National Waterways Study □ National Waterways Study — A Framework for Decision Making — Final Report

National Waterways Study– A Framework for Decision Making– Final Report

National Waterways Study □ U. S. Army Engineer Water Resources Support Center □ Institute for Water Resources

AUTHORITY FOR THE NATIONAL WATERWAYS STUDY

The Congress authorized the National Waterways Study (NWS) and provided the instructions for its conduct in Section 158 of the Water Resources Development Act of 1976 (Public Law 94–587):

> The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a comprehensive study and report on the system of waterway improvements under his jurisdiction. The study shall include a review of the existing system and its capability for meeting the national needs including emergency and defense requirements and an appraisal of additional improvements necessary to optimize the system and its intermodal characteristics. The Secretary of the Army, acting through the Chief of Engineers, shall submit a report to Congress on this study within three years after funds are first appropriated and made available for the study, together with his recommendations. The Secretary of the Army, acting through the Chief of Engineers, shall upon request, from time to time, make available to the National Transportation Policy Study Commission established by Section 154 of Public Law 94–280, the information and other data developed as a result of the study.

NATIONAL WATERWAYS STUDY- A FRAMEWORK FOR DECISION MAKING- FINAL REPORT

January 1983
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National Waterways Study □ U.S. Army Engineer Water Resources Support Center □ Institute for Water Resources

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FOREWORD

Section 158 of the Water Resources Development Act of 1976 directs the Secretary of the Army, acting through the Chief of Engineers, to prepare a report which reviews the capability of the existing system for meeting navigation needs, including defense and emergency requirements and make recommendations to insure that existing and future needs will be met. The nation's waterways — inland, intracoastal, coastal and Great Lakes — have served domestic and foreign policy objectives for over 200 years. In recent years the waterways have served to enhance U.S. policies of energy self sufficiency, agricultural export promotion, as well as provide support for the general economy and the nation's security. The Corps of Engineers has directly contributed to the development and realization of this waterways system since its first assignment to improve rivers and harbors in 1824. This report is the first nationwide study of the national waterways since 1908, when Theodore Roosevelt's Inland Waterways Commission reported its findings, conclusions and recommendations.

The waterways capability to serve future traffic is affected by the structural integrity of a progressively aging and more intensively used system. Future traffic demanding service on the waterways is expected to continue to be large volume shipments of low unit value bulk commodities which generally move over long distances. Overall, traffic is expected to increase from 24 to 51 percent during the 25-year forecast period (1978-2003). Coal and grain will dominate the growth nationally. The aging lock structures requiring major rehabilitation, replacement or supplementation to maintain safe, reliable and efficient performance, are major factors influencing capability of the waterways system through the remainder of this century and into the next. Congestion due to limited capacity is estimated to potentially increase the waterborne freight bill by over $1 billion annually by the year 2003 unless added capacity is provided. The National Waterways Study (NWS) finds that 62 U.S. locks and 8 Canadian locks should be modernized — renovated, replaced and/or supplemented — in the next 20 years. Additionally, channel work in a limited number of waterways and in coastal channels is found to be beneficial in achieving economical operation of equipment.

Costs estimated in 1982 dollars to complete the U.S. navigation projects under construction in 1981 are $2.9 billion. Based upon NWS criteria another $8.9 billion is estimated for inland waterway modernization with an additional $1.8 billion for deep draft ports. The total navigation investment from 1982 through 2003 is estimated at $13.6 billion.

Waterways problems identified during a hypothesized war of 5 years duration are situated on several reaches of the U.S. waterways. The Great Lakes and U.S. coastal reaches in particular face peak loadings of domestic ore and petroleum traffic, respectively, while inland, the Ohio River, Illinois Waterway, Lower Upper Mississippi River and Mobile River and Tributaries reaches face wartime-induced growth of a much broader mix of industrial support commodities. This additional traffic exacerbates known problems associated with the aging and in most cases, already congested lock structures. Generally, the need for waterways service in the nation's defense is for adequately maintained coastal channels to support rapid deployment of men and materiel and for reliable inland, intracoastal and Great Lakes reaches with sufficient capacity to transport commodities necessary for wartime industrial mobilization.

The NWS findings, conclusions and their implications for decision makers cover a wide breadth of areas. Below are several conclusions and their implications which are key to the nation's achievement of a modern water transportation system and consequently, to the nation's economic revitalization:

— FUNDS for capital expenditures to solve U.S. navigation problems as identified by NWS, would require a doubling over the 1970s level. Historic levels should be increased to provide for a safe, reliable and efficient water transportation system.

— WATER'S MULTIPURPOSE USE requires navigation planning to continue to focus on the multipurpose needs, not solely navigation.

— DEFENSE: The U.S. waterways provide a key support for industrial base mobilization in times of war. The coastal channels are indispensable for successful rapid deployment and resupply. All waterways require modern facilities and equipment such as locks, dams, and dredges capable of withstanding unpredictable surges in use. Waterway planning should directly address these defense needs.

— STREAMLINED PROCESSING: The everlengthening time span from study authorization through construction should be markedly shortened to insure a viable waterways system.

— FRAMEWORK OF ACTIONS FOR WATERWAYS developed within NWS provides the point of departure for setting funding priorities subject to future traffic, needs, physical conditions and national objectives.

— AN ACHIEVABLE MODERNIZATION PROGRAM for the mature Water Transportation System requires timely adoption if the nation's long term economic revitalization is to be achieved.

It is important to recognize that the National Waterways Study is a national scope framework study. It did not involve performance of systematic, economic, engineering and environmental analyses which are required for recommending authorization of specific improvements.

TABLE OF CONTENTS

ENVIRONMENTAL ASSESSMENT

APPENDICES

TABLES

FIGURES

SUMMARY

SUMMARY

BACKGROUND

From its beginning, the nation has looked to its waterways as a vital natural and commercial resource, guiding its westward development and shaping its role as the world's dominant industrial force. The U.S. Army Corps of Engineers has played an important role in managing this resource by executing the national policies which have maintained an unimpeded flow of foreign and domestic commerce and by managing the use of the waterways for a broad range of public and private purposes.

The waterways and ports displayed in Figures S–1 and S–2 have served the nation well, promoting national development, wealth and defense. The role of transportation in the U.S. economy has gradually changed in response to the shifts in population and in industrial production, the expansion of agriculture, and a growing national dependence upon foreign trade. The strategic role of the waterways in this dynamic interaction of production and distribution also has changed.

The free flow of commerce was a paramount objective in the earliest days of the nation. The Commerce Clause of the Constitution provided the basis for establishment of the Federal interest in the ports and waterways. The Ordinance of 1787 and other acts of Congress emphasized the importance of unimpeded access to the waterways for all users on an equal basis.

Today, there are over 25,000 miles of inland, intracostal and coastal waterways in the United States. Of these, the modern waterways system includes 11,000 miles of shallow draft channels (9–17 feet) and another 1,000 miles of deep draft channels (18 feet or greater). Over 200 lock and dam sites, in addition to thousands of training structures, are located throughout the modern system.

In reviewing the development of the waterway system over the past 200 years, Congress determined that there was a need for a more comprehensive analysis of the waterway system from a national perspective. Its concerns included the serious constraints that exist on the efficient use of our principal waterways, the fact that it was an aging system with increasing maintenance and rehabilitation problems, and the changing trends in world and U.S. trade, particularly in coal and agricultural commodities. Through Section 158 of the Water Resources Development Act of 1976, Congress directed the Secretary of the Army, acting through the Chief of Engineers, to prepare a National Waterways Study to review the capacity of the existing system for meeting a variety of national goals and objectives.

In undertaking this study, the Corps set forth a framework for critical decisions that will enable the nation to enter the 21st century with a strong and viable national waterway system.

TRAFFIC PROJECTIONS

In order to determine potential system needs, the National Waterways Study (NWS) projected unconstrained waterborne commerce under seven scenarios specifically constructed to show the wide range of potential conditions and events that might impact on future use of the waterways. None of the scenarios considered increases in user-charges beyond the fuel tax specified in P.L. 95–502.

Based on these scenarios, increases for total waterborne traffic ranging between 24 and 51 percent were projected for the period 1977 through 2003. The four leading growth commodity groups and their maximum potential growth include:

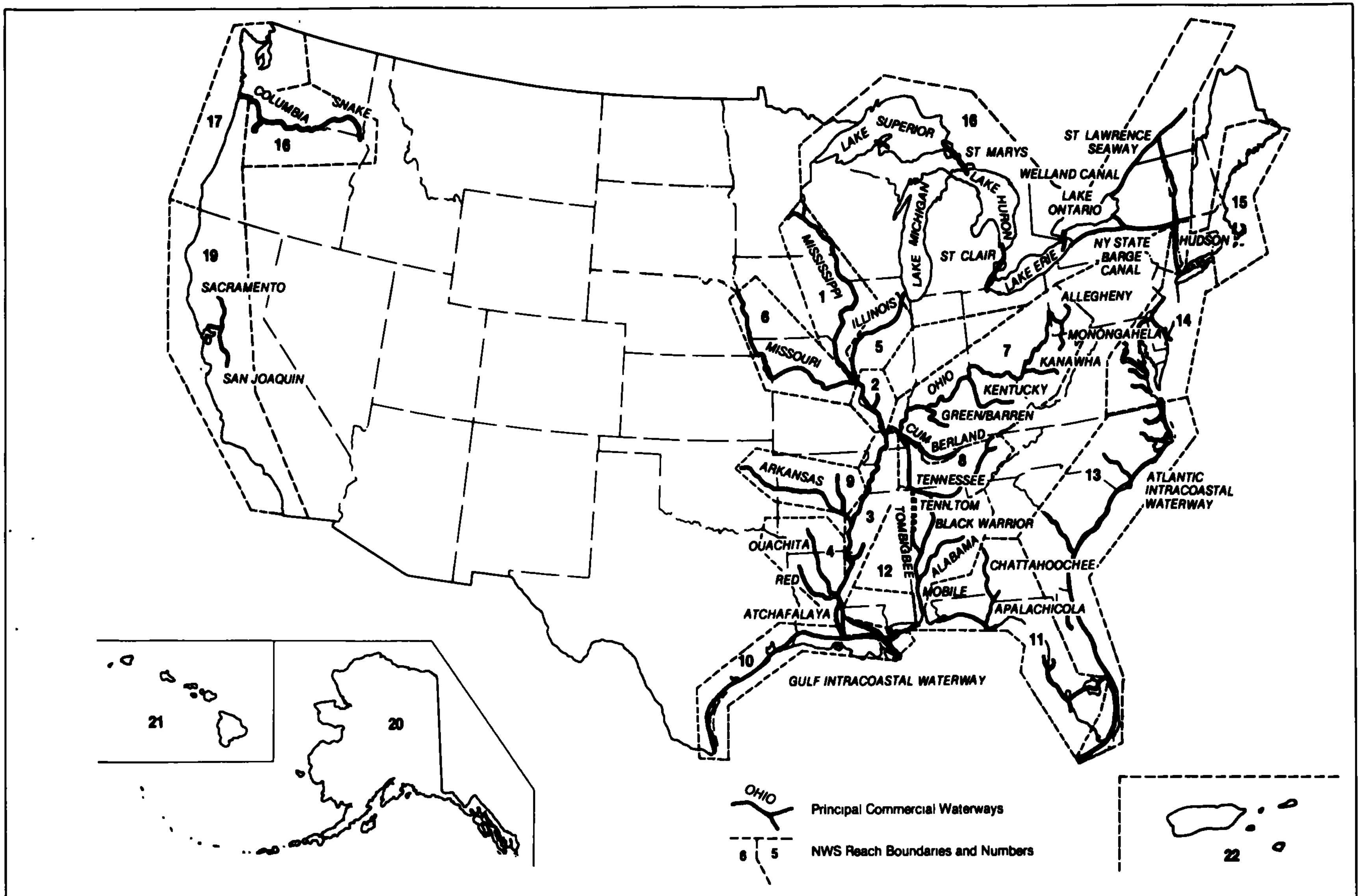
— Coal	280%
— Agricultural Products	127%
— Metals and Ores	112%
— Chemicals/Fertilizers	83%

In contrast, petroleum is projected to decline by as much as 37 percent between 1977 and 2003. With the increased emphasis on coal, domestic traffic in energy products begins to grow at an increasing rate as foreign imports of petroleum decline. Figure S-3 presents one set of these projections.

