER PORTS.

This uncertainty applies principally to ports on the east and gulf coasts. East Coast States depend upon other regions of the United States and upon foreign sources for three-quarters of their refined petroleum products. Refineries on the gulf coast supply nearly one-half of total east coast requirements. As the United States shifts from indigenous to foreign sources of supply for much or all of the incremental growth of its crude petroleum requirements, the petroleum industry could be expected to be influenced in locating required additions to refinery capacity by transport considerations applicable to imported sources of crude petroleum, including potential deepwater port locations and their proximity to principal marketing areas.

However, actions taken by governments at the state and local levels to prevent the construction of new refineries and/or deepwater port facilities for crude petroleum have introduced a great element of uncertainty regarding the location of additional refinery capacity required to meet east coast needs. These actions raise questions not only as to the particular location of additional refinery capacity on the east coast, but also as to whether such capacity will be located in this region at all. This uncertainty is further compounded by the corporate diversity of the petroleum industry itself, with its tendency toward individual corporate competitive decision-making, and possibly by the constraints of antitrust laws on joint decision-making on matters of this nature.

In the absence of a resolution to these uncertainties, capacity requirements for deepwater ports analyzed in this study are based on the arbitrary but reasonable assumption that refineries will expand at existing locations, and that some part of the east coast requirements for petroleum products will be supplied from foreign sources and from refineries on the gulf coast. It is unlikely that departures from this assumption would significantly affect the conclusions.

8. MOST CRUDE PETROLEUM DEEPWATER PORT ALTERNATIVES STUDIED SHOW HIGHLY FAVORABLE ECONOMIC BENEFIT-COST RATIOS.

Hypothesized regional deepwater ports supplying crude requirements in the New Jersey-Philadelphia-Delaware area show benefit-cost ratios ranging from about 5:1 to 8:1, assuming throughput volumes of 100 million tons in 1980 and 150 million tons in 2000, and a 10-percent discount rate over the period 1980-2009. With volumes of 150 million and 300 million tons in 1980 and 2000, the range of benefit-cost ratios is about 8:1 to 10:1. Of all the east coast alternatives examined, the least favorable ratio of 2.5:1 was for an offshore port in Lower New York Bay designed to handle estimated throughput requirements for refineries along the Arthur Kill of 30 million tons in 1980 and 35 million tons in 2000.

Regional ports on the Gulf of Mexico with assumed annual throughputs of 100 million tons in 1980 and 450 million tons in 2000 show benefit-cost ratios ranging from about 4:1 to 11:1. At assumed higher volumes of

150 million tons and 600 million tons in 1980 and 2000, respectively, the ratios range from about 5:1 to 14:1.

Two base cases were used for computation of benefit-cost ratios: ocean transport in vessels with drafts constrained by existing channel dimensions and ocean transport in larger vessels with offloading into barges in deeper waters (lightering).

All of the above ratios result when deepwater ports are compared with the base case of ocean transport in vessels with drafts constrained by existing channel dimensions. If the practice of lightering is assumed on the east coast, permitting the use of larger ocean vessels, benefit-cost ratios are less but are still highly favorable. Lightering was not considered at gulf coast ports because of the lack of requisite data and experience.

Benefit-cost ratios of deepwater port alternatives examined on the west coast are generally below those on the east and gulf coasts, but are also generally favorable when compared with the base case of no lightering. When compared with lightering, several alternatives studied would not be economic.

9. HYPOTHESIZED DEEPWATER TRANSSHIPMENT PORTS FOR HANDLING DRY BULK IMPORTS AND EXPORTS ON THE EAST AND GULF COASTS SEEM ECONOMICALLY UNFEASIBLE.

Benefit-cost ratios are less favorable than those applicable to crude petroleum ports because (a) total commodity flows are substantially lower, (b) unit ocean transport savings are less, and (c) transshipment costs to and from deepwater ports are higher than for petroleum.

10. RESTRICTED-DRAFT VESSEL DESIGN OFFERS A LIMITED BUT SIGNIFICANT OPPORTUNITY FOR INCREASING VESSEL CAPACITY WITHIN GIVEN DRAFT LIMITATIONS, WITH A FAVORABLE TRADE-OFF BETWEEN ECONOMIES OF SCALE AND DISECONOMIES OF RESTRICTED-DRAFT DESIGN.

At any given draft constraint, it is often technically and economically feasible, within limits, to increase the capacity of a vessel by increasing only the length and beam. Investment and operating costs are often modestly higher per unit of capacity than when unrestricted-draft design is used.

Restricted-draft design would appear to be particularly relevant to situations where the economic and environmental costs of incremental deepening of channels and harbors are high.

11. INCREMENTAL SCALE ECONOMIES IN OCEAN TRANSPORT DIMINISH SHARPLY FOR VESSEL CAPACITIES ABOVE 200,000 DEADWEIGHT TONS.

Our studies indicate a decline in unit costs per long ton for a 5,000 mile one-way voyage from approximately $4.00 for a 30,000-d.w.t. vessel to approximately $1.70 for a 200,000-d.w.t. vessel and $1.50 for a 500,000-d.w.t. vessel. Thus, 90 percent of the cost reduction is achieved at the 200,000-d.w.t. size.

12. THE DISTRIBUTION OF OCEAN TRANSPORT SAVINGS AS BETWEEN U.S. AND FOREIGN INTERESTS IS UNCERTAIN AND UNPREDICTABLE.

The use of supercarriers for the delivery of projected crude petroleum imports could result in annual ocean transport cost savings approximating $600 million in 1980 and $2.1 billion in 2000 (in 1970 dollars) over the costs that would apply with the use of maximum-size vessels that could be accommodated at existing ports without further deepening. The annual average over the 30-year period 1980-2009 would approximate $1.7 billion. If the lightering alternative is considered, these savings would be less.

The extent to which these savings would accrue to the U.S. economy and how they would be distributed within the economy cannot be predicted with confidence. If, in the long run, the f.o.b. prices of crude petroleum from foreign sources reached higher levels than they would in the absence of ocean transport savings, a diversion of such savings from the United States would take place. Such a possibility exists because of the increasing influence of the Organization of Petroleum Exporting Countries on crude petroleum export prices.

The United States can insure the recovery of capital and operating costs for deepwater ports, and some limited part of total transport savings, through the pricing of port services to users.

To the extent that transport savings are reflected in the delivered cost of crude petroleum to refineries, consumer prices for petroleum products would be expected to benefit in a competitive environment in the petroleum refining and ocean transport industries.

The same considerations would apply in principle to other bulk commodity imports, but both unit and aggregate cost savings would be relatively much smaller.

Ocean transport savings on bulk commodity exports could accrue to the U.S. economy in the form of higher export prices, but are more likely to result in lower delivered costs abroad for these commodities.

13. SECONDARY ECONOMIC EFFECTS WOULD BE LIMITED AND UNCERTAIN.

By affecting the location of refinery capacity, deepwater ports will affect employment and output in petroleum refining and in secondary economic activity. One cannot predict that deepwater ports in themselves would otherwise contribute measurably to national or regional output and employment in industries which produce or consume bulk commodities. There may be marginal effects in the form of higher exports of coal, grains, and phosphate rock, but it is impossible to develop quantitative measures. There may be other effects, particularly those induced by possible reductions in petroleum product prices.

Ocean transport savings on crude petroleum imports are of sufficient magnitude to have significant potential balance of payments effects. They are potentially available through the reduction of dollar payments to foreign-flag carriers. On imports transported in U.S.-flag vessels, there would be no net effect on the balance of payments from transport savings as such. However, there would be a direct gain from the substitution of U.S.-flag carriers for foreign-flag carriers.

Whether the reduction in payments to foreign-flag carriers resulting from ocean transport savings would be wholly reflected as a net gain to the balance of payments would depend on practices and decisions within the petroleum industry, about which information is not available. Relevant questions are, for example, the extent to which payments to foreign-flag carriers for transport services are made exclusively in dollar currencies, and whether any reduction in the payment of dollar currencies to foreign-flag carriers would ultimately be offset by other foreign exchange transactions by the petroleum companies and their foreign production, refining, marketing, and transport subsidiaries.

14. THE MAJOR ENVIRONMENTAL PROBLEM POSED BY THE DELIVERY OF WATERBORNE PETROLEUM IMPORTS IS THE POTENTIAL FOR PETROLEUM SPILLS.

No aspect of the import and export of bulk commodities ranks with the danger of petroleum spills as a potential source of environmental and ecological damage. The danger of the uncontrolled release of petroleum into the environment arises primarily from the possibility of accidental collisions and groundings of vessels, resulting in rupture of tanks; from the transfer of petroleum from oceangoing vessels either to other vessels or into pipelines and into storage tanks; and from the possibility of leakage from the tanks themselves. The degree of hazard is partly a function of the volume of petroleum to be imported and partly a function of the delivery system to be employed, including the size, design, operation, and control of vessel movements, and the design and control of all other equipment and operations related to the transfer and storage of petroleum. There is no scientific evidence that supercarriers present, or need to present, a greater risk than do smaller ships. The size of a potential spill can be controlled irrespective of ship size, and the probability of spills tends to increase with the greater congestion of waterways associated with the use of smaller vessels.

15. THERE IS A CRITICAL LACK OF KNOWLEDGE IN A NUMBER OF AREAS ESSENTIAL TO THE ENVIRONMENTAL ANALYSIS OF DEEPWATER PORTS.

There is a lack of adequate knowledge of ways to design and operate a system without spillage; of the technological capability to handle major spills; of the methodology for determining the probability of oil spills; and of the impact of oil spills on the ecosystem. Similarly, there is a lack of adequate knowledge on the changes which will occur from alteration of the physical configuration of a water body through dredging, dumping of spoil, and island construction; on the impact of such changes on biological organisms; and on the physical and biological characteristics and behavior of most geographical areas where petroleum import operations might take place. Studies are now underway by the Council for Environmental Quality, the Corps of Engineers, and others, which will provide some of the required data.

Overriding all of these lacks is the lack of proper and effective environmental safeguards.

16. DREDGING, WETLAND DESTRUCTION, AND ECONOMIC DEVELOPMENT ARE OTHER MATTERS WHICH POSE IMPORTANT ENVIRONMENTAL PROBLEMS.

Dredging and spoil disposal for deepwater ports, if resorted to on a massive and extensive scale, could create environmental problems almost equal to those of petroleum spills. If this action were taken, exhaustive studies should be made beforehand so that the environmental and ecological impacts could be reliably appraised. However, for the most part, offshore facilities requiring limited or no dredging offer an economic, and environmentally less destructive, alternative for crude petroleum imports, if not for dry bulk imports and exports.