Coal is forecast to make up 24 percent of the nation's waterborne commerce by 2003, up from 11 percent in 1977. Agricultural products and metals and ores account for the next largest increase; the former is expected to grow from 11 to 17 percent of total traffic, while the latter is expected to grow from 8 to 11 percent during the same period.

The number one growth leader geographically, in terms of total tonnage by 2003, is the Lower Mississippi River, south of Baton Rouge. Agricultural product exports play a key role in the growth within this reach. For purposes of this study the waterways were organized by reaches, see Figure S–1. Metal and ores play a corresponding role on the second ranking reach, the Great Lakes System. Growth in the third and fourth ranked reaches — the Ohio River System and the Mobile River and Tributaries — is based on expected increases in the transport of coal.

Figure S-1
NATIONAL WATERWAYS

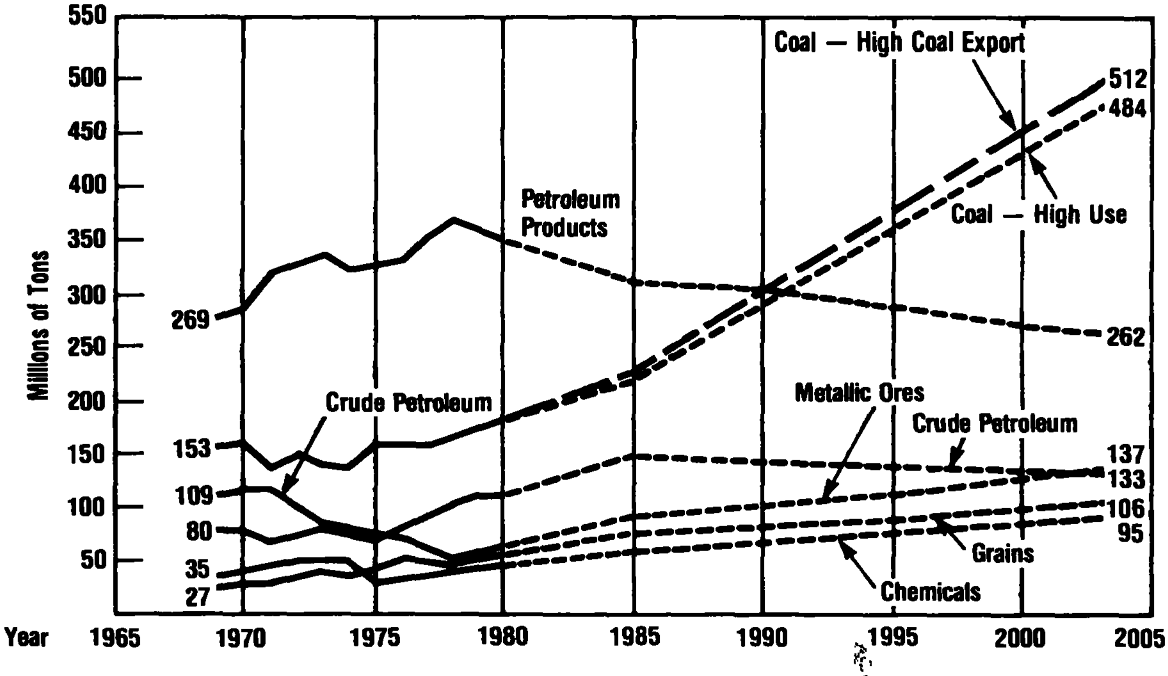


1. Upper Mississippi River
2. Lower Upper Mississippi River
3. Lower Mississippi River: Cairo to Baton Rouge
4. Lower Mississippi River: Baton Rouge to Gulf
5. Illinois Waterway
6. Missouri River
7. Ohio River System
8. Tennessee River
9. Arkansas River
10. Gulf Coast - West
11. Gulf Coast - East
12. Mobile River and Tributaries
13. South Atlantic Coast
14. Middle Atlantic Coast
15. North Atlantic Coast
16. Great Lakes System
17. Washington/Oregon Coast
18. Columbia - Snake Waterway/Willamette River
19. California Coast
20. Alaska
21. Hawaii and Pacific Territories
22. Caribbean

Figure S- 2
INLAND, COASTAL AND GREAT LAKES PORTS (Handling Over 5 Million Tons)

Figure S - 3

MAJOR COMMODITIES IN U.S. DOMESTIC WATERBORNE COMMERCE HISTORICAL AND PROJECTED (HIGH USE AND HIGH COAL EXPORT SCENARIO), 1969-2003



The requirements of maintaining a viable waterway system for national defense purposes were given special consideration in one NWS scenario. This scenario is based on the logistic requirements of a 5-year, two-front conflict. Under these assumptions, the Great Lakes system would dominate in terms of total traffic increases. The nation, during the hypothetical conflict, would use more of domestic iron ore, thereby raising the importance of the Great Lakes. And, to make up for the potential interruption in foreign petroleum shipments, U.S. refineries would need to rely upon coastal waterways as a route for shipments of crude oil fom Alaska and other Western Hemisphere sources.

Figure S–4 presents the range of lowest to highest projections (excluding those prepared for the Defense scenario) for total and foreign traffic. The lowest projections developed for the NWS provide a reasonable lower bound for traffic growth

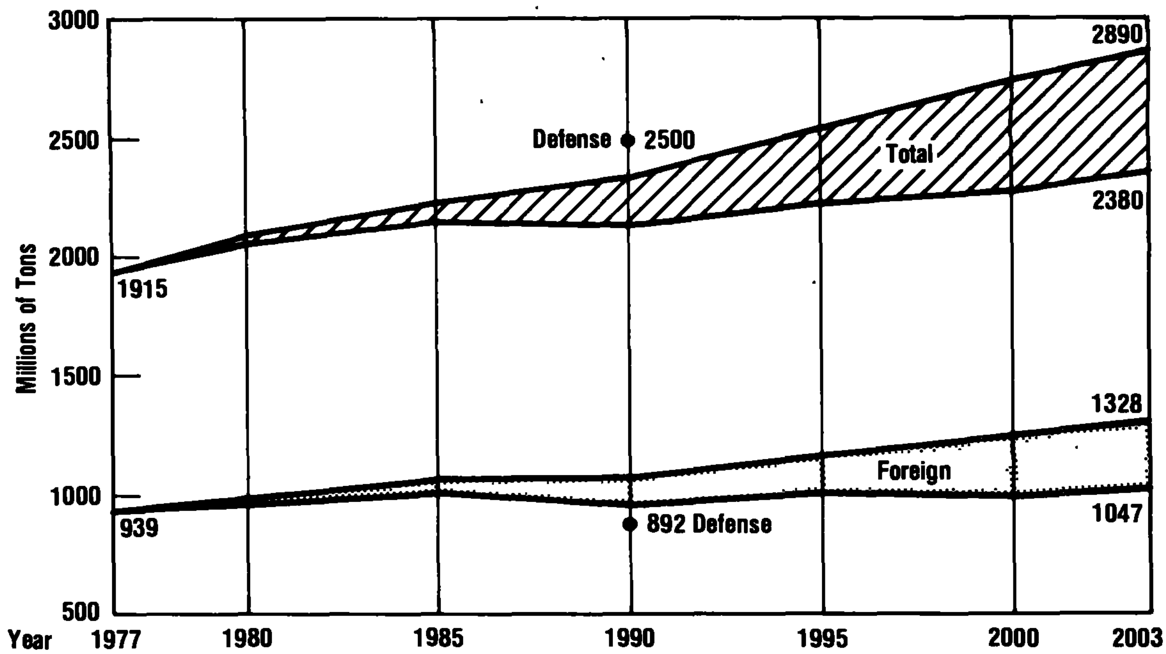
SYSTEM CAPABILITY

The potential water transportation-related problems addressed in NWS were classified as those associated with increasing age and technological obsolescence of facilities in the system and those due to limited system capacity. These problems are summarized in Table S–1.

The most common problem limiting capability of the waterway system is that of aging locks for which projected traffic levels will either exceed physical lock capacity or result in severe delays. Aging, coupled with obsolescence, increases the likelihood that some locks may go out of service during critical use periods. A few newer locks are expected to experience significant congestion and delays because of capacity limitations. Seventy locks are candidates for major renovation or replacement. Forty-four of those locks are probable sources of significant congestion and delay. Early in the 21st century, if high levels of coal traffic materialize, capacity beyond that available within two locks may be required on the Ohio River System.

Several coastal ports may require deepening to facilitate the loading of vessels in excess of 100,000 deadweight tons (DWT), if the potential foreign markets for U.S. coal are to be fully developed. Draft restrictions in Eastern and Gulf coast ports limit utilization of the most cost effective vessels which can access many foreign ports.

Figure S-4
U.S. WATERBORNE COMMERCE, 1977-2003



INDUSTRIAL MOBILIZATION—SUPPORT FOR MILITARY GOODS PRODUCTION

Waterways historically have been a critical element of the U.S. transportation system, which provides for the rapid expansion of the industrial base in support of the nation's defense. The industrial base necessary for defense mobilization was defined by Defense Mobilization Order No. 23, issued by the Director of Defense Mobilization on November 23, 1953:

> The mobilization base is that capacity available to permit rapid expansion of production, sufficient to meet military, war supporting, essential civilian, and export requirements in event of a full-scale war. It includes such elements as essential services, food, raw materials, facilities, production, equipment, organization and manpower.

Success of a nation in military conflict is dependent on safe, reliable transportation of input material for production, as well as delivery of final products. A study of the potential movements of production materials by water strongly suggests that waterways will continue to be the prime and critical mover of bulk commodities during times of industrial mobilization.

The NWS evaluated the contribution that the waterway system could make to mobilizing strategic materials for a two-front overseas war of five years duration. The analysis was based on an assumption of mobilization beginning in 1985 and ending in 1990. The Defense scenario is described in Appendix A to the NWS technical report, *Evaluation of the Present Navigation System*. The scenario envisions that steel mill production, grain exports, oil imports, domestic oil shipments, chemical movements, and other waterway commodity flows would be significantly affected. The scenario projects increases in domestic movements of metals and ores of over 140 percent, and in domestic petroleum flows of over 200 percent. In addition, domestic chemical flows are forecast to increase by over 20 percent and domestic agricultural and coal flows are forecast to increase by over 10 percent. The scenario assumes that foreign sources of strategic bulk commodities would be restricted, causing shifts to Western Hemisphere sources, affecting particularly Great Lakes and coastal waterways traffic.

Waterways problems identified during a hypothesized war of five years duration are situated on several reaches of the U.S. waterways. The Great Lakes and U.S. coastal reaches, respectively, face peak loadings of ores and petroleum. The Ohio River, Illinois Waterway, Lower Upper Mississippi River and Mobile River and Tributaries reaches face wartime-induced growth of a much broader mix of industrial support commodities. These traffic surges exacerbate problems associated with the aging and already congested lock structures.

Table S–1

WATER TRANSPORTATION PROBLEMS AND FORECAST MAXIMUM NEEDS THROUGH THE YEAR 2003

Reliability
- 105 locks (97 U.S. and 8 Canadian) are over 50 years old/or technologically obsolete (56 of these have substantial commercial use and 30 of the 56 are forecast to be at or near capacity by 2003).
- Dredging and material disposal restrictions impede maintenance.

Safety
- 210 sites with hazardous navigation conditions, include 12 lock related problems.

Efficiency
- 44 locks (36 U.S. and 8 Canadian) are congested (30 of these also pose reliability problems).
- 37 percent increase in domestic linehaul costs from 1977 to 2003 will occur in the absence of system improvements.
- Absence of deep draft ports (50-55 feet) on Gulf and Atlantic coasts reduces competitive position of the U.S. in world trade.
- Agricultural products and coal are most affected by efficiency-related problems.

Capacity
- 28 locks (20 U.S. and 8 Canadian) are forecast to constrain traffic physically (18 of these also pose reliability problems).
- Over 100 million tons are foreseen as not being handled by 2003 due to lock constraints.
- Agricultural products and coal are most affected by capacity limitations.

Defense[1]
- 70 million tons of commerce cannot be handled due to lock constraints.
- Metals and ores are most affected.
- Sault Ste. Marie lock site is a major bottleneck.
- 24 locks (16 U.S. and 8 Canadian) congest or constrain traffic.
- Traffic in coastal reaches increases drastically, principally petroleum.

1. Mobilization impact at the end of 5-year, 2-front conflict, ending in 1990

FRAMEWORK

A framework of potential improvements was developed, based on the premise of maintaining the capability of the waterway system to meet the projected needs for service. The framework emphasizes maintaining and achieving reliability and efficiency within the water transportation system. The summary framework presented in Table S–2 reflects forecast needs organized within closely interrelated portions of the waterway system. It is within those portions of the waterway system that the NWS needs are evaluated. The "earliest date" shown in Table S–2 is the date when any one project is forecast as being required This date highlights the need for process acceleration, that is, the need to shorten the current planning-construction process, which presently averages in excess of 15 years, in order to meet any given portion's earliest problem.

Aging lock structures requiring major rehabilitation, replacement or supplementation to maintain safe, reliable and efficient performance are major factors influencing the capability of the waterways system through the remainder of this century and into the next. By 2003, congestion due to limited capacity is estimated to increase the waterborne freight bill by over $1 billion annually. Based upon NWS physical evaluation parameters, 62 U.S. locks and 8 Canadian locks need to be considered for modernization — renovated, replaced and/or supplemented — in the next 20 years. Additionally, channel work in a limited number of waterways and in coastal channels would significantly contribute to achieving more efficient use of vessels and existing waterway structures.

Imposition of additional user fees and other changes in economic conditions may reduce traffic growth below the highest projection levels used to identify the capability limits of the waterway system in the NWS. If capability is assessed against the lowest NWS projections, the need for additional capacity at some sites would be delayed. Therefore, traffic should be monitored and projections systematically updated.

Costs, estimated in 1982 dollars, to complete the U.S. navigation projects currently under construction are $2.9 billion; another $8.9 billion is estimated for rehabilitation and improvement of the inland waterway system as shown in Table S-2.

Table S-2
SUMMARY FRAMEWORK — POTENTIAL INVESTMENT NEEDS[1]

Potential Investment Needs[2]		System Study[3]	Earliest Date Project Required[4]		Need for Process Acceleration[5]
Maintain	Improve		Aged	Congested	
L. Up. Miss.	Second Lock 26	Lock 26	—	1981	Yes
Great Lakes (3)	Sault Ste. Marie	Sault Ste. Marie	—	1990	Yes
Ohio River System and Tenn. R. (4)					
Gallipolis		Gallipolis	1985	1985	Yes
Emsworth Montgomery Dashields		Upper Ohio	1980	1990	Yes
Kentucky-Tenn.	McAlpine Newburgh Uniontown Lock 52 Lock 53 Deepen Channel	Lower Ohio and Tennessee	1995	1990	Yes
Monongahela-3, 4, 7 & 8		Monongahela	1980	—	Yes
Winfield-Kanawha Marmet-Kanawha		Kanawha	1985	—	No
Illinois Waterway (2) (4) and Lower Upper Miss. (3)					
Marseilles Peoria LaGrange Lockport Brandon Road Dresden Island Starved Rock	Lock 27	Illinois	1983	1985	Yes
Gulf Coast-West (2)					
Harvey Calcasieu	Algiers	Gulf Coast-West	1985	1995	No
Mobile River and Tributaries (1) (3)					
Oliver	Demopolis Coffeeville Warrior Holt Bankhead Channel Mod.	Mobile River and Trib.	1989	1990	Yes
Upper Mississippi (1) (3)					
Locks 2–17 Locks 18, 20–25		Upper Mississippi	1986	1990	Yes
Gulf Coast-East (0) (3)					
Inner Harbor		Inner Harbor	1980	1980	Yes
Columbia-Snake Waterway (0) (2)					
Bonneville		Bonneville	1987	1990	No

1 Based on consideration of four objectives — economics, energy, exports and defense, framework is for shallow draft and Great Lakes Waterway System

2 Reaches are listed according to number of times (first numeral in parentheses) each one is among the leading four contributors to the four national objectives. A second number (in parentheses), is shown only if different from the first, to reflect the total number of objectives the reach contributes significantly to, but need not be among the leading four contributors Projects are listed under the "maintain" column if the site includes a project which is both 50 years old and is heavily used by 2003 If the need involves projects which are less than 50 years old, but exhibit serious congestion by 2003, it is listed under "improve"

3 Studies are identified by the approximate geographical coverage, given the interrelationships between and within reaches.

4 Earliest date any one need in a closely interrelated group of projects is exceeded Need is expressed when a lock exceeds its 50 year engineering life (aged) or 80 percent utilization (congested)

5 The existing civil works process (median time of 15 years) as applied to any one project's status where that process requires process acceleration (Yes) or not (No) to meet the earliest forecast need

FINDINGS AND CONCLUSIONS

The National Waterways Study findings, conclusions and their implications for decision makers cover a wide breadth of areas. These findings will influence the nation's achievement of a modern water transportation system and consequently, the nation's economic revitalization.

TRAFFIC AND MODAL SHARES

Waterborne forecasts indicate a growth of between 24 and 51 percent from 1977 to 2003. Coal and grain are the chief contributors to this growth, increasing by as much as 280 and 127 percent, respectively. The Ohio River leads in total tonnage growth based on the High Coal Export scenario. In percentage terms, the Mobile River and Tributaries reach leads.

Rail is forecast to increase its share of the total movements of domestic commerce carried by three competing modes — rail, water and pipeline — from 39 to 48 percent by 2003. The share of domestic traffic moved by water is forecast to decline slightly from 28 to 26 percent, while that transported by pipeline drops from 33 to 26 percent.

WATERWAY CAPABILITY

Insufficient lock capacity at 28 locks, 20 U.S. and 8 Canadian, may restrict the transit of more than 100 million tons by 2003. An additional 16 locks are likely to reach significant delay levels. Increasing congestion due to capacity limitations will increase shippers' operating costs by nearly a billion dollars on the inland system and by another half-billion dollars on the Great Lakes by 2003.

The very large number of old (50 years old or more) structures, 97 U.S. locks by 2003, require a major program of site specific engineering and economic studies leading to resolution of a potentially major reliability crisis on the U.S. waterways.

Maintenance of the capability of the U.S. waterways will necessitate increased levels of funding for modernization of structures, possibily double the levels experienced in 1970s

DEFENSE

Traffic on the Great Lakes was forecast to increase by 137 million tons of traffic, a 45 percent increase over peacetime conditions, under the Defense scenario. This hypothesized surge resulted in a 70 million ton shortfall in lock capacity at the Sault Ste. Marie Locks. The eight heavily congested Welland Canal Locks (Canadian) were also forecast to remain congested under mobilization assumptions.

The U.S. waterways provide a key support for industrial base mobilization in times of war. The coastal channels are indispensable for successful rapid deployment and resupply. Defense and industrial mobilization considerations should be included in all future planning studies in the design of structural improvements and in the budget formulation process.

IMPEDIMENTS TO MAINTAINING AND IMPROVING WATERWAYS

The removal of physical constraints and the maintenance of a viable system of ports and waterways cannot be accomplished without first removing unnecessary administrative barriers. The time span from study authorization through construction averages 15 years, or more; procedural changes could reduce the time.

— Legislative authorization and appropriation processes are major contributory factors to this delay. As shown in Figure S–5, they consume almost half of the elapsed time for projects.

— Dredging and dredge material disposal have become increasingly complex due to the mix of restrictions associated with environmental and other regulatory policies. The Federal responsibility under the Interstate Commerce Clause requires that the Federal Government maintain waterways for free flow of interstate commerce. The rapidly increasing costs of dredging and disposal of dredged material in the 1970s, however, were linked to environmental and other regulatory policies, and to increasing fuel prices.

POLICY IMPLICATIONS OF THE NWS

Two major categories of policy change are required if the United States waterways system is to be maintained as an effective transportation system into the 21st century: the first, in maintaining support capability for waterway system decisions, and the second, in making administrative changes to encourage and allow more timely actions.