Wetland destruction and other forms of environmental change on the land arise essentially from the establishment of shore facilities for the shipment, reception, and storage of bulk commodity imports and exports. In addition, secondary development, such as the establishment of petroleum refineries or other heavy industries importing or exporting bulk commodities, poses problems of environmental damage and change.

Other than the environmental issues encountered in related economic development, dry bulk commodity imports and exports offer no apparent threat of serious environmental consequences that are not controllable by known technology.

17. THERE IS A CRITICAL LACK OF COORDINATION IN THE PLANNING, DESIGN, AND CONTROL OF PORT DEVELOPMENT WHICH PARALYZES THE DECISION-MAKING PROCESS AND FRUSTRATES ACHIEVEMENT OF ECONOMIC AND ENVIRONMENTAL GOALS.

The combination of (a) the sheer volume of anticipated imports of crude petroleum; (b) the magnitude of the economic and environmental costs and benefits associated with these imports; (c) the extent and diversity of the political, economic, and social groups potentially affected by such imports; and (d) the multiplicity of jurisdictional authorities that are involved, raises the whole issue of port planning, development, and operation to levels of complexity beyond the capabilities and responsibilities of any existing institution or institutional arrangements.

There is clearly a need for a mechanism which formulates and articulates policy goals; which integrates the interests of all responsible agencies at the Federal, state, and local levels; and which provides for inputs by regional political and economic interests. These should include specific industrial interests such as the petroleum industry, the ocean transport industries, and other private groups, including those representing environmental and ecological concerns.

There is a need for effective coordination of port-related decisions, including design, equipment, and operational standards for vessels utilizing U.S. ports, and for navigational controls of vessel movements in U.S. waters. At the international level, institutions are required within which the United States can move more promptly and effectively to assure the establishment and enforcement of essential standards. The nature of this problem is increasingly recognized by the Federal, state and local governments.

18. THE UNITED STATES HAS AN HISTORIC OPPORTUNITY TO ACHIEVE A BULK COMMODITY PORT DELIVERY SYSTEM WHICH OPTIMIZES ECONOMIC BENEFITS AND BENEFIT DISTRIBUTION AND WHICH PROVIDES ACCEPTABLE LEVELS OF PROTECTION OF ENVIRONMENTAL AND ECOLOGICAL VALUES.

The critical time to act on deepwater port decisions is now, before the oceangoing tankers to be employed in the import of crude petroleum have been designed and constructed, and before either private or public investments have been made in deepwater port facilities or alternative delivery systems. Once substantial investments have been made and changed delivery systems have been established and institutionalized, the opportunities for rationalized change with optimum benefits will diminish substantially. The public interest requires that policy goals and related programs and controls be established and effectuated before sizable investments and varied practices, which might be incompatible with such goals, programs, and controls, become embedded.

A fundamental consideration should be to utilize ocean transport savings to defray economic costs associated with acceptable levels of environmental protection. There is a strong probability that substantially increased costs to improve the environment will take place in this country even without changes in transportation systems. Efficient ocean transport can yield economic benefits that will serve to make higher total environmental costs less burdensome.

19. EARLY DECISION AND ACTION ON PETROLEUM PORTS ARE URGENTLY NEEDED TO INSURE ADEQUATE SUPPLIES OF CRUDE PETROLEUM AND PETROLEUM PRODUCTS.

Import requirements are growing rapidly. Considerable lead time is required for design and construction of all transport-related facilities, including ports, pipelines and bulk carriers. Construction of required bulk carriers may itself strain U.S. and foreign construction capacity. The need to take environmental considerations into account in the design of facilities will increase the required lead time. If prompt action on basic policies does not take place, the pressures of demand for more imports will result in decisions and actions by default which can prove most costly.

20. THE CENTRAL ISSUE FACING THE UNITED STATES IS THE NEED TO ADOPT AS A GOAL, AND TO ACHIEVE, A PETROLEUM DELIVERY SYSTEM WITH MINIMUM ACCEPTABLE RISKS OF OIL SPILLS AND WITH ADEQUATE SAFEGUARDS IN OTHER AREAS OF ENVIRONMENTAL CONCERN.

If oil spills are to be essentially eliminated and held to some minimum acceptable standard, it will be essential to establish and enforce standards for the design, equipment, and operation of all phases of the petroleum delivery system, including the vessels to be employed for reception (and transshipment, if any); oil transfer equipment, including pipelines; and oil storage facilities and equipment. A great deal is already known about design, equipment, and operational requirements for minimizing and controlling the danger of oil spills, and for the control of oil spills once they occur. Additional research and development work are undoubtedly needed. It is critical that the Government take appropriate early action to insure that effective techniques are developed and applied.

21. THE UNITED STATES MUST ADOPT AS A FIRM GOAL THE ACHIEVEMENT OF AN INSTITUTIONAL MECHANISM THAT CAN DIRECT AND COORDINATE AN EFFECTIVE PROGRAM OF PLANNING, DESIGN, AND CONTROL OF DEVELOPMENT AND OPERATION OF DEEPWATER PORTS AND RELATED ACTIVITIES IN THE PUBLIC INTEREST.

Existing Federal statutes need to be clarified and coordinated, and, if necessary, new statutes must be enacted which establish basic policy goals and guidelines, with requisite funds and authority for the conduct of necessary research, planning, and enforcement activities. They must also insure that the responsible Federal institution provides opportunities for effective collaboration with and participation by other agencies and groups. These include: (a) all other Federal agencies having a functional relationship to the problem, including the Coast Guard, the Maritime Administration, the Environmental Protection Agency, and the Corps of Engineers; (b) state and local governments, whose cooperation with efforts at the Federal level to achieve established policy goals is essential; (c) private industry groups, particularly the petroleum industry, without whose joint collaboration and participation it would be impossible to achieve the policy goals; and (d) other national, regional, and local groups having a genuine interest in and relevance to the economic and environmental issues encompassed within the policy goals and related programs.

22. THERE SHOULD BE AN ORDER OF PRIORITY FOR THE CONDUCT OF ADDITIONAL RESEARCH REQUIRED TO INSURE A PORT SYSTEM THAT WILL OPERATE IN THE PUBLIC INTEREST.

Areas in which additional research is most urgently needed are the following: (a) institutional and legal aspects of deepwater ports, including such matters as ownership and control, regulation, conditions of access or use, and user charges; (b) design, engineering and operational requirements and costs for all transport-related facilities to insure that the risk of oil spills will be held to acceptable levels, and that environmental damage from spills will be controlled within acceptable limits; (c) economic, engineering and operational characteristics and parameters applicable to the use of restricted-draft vessel design; (d) total petroleum distribution costs under alternative port systems; (e) elements determining the distribution of economic benefits and institutional means of influencing such distribution; (f) elements determining the balance of payments effects of transport savings, and (g) the shoreside impact of alternative port developments, and the possibility of minimizing shoreside environmental impacts through alternative locations of storage and processing facilities.

II. GENERAL APPROACH AND METHODOLOGY

The study was designed to provide a national overview of the deepwater port needs of the United States, of alternative means of satisfying those needs, and of the economic and environmental characteristics of selected alternatives. The major components of the study are:

1. Projection of imports and exports of selected bulk commodities, aggregate and by U.S. and foreign coastal zones, for 1980 and 2000 (Volume II, Annex A)

2. Survey of physical characteristics of U.S. coastal areas and ports, channels and harbors (Volume III, Annex B)

3. Selection of a limited number of representative deepwater port alternatives for detailed analysis on the Atlantic, gulf, and Pacific coasts (Volume III, Annex C)

4. Design and cost estimates for selected ports (Volume III, Annex C)

5. Review of world developments in bulk shipping, including vessel characteristics and shipping practices (Volume V, Annex E, Chapter I)

6. Analysis of economic and institutional factors influencing size characteristics of bulk carriers to be employed in bulk commodity imports and exports (Volume V, Annex E, Chapter II)

7. Estimates of unit ocean transport costs for vessels of varying capacities and dimensions (Volume V, Annex E, Chapter III)

8. Conceptual design of vessels and corresponding cost estimates for transshipment movements between new deepwater ports and the existing facilities, and for off-loading crude petroleum (Volume V, Annex E, Chapter IV)

9. Development of framework and criteria for environmental analysis; survey of available data on environmental characteristics of bulk commodities; evaluation of environmental and ecological aspects of deepwater port alternatives (Volume IV, Annex D)

10. Benefit-cost analysis of deepwater port alternatives (Volume V, Annex F), including:

a. Determination of commodity throughputs at selected deepwater ports

b. Determination of ship sizes and applicable costs to be used at deepwater ports, at existing ports, and for lightered petroleum

c. Determination of annual transport costs for each vessel size, commodity, and port

d. Present worth computation of transport benefits and port costs

e. Computation of benefit-cost ratios of deepwater ports.

Commodity Studies and Projections

The bulk commodities studied included U.S. imports of crude petroleum and petroleum products, iron ore, and alumina and bauxite; and exports of coal, food and feed grains, and phosphate rock. They provided essential inputs into the determination of ship sizes to be employed, the port requirements, and the commodity throughputs at these ports.

Variables affecting the demand for import commodities in the United States and for export commodities in foreign countries to the year 2000 were examined in detail, including economic and population growth trends; competitive relationships with other sources of supply; alternate or substitute materials; technological changes; locational characteristics of consuming and producing industries in the United States and abroad; institutional characteristics of the international trade in relevant commodities; and national policies affecting bulk commodity imports and exports.

Selection of Deepwater Port Alternatives for Detailed Analysis

The selection of specific hypothesized deepwater port alternatives was the result of a screening process which took into account such factors as the projected commodity flows; appropriate vessel size characteristics; locations of bulk commodity production and consumption; water depth characteristics of coastal, bay, and harbor areas; obstacles to deepening; existing concepts and designs for berths, transshipment, and storage; and current and past deepwater port proposals. The number of alternatives selected was limited arbitrarily by the time and resources available, but was sufficient to provide a representative group of potential alternatives on all three U.S. coasts, illustrating a range of engineering, geographic, economic, and environmental characteristics.

Design and Costing of Deepwater Port Alternatives

To meet the needs of order-of-magnitude cost estimates, general design criteria were developed for physical requirements of channels and maneuvering areas, berths, pipelines or trestles, and intermediate storage. For each alternative, the engineering requirements were determined taking into account specific site characteristics, service area, annual commodity throughputs, type of berth, and sizes of vessels to be accommodated.

Order-of-magnitude cost estimates were made for all major components of investment and for operation and maintenance, expressed in 1970 dollars and assuming that operations would begin in 1980, with initial construction phased as required in the period 1975-79.

Transport Costs

Vessel design concepts and corresponding unit cost estimates were developed for ocean shipping, for vessel transshipments to or from hypothesized new deepwater ports, and for offloading of crude oil. Ocean shipping costs were estimated in 1970 dollars for vessels of varying size and design characteristics, ranging from 30,000 to 500,000 d.w.t. The estimates included appraisal of potential economies of restricted-draft design over conventional-design ships at various draft constraints.

Environment and Ecology

A detailed framework for analysis of environmental and ecological aspects of the construction and operation of waterborne delivery systems for bulk commodities was developed, and a set of criteria for evaluating the environmental impact of selected systems alternatives was formulated, within the context of coastal zone management considerations. Data needs for conducting specific analyses and evaluations of port systems alternatives were formulated in terms of the existing situation in a particular area and the nature of a particular port development alternative.

The specific deepwater port alternatives were analyzed in terms of the analytic framework and criteria, employing background information on the environmental and ecological characteristics of specific bulk commodities, and on the area in which the port alternative would be located.

Benefit-Cost Analysis

Measured benefits were defined as the difference between total ocean shipping costs under a hypothesized deepwater port investment alternative, and under the "existing" or base situation, net of any required vessel transshipments in either case. Measured costs were defined as the total investment, operating, and maintenance costs required to install and operate the hypothesized facility, including any pipelines used for transshipment. Two alternative concepts were used in the base situation to derive transport cost savings: movement of a vessel to its final destination at the terminal of an oil refinery, and movement of a larger vessel to relatively deep water near the final destination, with transshipment of cargo to smaller vessels which complete the journey.

All facilities were assumed to operate from 1980 through 2009. The stream of benefits and costs was estimated annually and discounted to present (1980) values at rates of 5, 7, and 10 percent.

Alternative Courses of Action

Courses of action available to the United States, other than the provision of specified deepwater port alternatives, were identified, and their major economic and environmental characteristics were described in general terms.

Secondary Economic Effects

Possible secondary economic effects beyond the measured benefits were identified and analyzed in broad terms, principally employing data developed in connection with the commodity studies.

III. BULK COMMODITY PROJECTIONS

Bulk commodity studies and projections were limited to those which appeared to have potential requirements for deepwater ports. Projections for 1980 and 2000, compared with 1969 actual, are shown in table 1. The overwhelming importance of petroleum in terms both of rates of growth and of absolute volume relative to other commodities is apparent. By 1980, the volume would approximate 1/2 billion tons, and by 2000, 1.1 billion tons.

Crude Petroleum

The rapid growth in crude petroleum imports reflects the widely accepted view of the industry and of the U.S. Government that crude petroleum production in the lower 48 states will begin to level off and decline during the next 10 years, while demand for petroleum products will grow at rates above historical growth rates, chiefly because of substitution for short-supply natural gas and low-sulfur coal. Projections assume no change in Government policies affecting exploration for and development of petroleum and natural gas resources in the United States. However, even if policy changes were made that were designed to stimulate greater exploration and development, it seems unlikely that quantitatively significant results could be achieved before 1980.

The rate of growth of petroleum consumption after 1980 is assumed to decline to an average of 2.1 percent annually from long-term past growth rates of approximately 4 percent. There is a further assumption that

Table 1. U. S. Seaborne Imports and Exports of Selected Bulk Commodities, 1969, and Projected 1980 and 2000

(Millions of short tons)

Item	1969	1980	2000
Imports			
Crude petroleum...........	51.3	280.5	965.8
Residual fuel oil.........	a/	168.5	129.2
Other petroleum products..	83.4	56.2	--
Iron ore..................	29.0	34.1	48.3
Alumina...................	1.8	5.7	15.2
Bauxite...................	16.3	15.9	15.9
Exports			
Food grains...............	14.5	23.0	25.0
Feed grains...............	16.4	32.0	54.0
Soybeans and meal.........	11.7	24.0	38.7
Bituminous coal...........	40.3	54.7	53.7
Phosphate rock............	10.0	17.9	26.5

a/ Included in other petroleum products.

the downward trend in the volume of crude petroleum production would be reversed, and that commercial supplies of petroleum products would be available from petroleum shale and synthesis of coal. Should these assumptions prove to be invalid, import requirements would be more or less than projected.

The bulk of waterborne imports of crude petroleum is assumed to originate in African and Middle East countries, again reflecting the available evidence and the widely accepted judgment that these are the only sources having sufficient known reserves and production capacity to supply the bulk of U.S. import requirements.

The bulk of the U.S. requirement for crude petroleum imports in both 1980 and 2000 is in the Middle Atlantic and Gulf Coast States. Some of the gulf coast imports are assumed to be refined and transshipped as products to Atlantic Coast States. Arbitrary assumptions were made of the amount of refinery capacity that would be available in the Atlantic Coast States in 1980 and 2000.

Uncertainty as to the location of future increments to refining capacity required to supply the petroleum product needs of the Atlantic Coast States results from several factors. These include rejection of industry proposals for refineries and associated deepwater port facilities by several Atlantic Coast States; uncertainties as to future Federal Government policies with respect to petroleum imports and to deepwater ports; and the absence of an appropriate institutional framework for the resolution of these questions.

In the meantime, the industry is resorting to what are essentially short-term palliatives, including the lightering of petroleum into barges in designated protected areas on the east and west coasts; the transshipment of crude petroleum from deepwater ports in the Maritime Provinces of Canada; and the installation of refinery capacity in those provinces and in the Bahamas, the products of which would be shipped in whole or in part to the United States. The fact that expedient measures of this nature must be taken to maintain an adequate supply of petroleum underlines the urgent need for decisions on all relevant issues.

The paralysis of decision-making, and the nature of the problems posed by the volumes of crude petroleum and/or petroleum products to be imported, raise serious questions as to the adequacy of existing institutions for the planning, development, regulation, and operation of required port systems.

The questions of location, ownership, and operation of deepwater port facilities for the handling of crude petroleum imports cannot be answered, and the decisions required to finance and to provide such facilities cannot be made, without the creation of an appropriate institutional framework. As a minimum requirement, this framework would need (1) a national view of the problem, (2) participation by all of the interested Federal, state, and local public bodies and private interests, including, most importantly, the petroleum industry itself, and (3) the ability to produce a coordinated body of fact and recommendation for the execution of a deepwater port program in the national interest.

In addition, the following basic substantive questions remain which are dealt with in this study by assumption:

1. Does the United States have the basic resource and productive capabilities to avoid a substantial dependence on overseas sources of supply for crude petroleum?

2. To what extent could such capabilities be more fully realized through appropriate Federal Government policies related to crude petroleum prices, exploration, and import controls?

3. Will U.S. growth in demand for petroleum products after 1980 decline by as much as, or more than, that assumed in this study?

Dry Bulk Commodities

For a variety of reasons, dry bulk commodity requirements for U.S. deepwater ports are of a significantly lesser order of magnitude than for crude petroleum. These reasons include the relatively small volumes of dry bulk commodities wanted in a specific shipment; physical constraints in foreign ports; in some cases, the heterogeneous nature of the commodities themselves (such as grains and coal); and relatively short distances on many major routes.

Overseas iron ore is mainly imported at the ports of Baltimore and Philadelphia on the east coast, and at Mobile, Houston, and Baton Rouge on the gulf coast, primarily for consumption by steel mills in the immediate port areas. Key assumptions underlying projections of seaborne imports are a compound average growth of 2.25 percent from 1970 to 2000 in U.S. consumption of finished steel; continuation of combined raw material and finished product delivery costs as a basic determinant of the location of steel plants; and a favorable competitive position at most inland U.S. steel plants for U.S. and Canadian iron ore vis-a-vis seaborne imported ore.

The locational characteristics of the U.S. steel industry on the whole would not be significantly affected by the availability of iron ore from overseas sources, or by the availability of deepwater ports for the reception of iron ore imports. The import of significant quantities of seaborne iron ore for consumption by plants not at coastal locations is not foreseen except for some quantities in the Pittsburgh area.

Imports of both alumina and bauxite are expected to be constrained by policies of the less developed producing countries requiring the indigenous processing of aluminum raw materials. Other key assumptions underlying projected imports are that annual growth of U.S. aluminum consumption would decline progressively from 8 percent in 1970 to 4 percent in 1990 and 2000; aluminum imports would increase from approximately 10 percent of consumption in 1970 to 15 percent in 1980 and 27 percent in 2000; secondary recovery of aluminum would increase from 19 percent of total supply in 1970 to 25 percent in 2000; and primary aluminum production would increase from roughly 4 million tons in 1970 to 11.5 million tons in 2000.

Growth in exports of coking coal is expected to be constrained by decreases in the unit consumption of metallurgical coke per ton of pig iron produced. In addition, the Japanese market will be limited by the relatively higher costs of U.S. coal and by the anticipated success of the Japanese in developing alternative sources of supply. Most of the anticipated growth in exports would be in the European market.

Significant growth in exports of feed grains and soybeans and meal is projected. Meat consumption in Western Europe and Japan, particularly, is expected to rise sharply with the projected growth in per capita incomes, which will require increased consumption of animal feedstuffs. The United States is expected to continue to be the leading supplier of such feedstuffs in international trade, because of its superior agricultural resource position and government agricultural policies.

Moderate growth in the export of food grains is projected, reflecting the assumption that consumption of food grains in developed countries will rise very slowly, and that the more rapid projected growth in consumption in less developed countries will be largely met from increases in indigenous production.

It is assumed that there will be no change in U.S. agricultural policy as it may affect U.S. exports.

The international market for phosphate rock is highly competitive, and other countries, particularly Morocco and Tunisia in North Africa, have resources superior in both quality and magnitude. They have also emerged as major exporters to European and other markets.

Projection of growth in U.S. exports of phosphate rock assumes that the industry will maintain a competitive position in principal foreign markets, and that foreign consumers will wish to continue to use U.S. phosphate rock as a means to diversify sources of supply.

IV. EVALUATION OF ALTERNATIVE COURSES OF ACTION AVAILABLE TO THE UNITED STATES

In addition to the deepwater ports evaluated in detail, consideration must be given to other possible deepwater port alternatives, and to the implications of not providing or permitting such ports.

Other deepwater port alternatives may include the deepening of channels and harbors at existing ports where potential use by deep-draft vessels can be anticipated, or the construction of offshore facilities at locations other than those chosen in this study. Deepening of existing channels may take the form of selective deepening to maximum feasible depths at relatively few locations so as to meet broad regional requirements, or incremental deepening of all major ports and channels over time as appropriate to growing local needs.

Other Offshore Deepwater Port Alternatives in the United States

On the Atlantic coast, water depths of 60 feet or more lie within several miles of the shoreline off the northern and southern coasts of Maine; the New Hampshire coast; Narragansett Bay and Long Island; the northern coast of New Jersey; Delaware Bay; Cape Hatteras; Jacksonville, Florida; and Port Everglades and Miami in southern Florida. East coast offshore deepwater ports considered in this study minimize distance factors between petroleum refineries and available deep water, as well as requirements for dredging. Consideration could be given to the exploitation of naturally deep water at other locations for crude petroleum facilities for transshipment by barge or pipeline to existing refinery locations in the New York, New Jersey, and Delaware Bay areas, or to refineries at new locations.