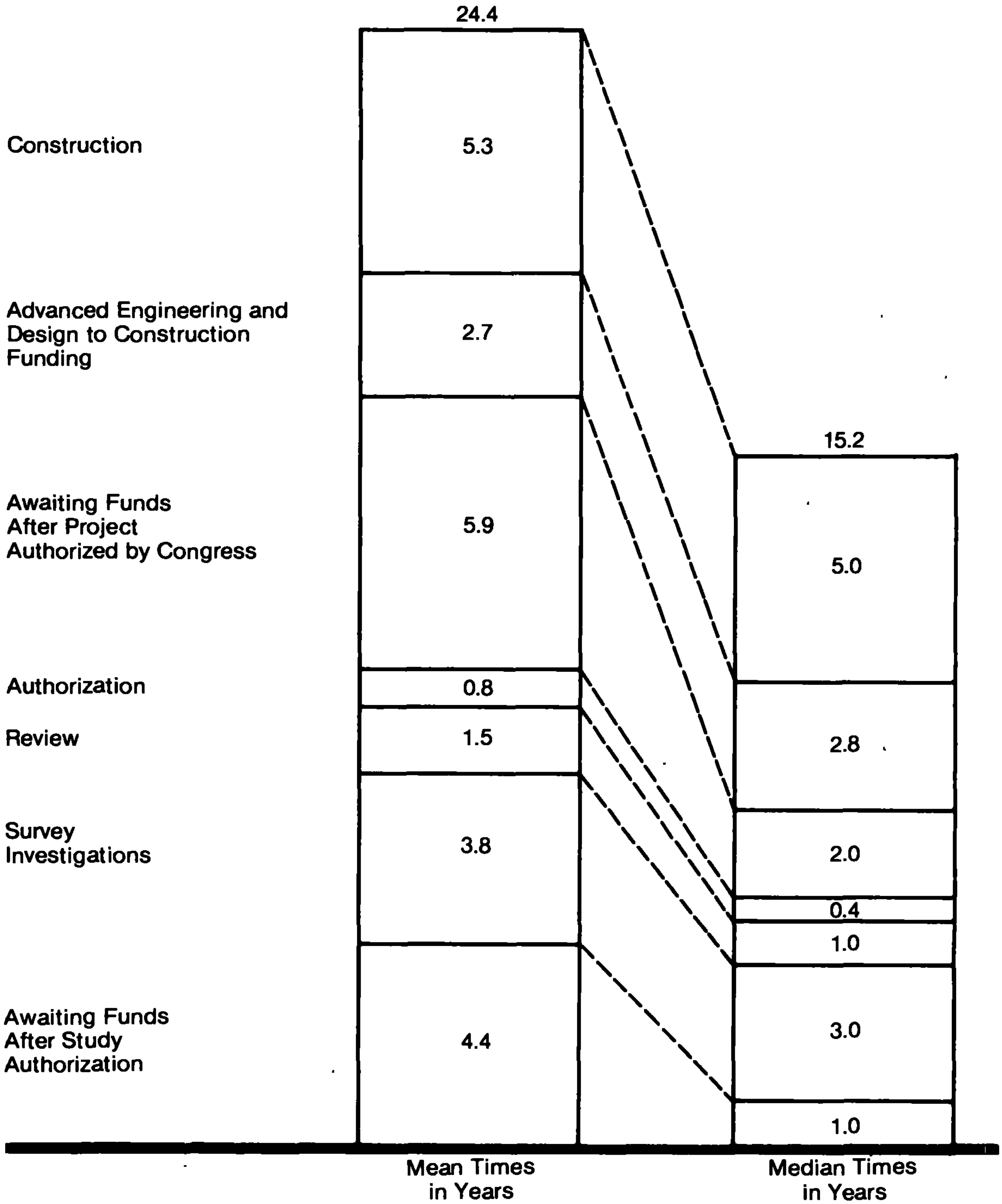
SUPPORT FOR WATERWAY SYSTEM DECISIONS

The National Waterways Study may be used to identify an early action phase for waterway improvements and to help schedule a complete study program. However, its value over the long run is in the process used in shaping the choices coming before decision makers. This can be done if new traffic trends, projections, needs, and priorities are consistently incorporated into waterway studies. A central support capability should be provided for:

— Monitoring and Analysis of Traffic Trends

Figure S- 5

MEAN AND COMPOSITE MEDIAN COMPLETION TIMES FOR MAJOR COMPONENTS IN THE PLANNING, DESIGN AND CONSTRUCTION OF CIVIL WORKS PROJECTS (YEARS)[1]



1. Times are based on 36 projects completed in Fiscal Years 1973, 1974 and 1975.

— Periodic Update of Traffic Projections
— Periodic Review of Waterway Investment Priorities
— Periodic Reassessment of Defense Mobilization Scenarios

The ability to plan and operate water transportation systems for their potential role of industrial base mobilization support during emergencies focuses attention on the need to develop systematic procedures for integration of defense mobilization requirements into the decision making process in the following areas:

— Project Operation and Maintenance
— Project Plan Formulation
— Project Design
— Budget Formulation

ADMINISTRATIVE CHANGES FOR TIMELINESS

Consideration should be given to additional administrative changes which could improve timeliness of decisions and implementation of actions. For example, one concept implemented by the Corps of Engineers in Fiscal Year 1982 allows for funding high priority projects for continued planning and engineering during Administration or Congressional review of the feasibility (survey) report. This would ready a project for construction start in the shortest possible time by maintaining momentum associated with the survey. It is expected that this technique alone will reduce project completion time by several years.

Other major changes identified by NWS as capable of improving timeliness substantially, but not yet acted upon, include:

— Implementation of a systems approach to modernization in order to maintain a viable waterway system. The interdependency of the various components of the inland navigation system, as demonstrated by the NWS, leads to the conclusion that systems approach to replacement and rehabilitation is needed. The criterion, furthermore, should be one of cost effectiveness, once the decision is made to maintain the system, per se. This procedure, as contrasted to the traditional benefit/cost analysis, would also provide the most efficient solution to accomplish a specific objective.
— Reduction of the number of projects which require full Congressional approval. This may be accomplished by authorizing the Secretary of the Army, acting through the Chief of Engineers, to undertake rehabilitations and improvements to the existing waterway facilities which, in his judgment, are necessary to accommodate projected navigation needs efficiently.

SECTION I

PURPOSE OF THE NATIONAL WATERWAYS STUDY

PURPOSE OF THE NATIONAL WATERWAYS STUDY

BACKGROUND AND LEGISLATIVE AUTHORITY

Waterways have served nation building, defense and economic development in the United States throughout its history. Today, our nation's waterways, improved and operated by the United States Army Corps of Engineers, illustrate a unique combination of public and private enterprise. Our waterways system moves 16 percent of the intercity freight and serves over 80 percent of the nation's cities. Water transportation provides low cost, energy efficient and safe transit of heavy and/or bulk commodities. The nation's waterways, improved and operated by the United States Army Corps of Engineers, provides for a unique combination of public and private enterprise. Additionally, these waterways are generally managed to serve other water uses such as municipal and industrial water supply, production of hydroelectric power, flood control, irrigation, general recreation and to support fish and wildlife habitats.

There are over 25,000 miles of inland, intracoastal and coastal waterways in the United States. Of these, the modern waterway system includes 11,000 miles of shallow draft channels (9 feet or more) and another 1,000 miles of deep draft channels (18 feet or greater). Over 200 lock and dam sites, in addition to thousands of training structures, are located throughout these 12,000 miles of channels. The replacement cost of the existing system is estimated at $78 billion in 1982 dollars ($52 billion in 1977 dollars).

The existing waterways system is now confronted by steady increases in traffic which contribute to growing, and costly, delays as lock capacity becomes fully used. At the same time, many of the waterway structures are approaching the end of their design lives and need replacement or major rehabilitation.

Against this backdrop, Congress authorized the National Waterways Study in Section 158 of the Water Resources Development Act of 1976 (P.L. 94–587). This report, the first overview analysis of the nation's waterways since the National Waterways Commission was tasked in 1908, discusses the steps necessary to provide the nation with an effective navigation system through the year 2000.

NEED FOR POLICY AND DECISION FRAMEWORK

The United States is faced with requirements to manage its total transport capacity to meet both foreign and domestic commodity movements. The nation's waterways together with its railroads, highways and pipelines provide the infrastructure to meet those commercial transport needs. And balanced development of all modes is necessary to accommodate economic and trade imperatives inside the nation, in world trade and during defense emergencies.

Our national waterways and ports have been developed through an incremental investment decision process which reflects the pluralistic aims of the nation's transportation and water resources policies. In the mid-1970s, executive and legislative efforts to bring these two policy fields into harmony were reappraised, leading to the National Transportation Policy Study Commission (Section 154, P.L. 94–280) and the National Waterways Study. The specific intent of the Congress in initiating the National Waterways Study was set forth in Section 158 of the Water Resources Development Act of 1976 (P.L. 94–587), and is reprinted on the inside cover of this volume. The National Waterways Study limited its analysis to the existing system (including projects now under construction) and evaluated its capability to meet needs of projected waterway traffic. It is an overall assessment, one that is necessary if scarce resources are to be invested in ways that meet the needs of the 21st century.

NATIONAL PERSPECTIVE AND PUBLIC WORKS

The traditional approach to water resource development has been a project by project approach which has facilitated the integration of Federal, regional, state and local interests. The Federal budget approval process places waterways in the context of other competing priorities including other water resources purposes and other transport modes. Comprehensive river basin plans help place navigation in the context of other water resource problems. This study, by presenting overall waterway projections, assessing the ability of the current system to handle this traffic, and evaluating alternative strategies for adding capacity and maintaining reliability of the system, allows the investment needs of the system to be placed in an overall national perspective and facilitates evaluation of alternative investment opportunities.

In the United States, public works investments play important and varied roles in all modes of transportation. Unfortunately, public works may be the least understood sector in the economic life of the United States, and the waterways may be the least known of the public investments in transportation. Effective development and management of public works, depend, in the long run, on the broad public understanding of their purpose and their value to the community and to the nation. The National Waterways Study provides a new look at the uses of U.S. waterways and ports and their value to the nation.

BRIEF DESCRIPTION OF THE WATERWAYS SYSTEM

The U.S. commercial transportation system utilizes three types of waterways: the shallow draft inland and intracoastal waterways and ports; the Great Lakes and the St. Lawrence Seaway System and associated ports; and the deepwater channels accommodating oceangoing vessels of many types. The National Waterways Study covers each of these. Figure I–1 displays the navigable waterways of the United States as distributed into 22 reaches for the national level assessment. Figure I–2 names the coastal ports serving over five million tons annually.