Coast of Maine

A precedent for the use of the naturally deep waters along the coast of Maine exists in the present use of Portland for the discharge of approximately 20 million tons annually of crude petroleum, which is transshipped by pipeline to refineries in Canada. Portland is the point on the U.S. east coast nearest the Canadian refineries being supplied.

Several proposals have been made in recent years by petroleum companies and other private interests for the construction of petroleum refineries in Maine that would utilize imported crude petroleum transported in deep-draft vessels. All were disapproved by the Maine Environmental Improvement Commission on environmental grounds.

None of these proposals was designed to provide a crude petroleum terminal with the capacity and facilities for receiving and transshipping the crude petroleum requirements of refineries in the New York-New Jersey-Pennsylvania area. One can only generalize about the economic and environmental characteristics of such a facility relative to the port alternatives analyzed in this study.

Transshipment costs to refineries would presumably be somewhat higher because of greater distances. However, this may be completely or partly offset by other cost differences, so that no definitive comparative judgment is possible. Applicable ocean transport costs would be approximately the same, assuming no difference in the size and other relevant characteristics of the tankers to be utilized.

Coast of Florida

The development of the port of Miami or of Port Everglades in southern Florida as a reception and transshipment point for crude petroleum to be either refined locally or transshipped via barge or pipeline to refineries in the Mid-Atlantic area has not been proposed. Petroleum activities in Florida are essentially limited to the receipt of petroleum products, either by water or pipeline, and their distribution to local markets. The development of refining or crude petroleum reception and transshipment to meet regional needs outside Florida would pose environmental issues similar to those in Maine.

As a point of transshipment for supplies to fulfill Middle Atlantic and North Atlantic needs for petroleum and petroleum products, Florida has a distance disadvantage vis-a-vis Maine and the Atlantic deepwater port locations studied in this report.

Chesapeake Bay

A potential deepwater port site exists in the Chesapeake Bay. The natural depth of the channels in the bay off the Eastern Shore of Maryland ranges from 80 to over 100 feet. However, access to these waters is through the Rappahannock Shoal, York Spit, and Cape Henry Channels in the Lower Chesapeake Bay, which are presently dredged to 45 feet. In addition, the Chesapeake Bay Bridge-Tunnel presents an obstacle to the dredging of entrance channels to the Chesapeake Bay beyond about 58 feet in depth. Therefore, the utilization of the naturally deep waters of the upper bay for deep-draft tankers would involve extensive dredging and structural changes in the Chesapeake Bay Bridge-Tunnel.

The bay would offer the advantage of relatively quiet and protected waters. The Eastern Shore of Maryland is almost entirely rural and relatively undeveloped. It might have potential for the development of a new refinery center for the Mid-Atlantic and North Atlantic States, and should provide relative ease of pipeline access to existing refineries. The distance to refineries would be about the same as the distance from Big Stone Beach in the Lower Delaware Bay. The major apparent disadvantage of the Chesapeake location would be the economic costs of dredging and of the structural changes in the bridge-tunnel, and the environmental aspects of dredging, channel deepening, and land-use changes.

Gulf and Pacific Coasts

The gulf coast does not have natural deepwater resources close to shore comparable to those found at several east coast locations.

The Pacific coast, on the other hand, has naturally deep water along most of the coastline, but relatively few sheltered harbors of sufficient area and depth to accommodate supercarriers. However, there are potential sites worthy of consideration other than those studied.

Deepening of Existing Channels

Two basic approaches to the deepening of existing channels as a response to present and prospective requirements for the accommodation of deeper draft vessels have been mentioned: incremental deepening of channels in response to expressed needs of local interests, or the selective deepening of one or more channels on a regional basis, with a view toward optimizing economic and environmental benefits relative to their costs. Although these may appear to be distinct approaches from the planning and conceptual point of view, they may not be mutually exclusive in the sense that one approach must be wholly substituted for the other, or that the exclusive pursuit of either approach would insure the desired environmental and economic optimization. Furthermore, the appropriateness of either option will depend on the specific circumstances, including relevant vessel size characteristics and physical conditions in the ports.

Incremental deepening of channels in response to local needs and desires is the present and the historical approach. It has been characteristic of this approach that authorized projects frequently become obsolete before or shortly after they are implemented because of the dynamic growth in the capacities and dimensions of bulk cargo carriers. The size of bulk carriers in international trade is usually determined by the users and owners of such vessels, subject to port constraints. The extent to which size characteristics of bulk carriers would increase could not readily be foreseen by those responsible for the determination of channel depth requirements in the past 15 to 20 years.

It is also increasingly characteristic of the incremental approach that differences in natural conditions affecting the costs and benefits of deepening and enlarging channels result in inequities among different ports and among the principal users of those ports.

It would appear that few of the port areas with the greatest prospective use for petroleum deepwater ports are suitable for deepening to desired depths. On the other hand, water depths required by vessels carrying dry bulk commodities in the largest volumes wanted in single shipment are substantially less than those required by the largest size supertankers. This suggests that incremental deepening of selected ports for certain dry bulk commodities may be economically sound, provided that such an approach is carried out within a policy framework designed to insure maximum regional coordination of investment and port development.

However, such incremental deepening should be appraised in relation to possibilities for use of restricted-draft vessels, adapted to existing or predetermined channel depth constraints, which can achieve significant transport cost savings in the absence of port improvements.

The Negative Course of Action

This alternative is defined as a policy of the U.S. Government and of other levels of government not to authorize the construction of deepwater port facilities and related channels and/or not to provide such public funds as may be required or requested for that purpose.

The environmental and economic implications of a negative policy toward deepwater port development can be discussed only in general terms. To a substantial degree, they would be determined by the responses of the petroleum industry and other bulk producing and consuming industries to the prospect that deepwater port facilities would not become available within the coastal waters of the United States, except in those few locations where they are available naturally.

Three specific responses by the petroleum industry, all of which are being resorted to at present to a limited degree, are (1) the lightering of deep-draft vessels in naturally deep waters, such as New York Bay, Lower Delaware Bay, and San Francisco Bay; (2) the transshipment of petroleum from deepwater transfer facilities in the Maritime Provinces of Canada and in the Caribbean islands, in vessels which either are lightered or are capable of transiting existing channels to refinery locations fully loaded; and (3) the construction of refinery capacity at these offshore locations where products are shipped to the United States.

These practices offer the possibility of taking advantage of the economies of deep-draft ships for the ocean transport of crude petroleum imports from foreign origins to the Western Hemisphere without the need for deepwater ports in the United States. However, draft constraints in sheltered lightering areas limit ocean vessel capacities, and costs of transshipment from deepwater facilities located in the Caribbean and Canada are greater than they would be from facilities located in U.S. coastal waters closer to refinery locations.

In addition, the use of smaller transshipment vessels increases traffic density in port and harbor areas over what it would be with pipeline transfer from deep ports.

V. DEEPWATER PORT ALTERNATIVES SELECTED FOR DETAILED ANALYSIS

The prime purpose of the selection was to provide a basis for preliminary economic and environmental evaluation of a limited number of specific deepwater port alternatives having capacity, locational, and engineering characteristics realistically related to the indicated requirements.

There is no generally accepted definition of a deepwater port in terms of depth characteristics. In principle we specified for analytic purposes depths sufficient to accommodate vessels with drafts of 70 feet or more, which appeared to be the minimum likely to be used for the long-haul petroleum imports. We also studied ports of lesser depths where physical conditions imposed such limits.

It was also considered essential to demonstrate the environmental and economic characteristics of different locational and conceptual approaches to the provision of deepwater port facilities. On the Atlantic coast, for example, we studied crude petroleum ports at locations in New York Harbor and Delaware Bay capable of supplying local as well as regional needs, with fixed berths and pipeline connections to refineries; monobuoys off the coast of northern New Jersey to supply regional needs, with pipeline links to refineries; and fixed berths connected to an artificial island in the Atlantic off the Delaware Capes, with barge links to refineries. Thus, a range of possible alternative solutions with varying engineering, geographic, economic, and environmental characteristics is evaluated.

The number of alternatives selected was limited arbitrarily by the time and resources available. The exclusion of other possible alternatives does not imply that they may not have environmental or economic merit equal or superior to some of the alternatives studied.

The tentative character of the estimates of first costs and operation and maintenance costs of the deepwater port alternatives studied must be emphasized. First costs were estimated for the major project components included in the engineering design on the basis of best available information, mainly from secondary sources, as were costs of operation and maintenance. The results should be regarded as order-of-magnitude estimates which serve the need of broad comparative evaluation of the benefits and costs of the alternatives studied. Although useful in determining the direction of further, more detailed studies, they would not satisfy the requirements of a feasibility study.

The need for consideration of deepwater port facilities on the Atlantic, gulf, and Pacific coasts was clearly indicated by the projected volumes of crude petroleum imports, the relatively long distances of ocean transport involved, and the availability of deepwater facilities at points of shipment. For petroleum products, principally residual fuel oil, projected volumes were sufficient to indicate the possible need for deepwater port facilities only on the east coast. However, an appraisal of a deepwater port to serve residual fuel oil imports was not made in this study because of the comparatively short distances of ocean transport from the projected sources of supply (implying only small savings in ocean transport costs), and the much more complex and diverse delivery and distribution systems required for residual fuel oil than for crude petroleum.

A somewhat similar problem was found with respect to some dry bulk commodities. No ship size determination was made and no deepwater port alternatives were studied for the import of alumina and bauxite or the export of phosphate rock. There appeared to be no need for the consideration of deepwater port alternatives for the major dry bulk commodities on the west coast.

The crude petroleum throughputs at the regional ports on the north Atlantic coast correspond with the crude requirements of the region, which in turn are governed by the volume of refinery capacity and output. A substantial share of the petroleum product requirements of the East Coast States is supplied from refineries on the gulf coast, which presently utilize domestic crude petroleum. As both gulf and east coast refineries are required to shift to imported crude, it would be more economical for east coast requirements to be supplied from refineries on the east coast than from refineries on the gulf coast. However, the prospects of required refinery expansion taking place on the east coast are so seriously clouded by environmental concerns evidenced at the political level that an assumption that all or most of the required capacity would be located on the east coast was considered unrealistic.

For purposes of the study, it was considered desirable to employ alternative assumptions as to the volume of refining capacity on the east coast, with the further assumption that product deficits other than for residual fuel oil would largely be supplied from refineries on the gulf coast. The alternative throughputs at the regional deepwater ports on the north Atlantic coast correspond with refinery outputs of roughly 2 million and 3 million barrels daily in 1980, and 3 million and 6 million barrels daily in 2000. The throughputs at the local ports for the New York and Delaware River areas correspond roughly with the present proportions of regional refining capacity at these locations. These alternative assumptions as to east coast refinery capacity have a reciprocal effect on the throughputs at the gulf coast ports.

In all cases, the throughputs at deepwater ports on all three coasts correspond with the total local or regional requirements for waterborne crude petroleum receipts from foreign or domestic sources, because the volume and other characteristics of the flows warrant the use of deep-draft vessels for transport from all origin points. In the case of dry bulks, however, lesser link volumes and distances, and institutional and structural characteristics of the trades, resulted in the exclusion of some link flows from use of the deepwater port facilities for purposes of benefit-cost analysis.

The major characteristics of the port alternatives studied and the estimated first investment costs are summarized in tables 2 and 3.

Table 2. Summary of Crude Oil Deepwater Port Alternatives Selected for Detailed Analysis

Port area	Location or site	Refinery areas served	Storage location	Type of berth	Type of transship.	Design vessel		Annual throughput (mil. long tons/year)		Estimated first costs (mil. of 1970 dollars)	
			A-Artif. island 0-Onshore	F-Fixed M-Mono-buoy	P-Pipeline B-Barge	Draft (ft.)	Size (1,000 d.w.t.)	1980	2000	1975-79	1980-2000
N.Y.,N.Y..	Lower N.Y. Bay	Arthur Kill	A	F	P	70	300/400	30/35	35/70	133/149	0-1
N.Y.,N.Y..	Lower N.Y. Bay	Arthur Kill & Delaware R.	A	F	P	70	300/400	100/150	150/300	231/346	8/36
N.Y.,N.Y..	Long Branch	Arthur Kill & Delaware R.	0	M	P	70	300/400	100/150	150/300	176/270	7/38
Delaware Bay......	Big Stone Beach	Delaware R.	0	F	P	70	300/400	70/115	115/230	139/221	27/42
Delaware Bay......	Big Stone Beach	Delaware R.	A	F	P	70	300/400	70/115	115/230	150/231	23/38
Delaware Bay......	Big Stone Beach	Delaware R. & Arthur Kill	0	F	P	70	300/400	100/150	150/300	217/275	3/78
Delaware Bay......	Big Stone Beach	Delaware R. & Arthur Kill	A	F	P	70	300/400	100/150	150/300	226/280	4/78
Delaware Bay......	Off Delaware Capes	Delaware R. & Arthur Kill	A	F	B	70	300/400	100/150	150/300	210/290	0/32
Miss. Riv. Delta....	Garden Island Bay	Gulf coast[a/]	A	F	B	55	200	100/150	450/600	220/261	114/145
Miss. Riv. Delta....	Garden Island Bay	Gulf coast[a/]	A	F	B	70	300/400	100/150	450/600	243/277	99/159
Miss. Riv. Delta....	Garden Island Bay	Gulf coast[a/]	A	F	B	95	500	100/150	450/600	253/288	130/171
Texas.....	Freeport	Gulf coast[a/]	0	M	P-B	55	200	100/150	450/600	325/393	312/429
Texas.....	Freeport	Gulf coast[a/]	0	M	P-B	70	300/400	100/150	450/600	328/420	307/424
Texas.....	Freeport	Gulf coast[a/]	0	M	P B	95	500	100/150	450/600	362/451	337/447

continued--

Table 2. Summary of Crude Oil Deepwater Port Alternatives Selected for Detailed Analysis continued--

Port area	Location or site	Refinery areas served	Storage location	Type of berth	Type of transship.	Design vessel		Annual throughput (mil. long tons/year)		Estimated first costs (mil. of 1970 dollars)	
			A-Artif. island O-Ohshore	F-Fixed M-Mono-buoy	P-Pipeline B-Barge	Draft (ft.)	Size (1,000) d.w.t.)	1980	2000	1975-79	1980-2000
Texas.....	Freeport	Gulf coast[a/]	O	F	P-B	55	200	100/150	450/600	400/480	283/373
Texas.....	Freeport	Gulf coast[a/]	O	F	P-B	70	300/400	100/150	450/600	543/643	257/384
Texas.....	Freeport	Gulf coast[a/]	O	F	P-B	95	500	100/150	450/600	878/963	301/395
Los Angeles - Long Beach..	San Pedro Bay	Los Angeles - Long Beach	O	F	P	70	300/400	28	111	44/51	6/8
Los Angeles - Long Beach..	San Pedro Bay	Los Angeles - Long Beach, San Fran.	O	F	P	70	300/400	43	171	178/189	38/47
San Fran..	Richmond	Richmond-Avon	O	F	P	50	157	15	60	63	3
San Fran..	Richmond-Avon	Richmond-Avon	O	F	P	50	157	15	60	81	0
San Fran..	Richmond	Richmond-Avon	O	F	P	58.5	250	15	60	86	16
San Fran..	Richmond-Avon	Richmond-Avon	O	F	P	58.5	250	15	60	167	0
San Fran..	Monterey Bay[b/]	Richmond-Avon	O	M	P	83	400	15	60	109	9
Belling-ham - Fern-dale...	Strait of Georgia	San Francisco	O	F	P	83	400	15	60	367	65
Belling-ham - Fern-dale...	Strait of Georgia	San Francisco, Los Angeles - Long Beach	O	F	P	83	400	43	171	570	562

a/ Gulf coast refineries are located at Houston-Baytown, Beaumont-Port Arthur, Lake Charles, Baton Rouge, New Orleans, Corpus Christi, and Pascagoula.
b/ Moss Landing.

Table 3. Summary of Dry Bulk Deepwater Port Alternatives Selected for Detailed Analysis

Port area	Location or site	Links to existing ports	Storage location	Type of transship.	Design vessel		Commodity and annual throughput (million long tons/year)						First Investment costs (mil. of 1970 dollars)
			A-Artif. island O-Onshore	B-Barge	Draft (ft.)	Size (1,000 d.w.t.)	Coal		Iron ore		Grain		
							1980	2000	1980	2000	1980	2000	1975-1979
Delaware Bay.	Big Stone Beach	Hampton Roads and Baltimore	A	B	58.5/ 65	250	11.5/ 45.4	6.4/ 43.7	--	--	--	--	66/ 210
Delaware Bay.	Big Stone Beach	Hampton Roads, Baltimore, Philadelphia-Trenton	A	B	58.5/ 65	250	11.5/ 45.4	6.4/ 43.7	12.5	17.1	--	--	160/ 306
Chesapeake Bay.........	Hampton Roads	Norfolk and Newport News	O	None	52	128/ 179	46.1	46.6	--	--	--	--	37/ 46
Miss. River Delta.......	Garden Island Bay	Miss. River, Texas & La. coast ports	A	B	50/ 58.5/ 65	120/ 250	--	--	--	--	18.0/ 32.8	23.6/ 58.9	142/ 256
Miss. River Delta.......	Garden Island Bay	Mobile,Houston, Baton Rouge	A	B	58.5/ 65	250	--	--	7.6	10.4	--	--	94
Miss. River Delta.......	Garden Island Bay	Garden Island Bay	A	B	50/ 58.5/ 65	120/ 250	--	--	7.6	10.4	18.0/ 32.8	23.6/ 58.9	207/ 322
Texas........	Freeport	Texas ports	O	B	50/ 58.5/ 65	120/ 250	--	--	--	--	18.0	23.6	98/ 122

VI. THE ENVIRONMENTAL AND ECOLOGICAL ASPECTS OF DEEPWATER PORTS

Introduction

The importance of environmental and ecological considerations to the achievement of a rational delivery system for bulk commodity imports and exports cannot be overemphasized. There is great public concern about the threat of massive petroleum spills resulting from ship collisions or groundings in or near U.S. coastal and port waters, and about the threat of petroleum spills of any significant quantity in waters and adjacent land areas where high levels of recreational, residential, and aesthetic uses prevail and where ecological values are high.

Another major subject of public concern, the intensity of which seems to vary among regions and even among local areas within regions, is the environmental threat posed by the prospects of the development of petroleum refining and other industrial activity in areas where such development conflicts with existing and planned land use.

This issue is eloquently demonstrated and dramatized by the State Government of Maine's disapproval of several applications for the construction of refineries and of related deepwater port facilities; by proposed legislation by the State of New Jersey prohibiting deepwater port facilities off its Atlantic coast; by the passage of legislation by the State of Delaware prohibiting deepwater port facilities within its boundaries in Delaware Bay, and the installation of heavy industry, including refineries, along its coastline; and by some negative actions on proposed deepwater ports off the Mississippi Delta and off the Pacific coast near San Francisco.

If the necessity for substantial increases in waterborne imports of crude petroleum or petroleum products is accepted, such uncoordinated efforts at the state and local level to shift the burden of ecological risks and environmental change elsewhere could, in the long run, be counterproductive. The problem should be viewed as the need to develop a system for the waterborne delivery, storage, handling, and processing of crude petroleum which minimizes ecological and environmental damage and the risks of such damage. Such damage and risks of damage cannot be avoided by policies or actions which prohibit petroleum refineries and deepwater port facilities, if one accepts that waterborne receipts of petroleum in some form must take place whether or not such facilities are provided.

Consideration must be given not only to the ecological and environmental aspects of alternative deepwater port solutions, but also to the delivery systems now in use or which may evolve in the absence of deepwater port facilities. The *a priori* assumption that the provision of deepwater ports is less desirable than the alternative of no such ports may be ill-founded from the environmental viewpoint.

Given the necessity to import petroleum, the degree of environmental risks, and the magnitude of the potential economic benefits from the use of deep-draft tankers, the public interest would appear to be better served by the establishment of appropriate policy goals for environmental protection and the institution of programs designed to insure their achievement. Thus, priority attention could be devoted to:

1. Definition of acceptable standards of risk for all future waterborne transport and transfer operations, and adoption of such standards as a goal

2. Intensive research and investigation at all relevant scientific and engineering levels of the means

by which the goal could be achieved through design, engineering, and operational innovations pertaining to transport and transfer equipment and operation

3. Examination of the institutional, legal, regulatory, and other changes which may be required to insure that the use of such design, engineering, and operational innovations will in fact be applied and enforced, and that relevant costs will become an offset against the ocean transport benefits derived from the use of deep-draft vessels.

Major Analytical Problems Encountered

Three major problems were encountered which contribute to the relatively high degree of uncertainty associated with the prediction of the environmental and ecological effects of a specific deepwater port development and its corresponding base situation.

The first problem is a lack of knowledge in a number of areas essential to the environmental analysis of a deepwater port. These include:

1. Knowledge about the changes which will occur as a result of the alteration of the physical configuration of a water body. A generalized ability to predict these changes does not exist at this time.