Other maps prepared for this study and included as Appendix G show the location and character of the waterways and the commodities carried, such as petroleum, coal, iron ore, chemicals, and grain. The importance of our waterways system is emphasized by the fact that the United States is now the world's principal export supplier of metallurgical coal and food grains, while at the same time our economy has become increasingly dependent upon imported raw materials such as crude petroleum and minerals. Our trade with the world remains dynamic and in the 1980s, coal for production of steam has become one of our principal exports

SHALLOW DRAFT SYSTEMS

Mississippi River System and the Gulf Coast

The Mississippi River and tributary navigation is the heart of the commercial inland waterways system of the United States. It serves the industrial and agricultural heartland of America from Minneapolis, Minnesota, Chicago, Illinois and Pittsburgh, Pennsylvania to New Orleans, Louisiana. There are important connecting links between the Mississippi River system and the shallow draft Gulf Intracoastal Waterway which extends along the Gulf of Mexico from the Mexican border to Florida, and, in turn, connects many of the navigable rivers in the South.

Atlantic Coast

The Atlantic Intracoastal Waterway extends from Norfolk, Virginia to Jacksonville, Florida, then the Intracoastal Waterway extends south to the Florida Keys. Above Norfolk, Chesapeake Bay and Delaware Bay, connected by a ship canal, serve both shallow and deep draft domestic and ocean traffic. Further north, the New York State Barge Canal connects with the Hudson River to provide shallow draft navigation from New York Harbor to the Great Lakes.

Pacific Coast

In the West, the Columbia-Snake Waterway provides shallow draft navigation above Portland, Oregon to Lewiston, Idaho. Ocean shipping reaches Portland by the Columbia River.

GREAT LAKES SYSTEM

The Great Lakes System provides the United States and Canada with navigation for medium-sized oceangoing vessels from Duluth, Minnesota in the West to Montreal, Quebec. It serves Chicago, Illinois; Detroit, Michigan; Cleveland, Ohio, and many smaller ports along the way. Some of the larger ore carriers on the Lakes cannot navigate the St. Lawrence Seaway due to its restrictive dimensions.

COASTAL PORTS AND RELATED WATERWAYS

Major ocean ports and related waterways have been developed on the Atlantic, Gulf and Pacific coasts. Several important ports are found at or near the mouths of the principal inland waterways. On the East and Gulf coasts there are no ports with sufficient depth to accommodate the very large crude oil tankers and dry bulk carriers. An offshore terminal capable of supporting very large crude oil tankers began service in 1981 off the coast of Louisiana. There have been increasing demands for greater harbor depths to accommodate deeper draft vessels hauling coal as the United States increases its role in the world trade of that commodity.

REPLACEMENT COSTS

The existing Federal waterway system would cost an estimated $52 billion (all costs are in 1977 dollars unless otherwise specified) to replace ($78 billion in 1982 dollars), with nearly equal amounts invested in the shallow draft inland waterways system and in the deep draft coastal channels and ports. Table I–1 presents the estimated replacement costs of the Federal investment as well as the annual operations and maintenance costs of the national navigation system. Annual dredging

Figure I-1
NATIONAL WATERWAYS

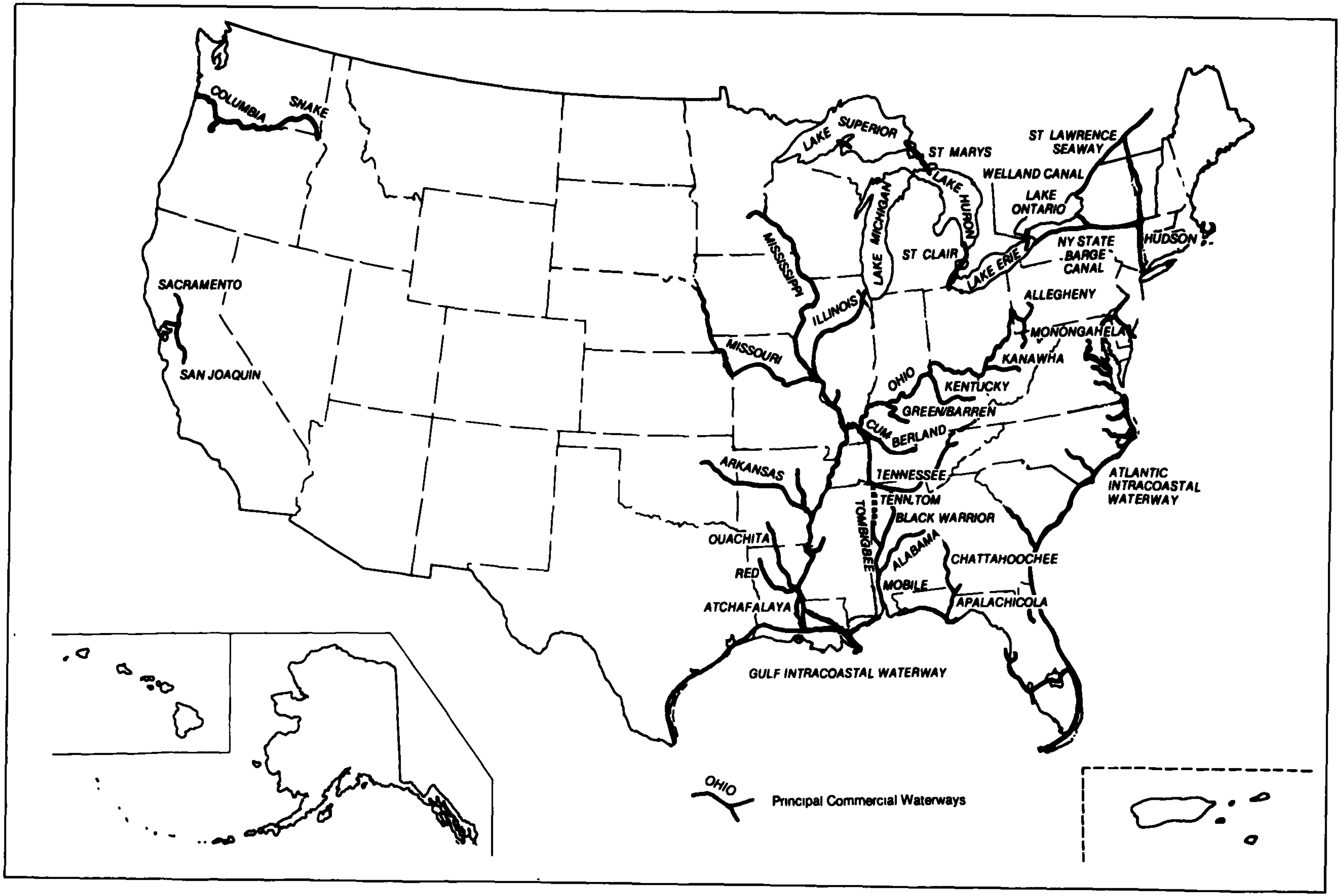


Figure I-2
INLAND, COASTAL AND GREAT LAKES PORTS (Handling Over 5 Million Tons)

volume averaged about 290 million cubic yards between 1973 and 1977, of which nearly two-thirds was devoted to dredging deep draft coastal ports. Total annual operating costs for dredging, lock operation, and other maintenance of the navigation system averaged approximately $320 million for the same period. Almost equal amounts were devoted to operation of inland waterways and coastal ports.

In addition to expenditures by the U.S. Army Corps of Engineers, approximately $15 million per year is spent by the State of New York to maintain and operate the New York State Barge Canal and $5 million per year is expended for operation of the St. Lawrence Seaway by the St. Lawrence Seaway Development Corporation. Additional expenditures are made by the U.S. Coast Guard for navigation. These expenditures serve both commercial and recreational boaters using navigable waterways.

The waterways and harbors of the United States are not only one of America's greatest resources, but through 200 years of private and public effort have become one of the greatest systems of commercial navigation in the world. There has been a long Federal involvement in the development and maintenance of the nation's navigation system. The navigation system, in turn, has played a key role in the development of the nation. Many generations have made use of the opportunities offered by our system. This report continues the tradition, one which on the Federal level began with the Gallatin report of 1808 which recommended a national plan for waterway development as a tool for nation building.

NATIONAL SIGNIFICANCE OF THE WATER TRANSPORTATION SYSTEM

The three major NWS determinants of a waterway system's capability and its importance to a nation are:

1. Capacity to accommodate commercial traffic.
2. Responsiveness to defense mobilization.
3. Reliability, safety and efficiency.

Each generation has developed and used our waterways to meet a number of objectives. In the colonial period, exploration of the largely unknown continent was greatly facilitated by the water routes to the interior. Settlers soon followed the explorers and the waterways became the principal arteries for the movement of families to the western lands. Many frontier settlements along the principal waterways grew in time to the major cities we know today. With the development of the steamboat, the waterways carried the products from the expanding west to the markets of the seaboard states. As the American economy grew, coastal ports became important stops in world trade.

In times of armed conflict, the waterways have served the nation well. The great forts built at the entrances to principal waterways during the 18th and early 19th centuries stand as reminders of the strategic importance of our waterways and harbors. Each war brings unique problems and the waterways have served a variety of defense needs. In World War II, for example, the waterways proved to be an effective way to move essential petroleum products from the Gulf area to the East coast refineries by a route protected from enemy submarines. The relative safety of industrial sites on inland waterways and Great Lakes has also proved a factor in placing defense related plants. More recently, the ability of the waterways to receive and move the huge increase in petroleum products required to serve the American economy has been of great value to both the military and civilian sectors. Indeed, it is primarily as a mover of bulk commodities that the waterways now serve the changing American economy. The U.S. is fortunate in having major harbors along the East, Gulf and West coasts and on the Great Lakes, along with an extensive system of ports on the inland waterways.

Table I–1
FEDERAL COSTS FOR THE NATIONAL NAVIGATION SYSTEM EXPENDED BY CORPS OF ENGINEERS
(All Costs in Millions of 1977 Dollars)

	Estimated Replacement Cost[1]	Annual Dredging[2]		Other Annual Operations and Maintenance Costs[2]	Total Annual Operations and Maintenance Costs[2]
		Volume (1000 Cu Yd.)	Cost		
Shallow Draft Waterways	24,386.0	94,116	49 9	96.6	146.5
Great Lakes System	4,837.0	7,009	15 2	9.3	24 5
Coastal Ports and Channels	22,659.0	187,706	127.0	19.9	146 9
Total	51,882.0	288,831	192.4	125.8	317.9

1 Based on historical first costs adjusted for inflation
2 Annual Average for 3 to 5 years ending 1977
Source Corps of Engineers, *NWS Inventory*

COMMERCIAL WATERBORNE TRANSPORT

Waterborne commerce is important to the economy of all regions of the United States, and to the U.S. economy as a whole. In 1980, U.S. waterways carried almost two billion tons of commerce, about equally divided between domestic and foreign trade. Energy commodities accounted for 58 percent of all U.S. waterborne commerce in 1980. Every community is influenced directly or indirectly by the pattern of these movements. The growth in national importance of waterborne low-sulfur coal, for example, has led to increased rail-barge movements on several major waterways.