2. Knowledge about the impact of such physical changes on the biological organisms in the area.

3. Knowledge about oil spills. No satisfactory methodology exists today to determine a probability distribution of oil spills from any given system.

4. Knowledge about the impact of oil pollution. A great deal of uncertainty exists about the impact of spills on the ecosystems. Scientific conclusions range from "no apparent significant long-term effects" to "a major catastrophe for the ecosystem."

The second problem is a lack of data on the physical and biological characteristics and behavior of most areas. With very few exceptions, the extent of actual field data collection and study is very limited. In some areas, comprehensive field studies are just beginning; in others, very little is even planned at this time. Where data exist, they are not always comparable or consistent because of disparate observation sites, times, and methods of measurement.

The third problem associated with the prediction of effects is the high degree of uncertainty as to whether environmental safeguards will be instituted or not. In many cases, identified potential environmental problems can be eliminated by modifying the design and operation procedures for the port and the surrounding area. At this time, the evaluation of environmental impacts must include an assumption that such modifications will, or will not, actually be implemented.

Planning Design and Control Problems

One of the major difficulties in handling environmental problems is the lack of coordinated and effective review and control over the design and operation of vessels and port developments.

Many of the vessels destined to use deepwater port facilities are not under U.S. control. Consequently, there is no guarantee that they will meet acceptable design criteria. Such vessels, although not actually entering U.S. waters, could nevertheless cause pollution in these waters. Binding international agreements which specify design criteria and operating procedures for these vessels, or unilateral enforcement by the United States for vessels in U.S. waters, would do much to control the oil pollution problem.

This lack of coordinated control is also very much in evidence in the various aspects of port development and operation. Some of the existing controls are in the hands of states, counties, or local communities, while others are federally managed. In many cases, controls are either nonexistent or grossly inadequate.

In addition, review of plans for a port development often does not take place in a framework of comprehensive, systematic analysis. Consequently, some important aspects of the development often remain unidentified or overlooked.

A further institutional problem pertains to the regional aspects of deepwater port development. Some areas are more susceptible than others to environmental damage, while the high costs associated with the construction of such a port make it evident that only a limited number can usefully be built. Evaluation of sites should therefore be done within the broader context of coastal zone management. The other essential uses of the coastal zone must receive consideration in terms either of multiple-use development or, where necessary, of limited single-purpose uses.

The mechanisms for evaluating, planning, and controlling such developments at the necessary scale do not exist today.

Results of Preliminary Analysis of the Selected Alternatives

The analysis of the selected alternatives was conducted within the bounds of existing and readily available information. It identifies the major problems most likely to be encountered if the alternative is actually implemented.

The analysis provides a starting point for evaluating the port alternatives at two different levels. First, it aids in differentiating between alternatives in one area. Second, it aids in differentiating alternatives in different areas. A brief statement about the environmental effects of each follows.

1. Lower New York Bay. There are two major issues for the alternatives proposed for Lower New York Bay. First, and most important, is the potential impact of an offshore facility on secondary development in the

bay. There are pressures for development of this area; for example, proposals have been made for building a major airport on the bay. The development of the offshore oil facility could pave the way for major alterations to the area. The possibility of major oil pollution is also an important issue in the area. Both these concerns involve a high degree of uncertainty and need further, more detailed investigation.

There is a possible environmental benefit involved in the regional port alternative located in Lower New York Bay: the elimination of the oil port development in Delaware Bay.

2. Long Branch, New Jersey. The development of an offshore oil facility in Long Branch, New Jersey, would have one major issue: the possible effects of a major oil spill. Monobuoys are exposed to the constant motion of waves and are susceptible to damage during operations. A major spill under certain wind conditions could reach the highly used recreational beaches of Long Island and New Jersey. As a regional port it would obviate both the Lower New York Harbor and the Delaware Bay alternatives.

3. Delaware Bay. The Lower Delaware, with its extensive wetlands and low level of shoreline development, may be affected by the port alternatives in a number of significant ways. Most serious are the problems of potential major oil spills and the pressures for secondary shore development which will accompany such a port. The dredging, although not extensive, can cause a major problem if it interferes with the major groundwater systems which underlie the bay. Further study of this aspect is warranted prior to such deep dredging. The Delaware Bay regional alternatives would eliminate the Lower New York Harbor and Long Branch alternatives.

4. Off Delaware Capes. An island off the Atlantic coast of Delaware for oil transshipment will have to deal with the oil spill issue. In addition, although this alternative would alleviate the need for deep water close to shore, it would substantially increase port traffic since the oil would move to the refineries in barges rather than by pipeline as in the above alternatives. Consequently, the chances for

collision and spills near shore would be increased. A submarine pipeline from the island would reduce this traffic and spill probability.

5. Chesapeake Bay. The Chesapeake Bay alternative is primarily for coal shipments and thus has no problems associated with major oil spills. The major issue is with the disposing of dredging spoil.

6. Offshore Louisiana. A number of possibly significant problems are associated with an island in the Mississippi Delta area. The question of the impact upon the local wetlands due to alteration of currents and waves is an area of much uncertainty. Another unresolved question at this time is the source of supply of material for constructing the island. Acquiring such material would require major mining operations either on or off shore. The environmental effects of such an operation would have to be considered.

7. Freeport, Texas. The alternatives proposed for an onshore port at Freeport require a tremendous amount of dredging, shore modification and wetland dredging and filling. The offshore alternatives do not require any major dredging. As at Long Branch, the monobuoy systems are more susceptible to oil spills, and a spill in open waters will be harder to contain. However, it may be less damaging to shore areas.

8. Los Angeles/Long Beach, California. The major environmental effects of the proposed deepening of these harbor channels are related to the method of spoil utilization. The proposal is to add to the land available for port facilities in the Outer Harbor. This area presently contains a large, valuable population of anchovies, which are the most important bait source for the marine sport fishery of southern California. What will happen to the anchovies in the event that this proposal is implemented is an open question requiring additional investigation.

9. Moss Landing. The most important environmental issue involved at Moss Landing is the potential damage which would be caused by a major oil spill. The prevailing wind would tend to move a spill on shore in the highly valued beach areas of Monterey Bay and possibly onto the rocky shores of the Monterey Peninsula.

10. San Francisco Bay area. The major environmental issue is again the danger of a major oil spill in the bay. In addition, a high degree of uncertainty is associated with the ecological effects of major dredging, especially in the upper reaches of San Pablo and Suisun Bays.

11. Puget Sound area. Puget Sound, with naturally deep waters, does not require dredging. The oil spill problem is the leading issue. Secondary development will also be a very important consideration if a new port facility is developed in a presently underdeveloped area.

The implementation of a regional oil port in Puget Sound would relieve the need for extensive dredging and deepwater port development in San Francisco Bay and possibly in Los Angeles/Long Beach.

The Effects in Summary

It is quite evident that each alternative area will have different environmental problems. Some alternatives include development in presently underdeveloped areas. Some include improvement of existing facilities. However, there is a problem common to all: the potential of major oil pollution. This is the major environmental issue to be addressed. Little can be said about it because of the lack of adequate knowledge about how to design and operate a system without spillage, and the lack of technological capability to handle a major spill.

In most cases where an environmental problem can be overcome by proper design and operation, there is a tendency to dismiss it with the assumption that it will be taken care of. Historical evidence does not support this conclusion. More adequate criteria and enforceable regulations for design and operation are necessary to overcome the major environmental problems associated with deepwater port development.

VII. TRANSPORT OF BULK COMMODITIES

World Shipping Supply and Demand

The world market for seaborne movement of bulk commodities is huge and is growing very rapidly. In 1971 it included more than 1.7 billion metric tons of the six major bulk commodities covered in this study. Among them, crude petroleum accounted for over 60 percent; petroleum products, around 12 percent; iron ore, 14 percent; and coal and grain, most of the balance. The United States accounted for about 15 percent of total world seaborne trade in these commodities, ranging from less than 5 percent of crude petroleum movements to over 50 percent of bauxite and alumina shipments. Japan's participation has been relatively greater, recently exceeding 20 percent of total trade.

The world supply of bulk vessels has kept pace with demand. Further, it has registered remarkably rapid increases in vessel size and in distances of haul for many commodities. The average oil tanker in the world fleet recently exceeded 52,000 d.w.t.; the average dry bulk carrier, 29,000 d.w.t.; and the average combined carrier (vessels capable of carrying oil or dry cargoes), 80,000 d.w.t. In 1971, 131 tankers exceeded 200,000 d.w.t., while 32 combined carriers and 17 dry bulkers exceeded 100,000 d.w.t. In addition, several 477,000-d.w.t. tankers had been ordered.

These general trends mask the reality of diverse ship size distributions among numerous commodities and routes, each with specific characteristics. Thus, only 2 percent of 1970 U.S. crude petroleum imports arrived in tankers exceeding 100,000 d.w.t., as compared with 25 percent of world crude petroleum imports. However, some 42 percent of both U.S. and world crude imports were shipped in vessels of less than 60,000 d.w.t.

U.S. iron ore imports in 1970 were also transported in typically smaller vessels than those used by the rest of the world. However, for the other four major dry bulk commodities, typical sizes of ships engaged in U.S. seaborne trade were larger than their counterparts in world trade generally.

Most of the new and larger vessels have been built in Japan and Western Europe, and they are operated especially under Liberian, Japanese, Norwegian and British flags. U.S.-flag vessels play a negligible role in U.S. bulk commodity trade. However, U.S. owners control a substantial proportion of Liberian and Panamanian tonnage, which is important to U.S. oil and some other bulk commodity imports and exports.

Dimensional characteristics for both tankers and bulk carriers of any given size vary widely. For example, existing vessels of 60,000 to 80,000 d.w.t. have loaded drafts which range between 36 and 50 feet, and today's tankers requiring 50- to 55-foot drafts range from less than 100,000 d.w.t. to more than 200,000 d.w.t. Relationships between vessel size or capacity and draft accordingly depend mostly on the particular combination of length, beam and draft incorporated in a ship's design.

Institutional and Operating Patterns

Most ocean vessels transporting major bulk commodities in world trade, whether U.S. or foreign flag, are owned and run by independent shipping operators who compete vigorously for long- or short-term charters. However, some tonnage is directly controlled by large international oil companies and other cargo interests, particularly among metal and mining concerns. Generally, most world seaborne movements of crude petroleum, iron ore, bauxite and alumina reflect continuing shuttle movements between essentially fixed origins and destinations. Shipping costs under proprietary operation and negotiated prices under predominantly long-term charter arrangements both approach long-run real economic costs.

The above pattern of long-range stability in commodity flow patterns is reinforced by typically integrated control of or interest in raw material supply sources and subsequent processing at destinations. It is also conducive to employment of large ships, the financing of which is facilitated when long-term use can clearly be established in advance.

Vessel size and design characteristics, as well as operating patterns, tend to be optimized for specific commodity movements among relevant links. Selected vessels approach the lowest total cost feasible, given desired shipment sizes, physical constraints in foreign as well as in U.S. ports and channels, storage capacity, loading or unloading rates, voyage distance, etc. Sometimes those circumstances are consistent with employment of the largest size vessel physically feasible at the ports to be served (especially for crude petroleum and some minerals). These and other factors suggest that crude petroleum is most suitable for efficient movement in supercarriers, with iron ore and coal the most promising among dry bulk commodities in U.S. foreign trade.

Ocean Shipping Costs

Ocean shipping of bulk commodities is characterized by substantial scale economies which tend to diminish beyond a certain point. This is well illustrated by our independent estimates of ocean shipping costs for numerous foreign-flag tankers of varying size and design characteristics (all made in pre-devalued 1970 dollars). For 5,000 mile (one-way) journeys, shipment in a 30,000-d.w.t. vessel would cost a bit over $4.00 per long ton. The unit cost would drop sharply to $3.00 per ton in a 50,000-d.w.t. ship and to some $2.10 in a 100,000-d.w.t. vessel. Another doubling of vessel size to 200,000 d.w.t. would lower unit costs to approximately

$1.70, a decrease of around 20 percent. A jump to a 300,000-d.w.t. tanker would produce a further reduction in unit cost of about 10 percent. However, a 500,000-d.w.t. vessel would be expected to reduce costs only by an additional 7 percent.

U.S.-flag tankers are estimated to incur total unit costs which would be some 57 to 71 percent higher than foreign-flag equivalents on similar journeys. The competitive disadvantage of U.S. vessels tends to decrease as vessel size and trip distance increase. The disadvantage is nevertheless substantial under all circumstances and easily explains the inability of unsubsidized U.S. operators to compete effectively in open markets.

Very substantial scale economies in ocean transport can be realized only by increasing all vessel dimensions, including draft. However, within certain practical limits, moderately significant scale effects can be achieved at a given draft by increasing the vessel's other dimensions. This approach can provide meaningful reductions in total unit costs over smaller ships of equal and unconstrained draft. For vessels limited to 35 feet or 40 feet of draft, design optimization could reduce total unit costs by as much as 20 to 25 percent over typically smaller ships of equal draft.

All unit cost estimates for ocean shipping reflect a single set of explicit assumptions about numerous variables. Sensitivity of the estimates to alternative assumptions is tested in Annex E, chapter III. Since all ships costed lack special design features for environmental protection, the implications for their costs of three design features are considered: fully clean ballast, double bottom, and wing tank size limitations. Any of these would tend to modestly increase unit costs. The last would be expected to apply only to supercarriers, but quantitative impacts of likely new standards are relatively minor. However, if the first two features applied to vessels of all sizes, the monetary impact per ton would be greater for smaller ships than for larger ones, and hence would increase the latter's unit cost advantage somewhat.

Water Transshipment

Water transshipment of bulk commodities is important to deepwater port issues in two different ways:

1. Most hypothesized deepwater ports are entirely new facilities which require connecting movements to or from existing port facilities. In practice, all dry bulk commodities passing through an offshore deepwater port would have to be transshipped by water, while crude petroleum might be transshipped either by water or by pipeline. Costs of transshipment by vessel on each relevant link affect the economic viability of most deepwater port concepts.

2. In the absence of a deepwater port, crude petroleum might conveniently be transported across the sea in relatively large tankers, and then offloaded into smaller vessels outside shallow U.S. harbors. This approach offsets some of the physical constraints at existing refinery terminals without requiring large new investments in deepwater port facilities.

Water transport of the various commodities between existing terminals and a new deepwater port could be most efficiently performed by specially designed superbarges of around 40,000 d.w.t., which would be pushed by tugs operating at modest speeds over the relatively short distances involved (mostly between 50 and 450 nautical miles one-way). Estimated costs for such movements would range from $0.23 to $0.30 per long ton for the shortest hauls to $0.86 to $1.05 per long ton for the longest hauls, depending upon the type of commodity and vessel design features.

The practice of lightering crude petroleum and petroleum products from large tankers to barges has been growing rapidly in recent years, especially on the east coast. However, ocean vessels and barges used are both generally much smaller than optimal. Relatively deep water and protected anchorages are available for lightering operations in three major relevant U.S. port areas: New York, the Delaware Bay, and San Francisco Bay. Assuming tug-barges of the same design and size characteristics as for the shuttle ship movements from deepwater ports, offloading costs per long ton would range between \$0.23 and \$0.36. Such cost increments would be more than offset by potential savings in ocean shipping costs attainable by the use of large tankers. For the three areas indicated, vessels of up to 110,000 d.w.t., 236,000 d.w.t., and 183,000 d.w.t., respectively, could be accommodated if their designs were optimized for draft conditions.

VIII. TRANSPORT BENEFIT-COST ANALYSIS

The Approach

A preliminary appraisal of numerous hypothesized deepwater port investments for crude petroleum and iron ore imports, and for coal and grain exports, is designed to serve three major purposes:

1. To indicate a possible analytic approach to any specific deepwater port project

2. To determine whether and to what degree further investigation of deepwater ports generally appears warranted

3. To identify possible location, design, and other characteristics among alternatives which appear relatively more attractive than others.

The significance of the analysis is subject to three major qualifications. First, only a limited number of basic investment alternatives is considered. However, for each selected site, varied assumptions are made for such major variables as water depth, vessel size, port design, annual throughputs, and comparative base concepts. Thus, 148 benefit-cost ratios for crude petroleum facilities, and 23 for dry bulk port concepts, have been made, each at discount rates of 5, 7 and 10 percent.

Second, benefit-cost calculations reflect numerous simplifying assumptions. They should accordingly be taken as very general order-of-magnitude indications of feasibility.

Third, only some major elements of benefit and cost are quantified. Measured benefits are defined as estimated "savings" in ocean shipping costs, net of any required vessel transshipments. Costs are defined as estimated investment, operating, and maintenance costs of new deepwater ports, including any pipelines. They thus exclude costs which may be required at refinery terminals either in the base situation or under deepwater port concepts requiring vessel transshipments; allowance among port alternatives for differential impacts on vessel traffic in possibly congested waterways; or environmental implications. Exclusion of these elements is believed to have negligible significance for dry bulk port investments studied.

Two base situations are used to compute benefits: (1) the use of ocean vessels with drafts restricted by existing channel dimensions; and (2) the use of larger ocean vessels which offload in deeper water into barges. These appear to be most relevant, but other base situations are also worthy of consideration.

Major assumptions underlying the benefit-cost analysis include:

1. All ports have a life cycle of 30 years (1980 through 2009)

2. All ocean vessels operate under foreign flags (except for crude imports from Alaska to the west coast) and at a 50-percent load factor, normally with full cargo in one direction and return in ballast

3. Under all deepwater port concepts and corresponding base situations, loaded drafts of all ocean vessels correspond to the maximum permissible draft available at each relevant port or lightering area

4. For crude petroleum imports, restricted-draft vessel designs permit maximum feasible cargo capacity and lowest feasible unit costs in each case.

<u>Crude Petroleum Findings</u>

All hypothesized deepwater port investments for the east coast, the gulf coast, and southern California, as well as some port development concepts for northern California, are at least marginally feasible. Several offer exceptionally high returns on the basis of measured benefits and costs, as suggested in table 4. The wide range of values shown there reflects alternative assumptions on key variables indicated above.

Tentative findings on specific port investment choices within each coastal region are detailed in Annex F, chapter I. Only such general findings as can be made on the basis of the limited investigation of specific alternatives analyzed are summarized here.

1. Apparently attractive deepwater port investment alternatives are available to serve crude petroleum imports in all three coastal regions. More detailed study of the more promising ones uncovered by this report, and perhaps others not analyzed here, therefore seems warranted.

2. Benefit-cost ratios are generally most favorable on the gulf coast, somewhat less favorable on the east coast, and decidedly less favorable on the west coast (especially northern California).

3. The issue of the optimum number of deepwater ports for crude petroleum importation is partially clarified by the results of this study. Limited appraisal of interregional transfer costs for petroleum suggests great economic advantages to separate accommodation of crude imports by broad coastal region. Thus, east coast markets would have to pay substantial penalties for petroleum shipped to the gulf, refined, and transshipped to the east coast, as against ocean shipment of crude to the east coast and local refining.

<u>Within</u> coastal regions, however, the optimal number of deepwater ports appears highly sensitive to specific conditions meriting further analysis. Thus, benefit-cost ratios of the alternatives appraised in this study suggest that a single deepwater port serving

Table 4. Range of Benefit-Cost Ratios for Crude Petroleum Deepwater Ports Analyzed by Coast, by Concept, and by Assumed Base Situation at 10-Percent Discount Rate[a/]

Port location and concept	Base situation assumed	
	Lightering	No lightering
East coast (all 70-foot draft)		
New York local...........	1.28-2.25	2.50-4.45
Delaware Bay local.......	1.94-2.85	6.14-9.30
East coast regional:		
Single facility.........	1.33-3.45	5.14-9.86
Two facilities..........	1.64-2.63	4.51-7.50
Gulf coast (all single facilities)		
55-foot draft............	b/	4.46-10.35
70-foot draft............	b/	5.44-13.06
95-foot draft............	b/	4.24-13.60
West coast		
Southern California local.	b/	3.40-4.01
Northern California local.	0.51-1.25	1.12-3.85
West coast regional:		
Single facility..........	0.73-1.49	1.01-2.68
Two facilities...........	0.91-2.12	1.43-3.92

a/ Corresponding values at 5 percent and 7 percent discount rates are uniformly higher but do not affect the relationships shown.
b/ Suitability of lightering and appropriate locations and conditions uncertain.

Source: Annex F, chapter I.

all major east coast refineries is economically preferable to two separate facilities serving the major refining centers in the New York and Delaware Bay areas, respectively. On the other hand, two separate investments serving the dominant northern and southern California markets and refinery concentrations appear more advantageous than a single integrated facility designed to serve both of them.

Since only regionally integrated deepwater ports on the gulf coast were analyzed in this study, further investigation will be necessary to determine whether two or more separate ones offer economic advantages.

4. The absolute, as well as relative, investment feasibility of offshore deepwater port alternatives which provide pipeline rather than vessel transshipment to refinery terminals would be higher, and perhaps much higher, if allowance were made for the favorable impact on vessel traffic and on risks of accident in possibly congested waterways, as well as on reduced needs for terminal improvements at refineries.

5. Resort to relatively large tankers for importing crude petroleum to deepwater anchorages not far from refineries, with offloading to smaller transshipment vessels, offers an opportunity to substantially reduce total transport costs without incurring major investments in new port facilities. However, this approach, if pursued on a large scale, raises major questions of environmental risk and of traffic control which may be worthy of further analysis. However, even if general resort to lightering were considered acceptable, many possible deepwater port investments studied would still be relatively attractive.