While growth in domestic waterborne commerce has been steady, foreign waterborne commerce has increased fivefold in the period from 1947 to 1980. Grain exports stand out as a major factor in U.S. foreign trade. And, in the export trade, barge movements account for 61 percent of soybean shipments, 50 percent of corn, and 29 percent of wheat.

A careful study of the potential for waterborne commerce under a series of possible future conditions strongly suggests that waterways will continue to be prime movers of bulky and heavy commodities. Total U.S. waterborne traffic is forecast to increase from 1,915 million tons in 1977 to a maximum of 2,890 million tons by 2003. Coal and grain figure importantly in these forecasts of waterway commerce. Projected growth in waterway traffic is substantially lower than traffic projected for rail and is lower than the actual increases in waterway traffic during the 1970s. Declines in petroleum and shifts to western coal explain the declining shares. Section IV examines historical and projected waterborne commerce in further detail.

POTENTIAL DEFENSE AND EMERGENCY ROLE OF WATER TRANSPORTATION

Water transportation is vital to mobilizing for national defense and emergencies. The National Waterways Study evaluated the contribution that the waterway system could make to mobilizing strategic materials for an overseas war of five years' duration. The analysis was based on an assumption of mobilization beginning in 1985 and ending in 1990. If the analysis had assumed a later date, more severe impacts would occur. This defense scenario substantially affected steel mill production, grain exports, oil imports, domestic oil shipments, and other waterway commodity flows. Under the defense analysis, the Great Lakes System experiences the greatest impact; traffic in the year 1990 would be 120 million tons greater than that projected for peacetime conditions.

RELIABILITY, SAFETY AND EFFICIENCY OF THE WATERWAYS TRANSPORTATION SYSTEM

Public and private investments made in the inland waterways have produced a reliable and effective system for commercial navigation. Today, many of its rivers are carrying a record volume of traffic while maintaining an exceptional record for safety among transport modes. It is important to maintain this reliability if the system is to fully serve the nation. The continued effectiveness of U.S. waterways and ports may be seriously impaired in the near future by the increasing age of structures, technological obsolescence in the system, and basic physical limitations at strategic points along several principal waterways. The National Waterways Study identifies the nature and significance of these constraints to system effectiveness and presents a framework for decisions on waterway improvements.

During the steamboat era, collisions and fires resulting in loss of life and property were commonplace. Modern towboat technology, channel marking and radar guidance have reduced accidents to a very low level. Today the safety record has improved, but safety requires constant attention. These issues involve waterway design, operation and maintenance. The U.S. Coast Guard has primary responsibility for waterways safety.

Our waterways, coupled with the modern vessels developed for the inland waterways, the Great Lakes and the coastal waterways, are probably the most efficient movers of bulk commodities in the world today. The challenge of the 21st century is to maintain this record in the face of congestion and rising costs. Readily available studies document that waterways are among the most fuel efficient modes of transport. Fuel efficiency of waterways varies greatly from river to river and decreases under high water, low water and ice conditions.

THE FEDERAL ROLE IN WATER TRANSPORTATION

The origin and formulation of national policy for transportation, and particularly for water transportation, holds a key place in the development of the American way of governing. Leaders of the American Revolution were deeply concerned that the waterways serve the whole nation and all the people. They had strong reasons for concern, for under the Articles of Confederation commercial rivalries had quickly developed among the states, leading to taxes and tolls when commerce crossed state lines. Delegates to the Constitutional Convention in 1787 recognized the need for Federal control of both foreign and interstate trade and drew up a strong commerce clause which placed the navigable waters under Federal jurisdiction. One of the first acts of Congress under the new Constitution was the adoption of the Ordinance of

1787 which spoke strongly for the freedom of access to navigable waterways.

Federal interest in waterway improvement is often dated from the 1808 report by Albert Gallatin, Secretary of the Treasury, on ". . . roads and canals." Gallatin prepared a long list of projects worthy of Federal support to help connect New England with the South and the seaboard states with the interior of the young nation. But there were many members of Congress who believed that the constitution left waterway improvements to the states and it was many years before the Federal role in waterway improvement was fully established.

Under the watchful eyes of states rights supporters in Congress the Federal Government moved very slowly into waterway improvement. In 1823, the Corps of Engineers received its first legislative assignment for navigation improvement involving examination and surveys of the channel leading into the harbor of Presque Isle on Lake Erie in Pennsylvania. In 1824, Congress authorized President Monroe to have surveys made ". . . of the routes of such roads and canals as he may deem of national importance from a military point of view." This act became known as the General Survey Act, and was a key piece of legislation in the history of navigation improvements. The act dated May 24, 1824 initiated Federal improvements for navigation in the Ohio and Mississippi Rivers, appropriating $75,000 for this work. This act is generally considered as the true beginning of the Corps of Engineers' role in developing the commercial waterways of the United States.

The aid given by the Federal Government to the inland waterways before the Civil War was very limited. It was in the 1870s that Congress began to regularly enact rivers and harbors legislation, usually each biennium, making appropriations for harbors as well as for inland waterways. Prior to 1890, however, Congress approached waterways improvements on a piecemeal basis, authorizing specific improvements to be made and operating on the basis of partial appropriations made year by year to carry out the authorized work. In 1890, Congress adopted the policy of putting the larger works such as Mississippi and Ohio river improvements upon a "continuing basis." Power was given to the Secretary of War to contract for the execution of the authorized projects, obligating the government to make subsequent appropriations as required to fulfill the executed contracts.

Under this approach, waterways improvements for navigation did not move rapidly. In fact they moved so slowly that following the business depression of 1893–98 it seemed that the national transportation facilities would be woefully inadequate to meet future needs. Not only were the waterways lacking in improvements, but the railroads had not yet become technologically efficient and the highway program and the subsequent development of the automobile was still in the future. It was in this setting, in 1907, that the Inland Waterway Commission created by President Theodore Roosevelt began its work. Roosevelt's activities on behalf of the waterways had several important consequences. In the Rivers and Harbors Act of March 3, 1909, Congress provided for the establishment of a United States National Waterways Commission, composed of members from the House of Representatives and the Senate. Much of the work of this commission was directed to the development of a harmonious relationship between the waterways and the railroads and in the interest of developing an integrated transportation system, the commission, in its final report of 1912, recommended that the Interstate Commerce Commission ". . . be given power to compel physical connection between railways and waterways whenever practicable and necessary for the formation of through routes."

World War I placed an unprecedented burden upon transportation facilities. The Federal Government commandered the railroads in December 1917 and soon afterwards took over all suitable floating equipment on the New York State Barge Canal and the Mississippi and Warrior rivers for use in furthering the war effort. In addition, the government provided new equipment for use on the Chesapeake and Ohio Canal, began operations on the Delaware and Raritan Canal, and made certain improvements for dredging the Illinois and Michigan Canal. Seventeen million dollars were made available for the purchase of equipment for operation on the New York State Barge Canal and the Mississippi. These efforts led to the creation of the Inland Waterway Corporation (Federal Barge Lines) on June 2, 1924. The corporation was to provide waterway navigation service to the nation until it could be demonstrated that such a service was a viable operation, and attractive to private capital. This government owned and operated service is the only example in the United States of departure from the principle of private ownership and operation of vessels on the inland waterways.

The efforts of the government to demonstrate the value of the waterways succeeded. Private interests gradually took up the task of providing public transport on the waterways and the government corporation was eventually sold. The policy of Federal responsibility for planning and construction of inland waterway improvements and for the dredging of the required channels at ports with private interests providing the transportation services is now well established. The Federal role in waterways improvement has gradually become part of the broad Federal program for water resource development, often carried out on the basis of basin-wide plans for the major rivers. However, many aspects of the project by project approach still exist and the practice of overlong planning and construction periods is very evident today. The increasing environmental awareness and energy cost increases of the late 1960s and 1970s brought new challenges to traditional waterway planning and management and contributed to protracted implementation schedules. Under these conditions, the National Waterways Study was conceived with its emphasis on the need for broad-scale assessment of the adequacy of the waterways to meet the nation's needs in a timely fashion.

PROBLEMS AND ISSUES

A prime objective of this study is to provide an overall assessment of future traffic projections, waterway capability, and needed improvements. The study would permit open discussion of the overall importance of increasing waterway capability, its costs and various investment strategies. It would address many of the critical issues and facilities reaching a consensus on a process for waterway development and management.

Current approaches to development and management are confronted by growing delays between planned and actual construction and in maintaining authorized channel dimensions. This results in increasing congestion and operating costs for waterway operators and the shippers. More timely decisions require better coordination between Federal, state and local governmental agencies and private and public interests. An effective decision making process should embody or provide a mechanism for establishing goals and objectives for waterway development and operation; providing a water transportation development process which adapts to changing conditions and reflects competing and complementary uses of water; coordinating commercial waterways transportation and defense objectives; and utilizing limited funds to achieve high priority goals.

SECTION II

DESIGN OF STUDY

DEFINITIONS

Segment: A portion of, all, or a grouping of closely related river, lake and coastal waterways used to facilitate analysis.

Reach: One or more segments.

Scenario: A group of assumptions about possible external events affecting the level of traffic on the navigation system.

Strategy: A set of assumptions concerning public policies and management regarding such decisions as funding and allocating funds for various actions to meet water transportation needs.

Forecast Use: Estimated future waterborne commodity flows—shipments, receipts, imports and exports.

DESIGN OF STUDY

STUDY MANAGEMENT AND INPUT COORDINATION

Congress placed the National Waterways Study (NWS) under the direction of the Secretary of the Army, for implementation by the Chief of Engineers. The study was organized to allow input from the public, Corps of Engineers staff and representatives of other agencies and groups. Figure II–1 diagrams the key relationships.

MANAGEMENT

The management included a Study Director, Steering Committee, Study Manager and staff:

Study Director — The Deputy Director of Civil Works served as Study Director, chairing the Steering Committee and deciding issues of study policy and interagency coordination. The following individuals served as director during the period of study: MG Drake Wilson; MG Hugh Robinson; BG George Robertson; BG Sam Kem; BG Forrest Gay III and BG C.E. Edgar III.

Steering Committee — A Steering Committee chaired by the study director provided overall policy guidance for the NWS. Non-Corps of Engineers members included representatives of the U.S. Department of Transportation; U.S. Department of Interior; U.S. Department of Commerce, Maritime Administration; and the Council on Environmental Quality. Corps of Engineers members included: Director, Institute for Water Resources; Technical Director, Board of Engineers for Rivers and Harbors; and the Chiefs of Construction—Operations, Planning, Engineering, and Office of Policy in the Office of the Chief of Engineers.

Study Management — Day-to-day management of the study was performed by the U.S. Army Corps of Engineers Institute for Water Resources (IWR), Water Resources Support Center, Ft. Belvoir, Virginia. The IWR managed all phases of the study under the guidance of a full time study manager drawn from the Institute's staff.