Dry Bulk Findings

The investment feasibility of entirely new transshipment terminals to evacuate coal from Hampton Roads and cereals from the gulf coast, as well as for accommodation of iron ore imports to both east and gulf coasts, has been broadly considered. All coal and cereal exports to major markets (Western Europe and Japan), and all iron ore imports to the U.S. gulf and east coasts, are assumed to warrant shipment in 250,000-d.w.t. supercarriers on all relevant links where savings in ocean shipping costs (net of vessel transshipment costs) can be attained. In addition, cereal exports were assumed in the alternative to be shipped uniformly in 120,000-d.w.t. vessels under the same conditions.

Despite those highly optimistic assumptions, all tested deepwater port concepts were found to have decidedly unfavorable benefit-cost ratios, which ranged from 0.11 to 0.61 at a 10-percent discount rate. Those ratios would be even lower if more conservative ship size projections were made. This very different result in relation to transshipment terminals for crude petroleum imports reflects the combined effect of four factors:

1. Dry bulk transshipment terminals have much smaller throughputs over their entire life cycles

2. They offer smaller average savings in ocean shipping costs per ton because link distances are typically shorter or require large vessels to make circuitous movements (e.g., Panama Canal constraint)

3. They incur significantly greater investment, maintenance, and operating costs per ton of cargo handled, mostly because dry bulk storage and handling facilities are inherently more expensive and partly because of smaller throughputs

4. They usually require higher unit transshipment costs because the pipeline alternative is unfeasible and vessel transshipment imposes inherently more costly handling.

The preceding findings as to dry bulk transshipment terminals do not apply to the single investment alternative considered which involves deepening of an existing port. That alternative, which calls for deepening of channels serving Hampton Roads to permit the use of vessels drawing 52 feet instead of the present 42 feet, does not have to bear substantial costs for construction and operation of new storage and handling facilities and for vessel transshipment. Measured benefits are 1.6 to 2.2 times measured costs, depending upon one's choice of vessel design characteristics. Results may be sensitive to the crudely projected ship size distributions, but they are much more conservative than for all hypothesized dry bulk transshipment terminals. This improvement therefore seems worthy of more detailed study.

IX. DISTRIBUTION OF MEASURED BENEFITS AND SECONDARY EFFECTS

Two broad issues related to the economic evaluation of port alternatives need to be considered. One is concerned with the distribution of the measured net benefits; the other, with the possible secondary economic effects associated with or induced by net savings in transportation costs or deepwater ports as such.

Distribution of Measured Net Benefits

The central question with regard to the distribution of measured transport savings is whether a reduction in the real economic costs of the transport of crude petroleum[1] to U.S. refineries would result in an equivalent or lesser net benefit to the U.S. economy in the form of reduced petroleum import costs. A second question is how, if such benefits are realized by the U.S. economy, they might be distributed within the economy.

Definitive answers to these questions are not possible. However, some discussion of the elements that may influence the distribution of net benefits may be helpful.

At least two possibilities suggest themselves for the diversion of transportation net benefits from the

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1/ Petroleum is the only commodity of significance to this question.

U.S. economy. These are: (1) a higher f.o.b. price for crude petroleum at foreign ports of shipment than would otherwise apply; and (2) an increase in the net profit of the tanker owner or operator.

F.o.b. prices for crude petroleum are increasingly influenced by the tax policies of the petroleum-producing countries, acting in concert through the Organization for Petroleum Exporting Countries. There were substantial increases in taxes in 1971, and further increases are anticipated. It is conceivable that tax demands in the long run will reach a limit set by the cost of developing alternative sources of petroleum, or other forms of energy, in petroleum-importing countries. This could be an important consideration in the United States, which promises to emerge as one of the major markets and which has energy resources that can be exploited at higher prices.

If the tax policies of the exporting countries test such economic limits and delivered costs of U.S. crude petroleum imports reach the level of competitive energy sources in the United States, irrespective of transport costs, transport savings would in effect be absorbed by the producing countries.

Of course there is no way of reliably assessing the prospects of such a development. The determination of crude petroleum prices is an intricate process in which both producing countries and producing companies play an important role. Furthermore, both are concerned with the impact of prices on the total world market, of which the United States will be an important part.

The absorption of transport savings by the ocean shipping industry in the form of increased profits appears to be a very remote possibility because of its highly competitive nature. In the long run, charter rates for bulk carriers approximate real economic costs.

If net savings in transport costs are realized by the United States in the form of reduced delivered costs of crude petroleum, they could result in lower consumer prices for petroleum products, higher profit margins for refiners and distributors, or both. Given the competitive nature of the petroleum industry and the expectation that imported crude petroleum would be a major source of supply for most refiners in major marketing areas, it appears likely that real cost savings would ultimately be reflected in the level of consumer prices.

The United States should be concerned with the issue of measured benefit distribution in formulating deepwater port policy. At a minimum it should insure the recovery of port costs and the costs of environmental protection. This can be accomplished by the assessment of user charges at the ports. Beyond this the user charge may be a means of recovering for the U.S. economy some limited part of the balance of transport savings. However, the way in which charges above port costs are to be distributed would have to be considered.

Secondary Economic Effects

Secondary economic effects may be induced or generated by savings in transport costs for bulk commodity imports and exports, and by the operation of the deepwater port facilities. Such effects would take the form of net increases in national output and employment. There may also be an impact on the U.S. balance of international payments.

Changes in national output and employment might occur in (1) the production of bulk commodities for export; (2) the production of products either for internal consumption or for export, utilizing the import bulk commodities; and (3) the output of other goods and services.

The most readily identifiable relationship between deepwater ports and national and regional output and employment pertains to the refining of crude petroleum. As discussed elsewhere, the petroleum industry, lacking deepwater port facilities in the United States, is tending to establish refineries at deepwater ports at nearby locations outside the United States and to ship products to the United States. Thus, refining capacity which might otherwise be constructed in the United States is being exported. The United States is being denied the benefits of output and employment in such refining capacity, as well as of secondary industries such as petrochemical plants. How much refining capacity will be exported if no deepwater port facilities are established in the United States is not known, but there presumably would be some limits.

If petroleum deepwater port facilities are provided at appropriate places and under appropriate conditions, it appears reasonable to anticipate that the export of refining capacity would be quite limited. The location of additions to refinery capacity and of secondary industries in the United States may be influenced by the location of deepwater ports. Thus, there is a direct relationship between the locational characteristics of the ports and regional output and employment.

Other than these impacts on crude petroleum refining and related secondary industrial activity, changes in the production of bulk commodities for export or in the production of products utilizing imported bulk commodities are not readily identifiable or predictable. On the whole, potential transport savings for dry bulk commodities are relatively unimportant compared with the import of crude petroleum. The potential impact of net transport savings on the volume of exports, or on the output and locational characteristics of consuming industries, cannot be quantified but is subject to a number of constraints.

U.S. steam coal is not competitive with other sources of energy in most foreign markets, and its future competitive relationship is unpredictable, irrespective of marginal differences in ocean transport costs. U.S. metallurgical coal producers have a quasi-monopoly in the principal foreign markets for the grades and qualities which constitute the bulk of our exports. In the long run, potential savings in transport costs would not appear to be a critical determinant of the volume of U.S. exports of such coals.

The situation with respect to feed grains and soybeans and meal is somewhat similar to that of metallurgical coal, in the sense that the United States appears to have a superior agricultural resource base to competitive sources of supply. There is the further consideration that the volume and price of U.S. exports of agricultural commodities are heavily influenced by U.S. internal agricultural policy.

On the other hand, foreign markets for U.S. phosphate rock are believed to be highly sensitive to changes in delivered costs relative to other supply sources. Export volumes may, therefore, be favorably influenced by potential transport savings.

It is not anticipated that either the level of U.S. steel production or the location of a steel plant in the United States will be perceptibly influenced by potential savings in ocean transport costs for waterborne imported iron ore. A similar conclusion is indicated with respect to the effect of potential transport savings in the import of alumina and bauxite on the level of activity in the aluminum industry and on the location of aluminum plants.

Changes in output of other goods and services would be the tertiary benefit of the changes in national and regional output employment discussed above, and those induced by a reduction in internal prices. If, for example, average annual transport savings of roughly $1 billion were to be reflected in reduced prices for petroleum products, it would have the effect of increasing demand for other goods and services with consequent effects on economic activity.

The impact of ocean transport savings on the balance of international payments is not readily determinable. Considering the question in terms of imports of crude petroleum, it would depend in the first instance on the proportion to be carried in U.S.-flag vessels. For imports in foreign-flag vessels, there would nominally be a reduction in U.S. payments for foreign-flag services equivalent to the reduction in transport costs. However, there is no certainty, given the vertically integrated and international characteristics of the petroleum industry, that all such payments would be made in dollars, or that they might not be offset by other foreign exchange transactions of the petroleum companies and their subsidiaries.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Robert R. Nathan Associates, Inc. 1200 Eighteenth St. N. W. Washington, D. C. 20036	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP NA

3 REPORT TITLE

U. S. Deep Water Port Study

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report

5 AUTHOR(S) (First name, middle initial, last name) Ralph L. Trisko, Philip Cheney, Jacobus de Rover, Jeremy C. Ulin, and B. Ahnert, Lee Bertman, James Cavin, Marcella Czarnecki, Edmund Getzin, Dieter Harper, Orest Koropecky, James Leonard, Richard Maurice, and Harold Wein

6 REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
August 1972		

8a. CONTRACT OR GRANT NO. DACW 31-71-C-0045 b. PROJECT NO. NA c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) IWR Report 72-8 (in 5 volumes) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) None

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale, its distribution is unlimited.

11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY U. S. Army Engineer Institute for Water Resources, Alexandria, Virginia 22314

13. ABSTRACT

This report provides an overall appraisal of deep port needs for the United States by means of identification of the factors critical to U. S. deepwater port decision; development of criteria appropriate to the evaluation of engineering, economic and environmental aspects of deep port needs and policies, analysis of the development options available at this time and the critical issues surrounding each and the identification of critical issues which need further analysis. The study emphasizes port requirements for bulk commodities.

Volume 1 contains the Summary Report
Volume II contains Commodity Studies and Projections
Volume III contains Physical Coast and Port Characteristics, and Selected Deepwater Port Alternatives
Volume IV contains The Environmental and Ecological Aspects of Deepwater Ports
Volume V contains Transport of Bulk Commodities and Benefit-Cost Relationships

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Security Classification

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Commodity Studies, Projections, Deepwater Port Alternatives, Transport Costs, Benefit-Cost Analysis, Secondary Economic Benefits, Environment and Ecology of Deep Ports						

Security Classification