COORDINATION

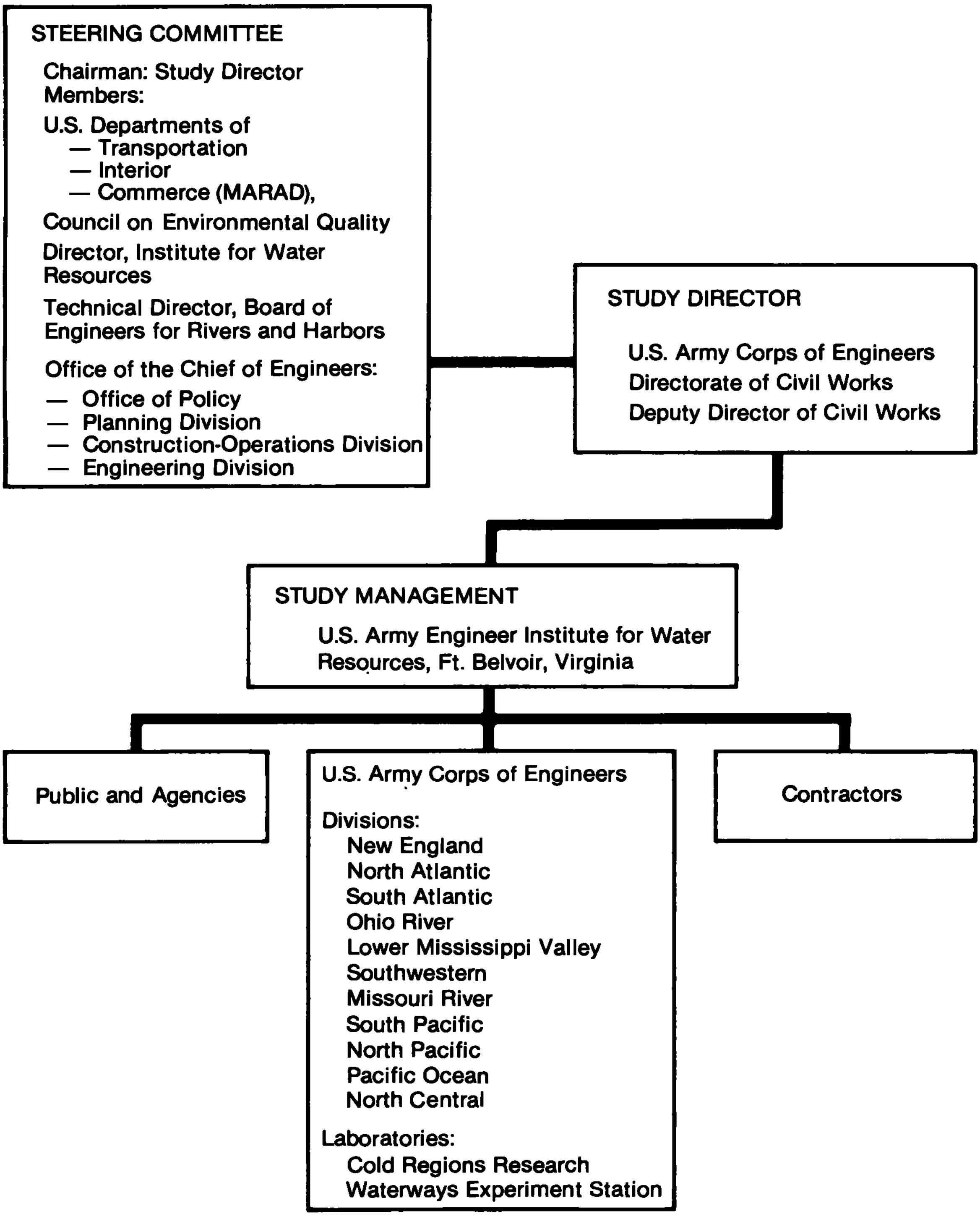
In order to seek the advice of many groups with a wide range of knowledge and experience in ports, waterways and their development, the study team coordinated their activities with those of Corps offices, other agencies at all levels and the general public. They presented preliminary results coming from the study to many groups to encourage discussion and comment. Details on the public involvement plan and implementation are covered in the NWS technical document entitled *Public Involvement*. Table II–1 lists the formal meetings, their purposes and the participation. A more extensive series of informal briefings and presentations were given during the study for professional, regional and special interest groups. Figure II–2 displays the geographical distribution of both the formal and informal programs participated in by the management team.

Corps of Engineers districts, divisions and laboratories with responsibilities for waterways development, maintenance and research took active roles in the study. Coordinators from 11 Corps of Engineers division offices assumed a major role in providing data to IWR and study contractors, managing division and district review of draft and final reports, and furnishing continuing technical counsel to the study. They in turn were supported by navigation specialists from 36 district offices. The Board of Engineers for Rivers and Harbors provided several specialists who assisted in development of the Plan of Study and supervision of contractual efforts. Two U.S. Army Engineer laboratories, Waterways Experiment Station and Cold Regions Research and Engineering, added their specialized technical knowledge to the study.

CONTRACTED WORK

Contracts and agreements for research and investigative analysis were used to support the study. A. T. Kearney, Incorporated (ATK) of Chicago, Illinois was the prime contractor for the NWS. Subcontractors to ATK included Data Resources, Incorporated (DRI) of Lexington, Massachusetts, and Louis Berger and Associates (LBA) of East Orange, New Jersey. A number of smaller contracts were utilized to develop study approaches, provide data on institutional issues associated with waterways and ports, and to report on the history of stream improvements for navigation, the progress of port development and the evolution of vessels. The U.S. Geological Survey, Reston, Virginia, produced 20 of the set of

Figure II-1
NATIONAL WATERWAYS STUDY MANAGEMENT AND COORDINATION



24 waterways maps for the study. Tech-Drafting and Photo Inc. prepared the four regional maps to this set.

CONTROLLING ASSUMPTIONS OF THE NWS

The authorizing legislation set forth the basic requirements of the study:

> Review the existing system and its capabilities for meeting the national needs including emergency and defense requirements and an appraisal of additional improvements . . .
> The Secretary of the Army, acting through the Chief of Engineers, shall submit a report to Congress . . . together with his recommendations.

Based on this legislative mandate a working objective was established, the study scope specified, and formulation goals selected.

WORKING OBJECTIVE

The working objective established for NWS was to:

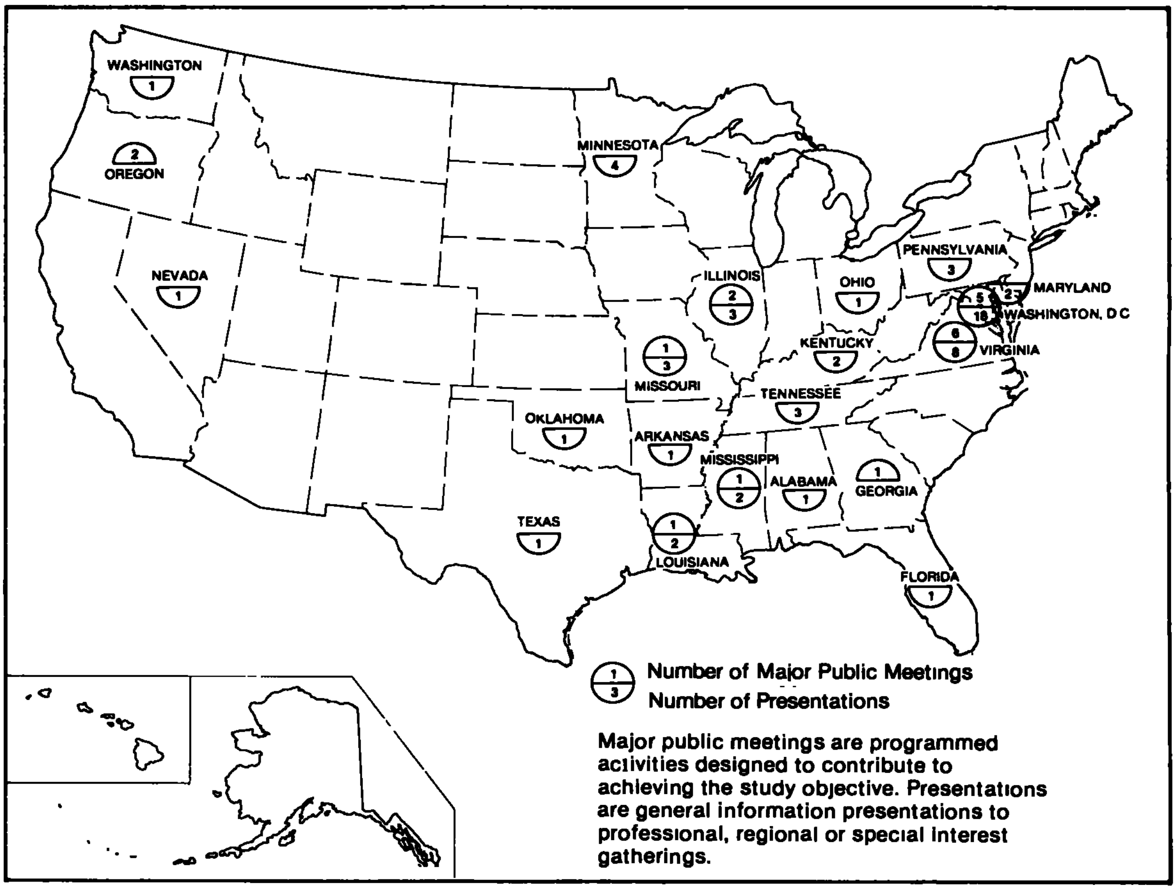
> IDENTIFY AND ANALYZE ALTERNATIVE STRATEGIES FOR PROVIDING A NAVIGATION SYSTEM TO SERVE THE NATION'S CURRENT AND PROJECTED WATER TRANSPORTATION NEEDS.

The focus of the study as set forth in the legislation, was on the overall waterway system. Other water uses were considered to the degree that they significantly conflicted with or complemented navigation use. The findings from meeting this working objective provided the basic input for the final framework formulation and conclusions.

To meet the objective, the NWS:

1. Projected the nation's potential requirements for water transportation.
2. Assessed the capability of the existing waterways system to serve both current and projected traffic.

Figure II-2
PUBLIC INVOLVEMENT ACTIVITIES BY STATE



3. Examined the relationship between the use of waters for transportation and for other uses, including the environment.

4. Developed and evaluated alternative strategies to meet the projected water transportation needs. These strategies were designed to assess the consequences of diverse managerial and policy options including: funding levels for investment, operations and maintenance; weight given to maintenance versus new construction; and timing for adding capacity.

Table II–1
PUBLIC INVOLVEMENT PROGRAM

Type of Meeting	Date	Subject	Participants	Location
1 Federal Interagency	3/24/78	Introduction of NWS to other Federal agencies; request for input into Plan of Study.	Representatives of various Federal agencies	Wash., DC
2. Public Meeting for Plan of Study	6/22/78	Presentation of NWS preliminary Plan of Study; solicitation of questions and comments.	General public, including water transportation industry, other industries, Federal agencies, members of congressional staffs, trade associations, academia, and others	Wash., DC
3. Shaping the Future of the Waterways	3/28–29/79	Workshop to aid in the review and identification of data sources for NWS; suggestions for areas of technical research for study	Corps, other Federal agencies, state agencies, national organizations, industry and selected experts.	Atlanta, GA
4. Shippers and Carriers	5/24/79	Presentation of NWS Plan of Study and solicitation of industry help in providing necessary data and information	Members of shipping and water carrier industry and trade associations.	Wash , DC
5. Railroad Representatives	6/14/79	Briefing on NWS, techniques for commodity forecasting, and general overview of study plan	Railroad industry representatives and railroad trade associations.	Wash.. DC
6. Environmental Briefing	9/11/79	Briefing for representatives of environmental interests on NWS and how study will deal with environmental aspects of navigation.	Environmental groups and organizations, related Federal and state agencies, other interested individuals	Ft. Belvoir, VA
7. Regional Public Meetings on NWS Preliminary Findings	12/11/79 12/12/79 12/14/79 12/18/79	Presentation of NWS contractors' preliminary findings and forecasts of waterway traffic through 2003, including major increases in coal and grain movements	General public (similar to #2).	Wash , DC Chicago, IL Portland, OR New Orleans, LA
8 Public Technical Workshops	1/30/80	General meetings and workshop sessions on the technical elements of NWS, including methodologies involved and preliminary findings	General public	Ft Belvoir, VA
9. National Waterways Roundtable	4/22–24/80	Presentation of papers and discussions on historical, current, and future aspects of the waterway system	Corps, other governmental agencies, industry, academia, trade organizations.	Norfolk, VA
10 Waterway Science and Engineering Sessions	7/1–2/80 7/7/80	Review sessions by panels of experts on NWS contractor products concerning dredging, river training/channel design, lock design, and season extension.	Largely Corps, some representation of industry, academia and trade associations.	Vicksburg, MS Chicago, IL
11. Evaluation of the Present Navigation System	9/4/80	Presentation of contractors' preliminary evaluation of the existing waterway system. Forecasts of future traffic use were compared with capability analysis of the existing system.	General Public.	Arlington, VA
12. Development and Evaluation of Alternative Strategies	11/13/80 11/18/80 11/19/80	Presentation of the contractors' four alternative strategies for dealing with waterway system problems as identified in the *Evaluation of the Existing Waterway System* report.	General Public.	Arlington, VA St. Louis, MO Portland, OR
13. Final Report Conclusions	7/21/81	Presentation of the Corps' draft final report on preliminary conclusions and framework plan. Framework identifies problems, sequences solutions, and specifies investment level.	General Public.	Arlington, VA

STUDY SCOPE

Major influences on the scope of the NWS included: the physical system, time horizon, commodities, user charges, and intermodal coordination.

Physical System

The nation's waterways for this study included the navigation system in use in December of 1978 plus commercial navigation projects which would be funded for construction initiation by 1981. These additions included:

1. Tennessee-Tombigbee Waterway
2. Red River to Shreveport, Louisiana
3. Lock 26 (single 1200-foot lock), Alton, Illinois
4. Vermilion Lock replacement on Gulf Intracoastal Waterway in Louisiana
5. Two locks on Ouachita River in Louisiana
6. Additional chamber at Pickwick Lock on the Tennessee River
7. The Mississippi River regulatory works to facilitate maintenance of the navigation channel from Cairo, Illinois to Baton Rouge, Louisiana.

For analytical purposes, the nation's river, lake and ocean waterways (including ports) were divided into 61 segments. These segments were grouped into 22 geographic areas called reaches to facilitate discussion in this report; see Figure II–3. The reaches and segments are defined in Appendix A.

Time Horizon

Throughout the study every attempt has been made to cite data for 1977 (the study base year) wherever possible. When data were simply not available for 1977, the closest year was chosen and noted. Cost data are cited in 1977 dollars. Where appropriate, 1982 dollars are also displayed.

The planning horizon for this study was a 25-year period ending in 2003. Because of the very long leadtime in civil works construction, the study identifies locks and systems with capacity problems and those with significant congestion problems by 2003.

Commodities

Traffic projections have been prepared for 48 commodity groups through 2003 in five-year increments. For reporting ease, commodity groups were combined into seven categories for presentation; these commodity groups are described in Appendix C.

Estimates of future traffic for domestic and foreign commerce were developed for each reach. No detailed studies of individual coastal ports were made.

User Charges

This study has included the impact of existing user charge legislation (P.L. 95–502) which imposed a fuel tax increasing to 10¢ per gallon after 30 September 1985 on water carrier cost structures. However, the NWS did not analyze other user charge and cost recovery policies. The U.S. Department of Transportation (DOT) was directed under Section 205, P.L. 95–502 to study the impacts of cost recovery and user charges. Its report was completed in 1982.

Intermodal Coordination

Although the enabling legislation directed that the NWS consider intermodal coordination, results were quite limited. Data base and analytical requirements to identify potential intermodal shipments are massive and costly. The NWS evaluated emerging trends in the location of production and consuming industries, their logistics decision processes, and their impacts on waterway traffic forecasts. The impacts of rail deregulation were incorporated into water traffic forecasts. Also, major joint movements by rail and water which now exists due to the eastern flow of western coal were factored into the development of future flow patterns. Opportunities for continued or increased joint hauls were considered in making waterborne traffic forecasts.

NATIONAL GOALS

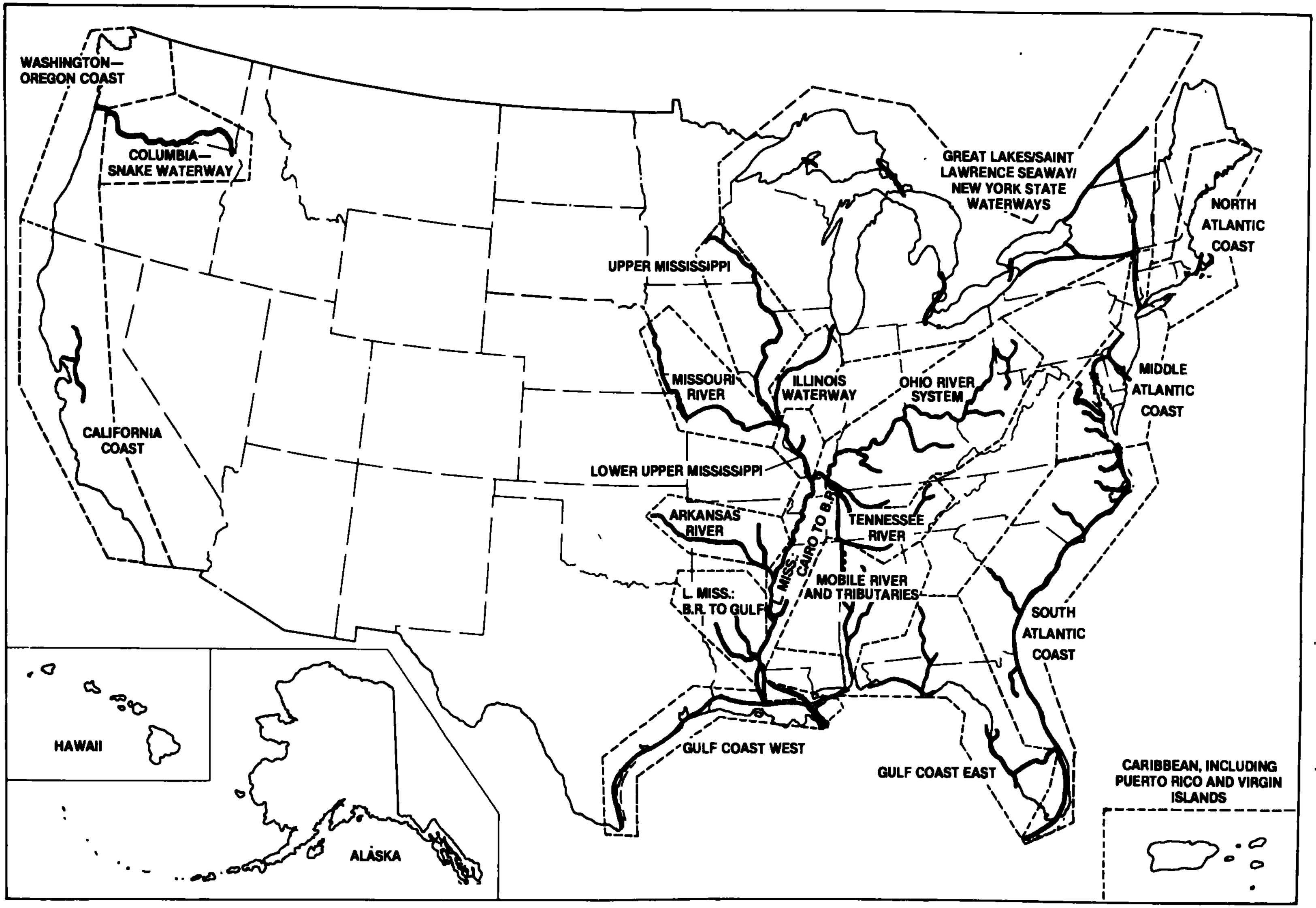
The authorizing legislation specified that "The study shall include a review of the existing system and its capability for meeting the national needs including emergency and defense requirements . . ." These "national needs" are not the planning objectives articulated in the Water Resource Council's *Principles and Guidelines* (the official guide for Federal water project planning), but are issues of substantial national interest which the navigation system clearly influences. Four major goals are significantly influenced by the capability of the U.S. navigation system.

1. *Defense and Emergency*—The navigation system has an important role in assuring the capability for military and industrial mobilization for armed conflict and national emergencies. It provides vital domestic and overseas transport of strategic materials such as iron ore, iron and steel products, petroleum, and chemicals.

2. *Energy Production*—Over half of the waterway traffic is energy products—coal and petroleum. Most of the nation's refineries and electrical power generation units are located on navigable inland and coastal channels, explaining why one-quarter of the coal and petroleum products transported have some movement by water.

3. *Export*—The United States is the world leader in the export of both agricultural products and metallurgical coal. With one-third of the world coal reserves, the United States has the potential of

Figure II - 3
NWS REPORTING REACHES



becoming a major world steam coal supplier—possibly as much as 38 pefcent of the world market by 2000. Half of the U.S. grain exports move by inland waterways to coastal ports for shipment overseas, thus supporting the U.S. balance of payments (agricultural products contributed $43 billion to the U.S. balance of payments in 1980). Efficient, reliable inland and coastal navigation will continue to play an important role in improving the nation's balance of payments.

4. *Economic Development*—Water transportation moves nearly two billion tons of U.S. commerce annually and is a basic component of the nation's transportation infrastructure. It transports commodities which support the national goals of economic revitalization, such as export promotion and energy self-sufficiency. Waterways, one link in the increasingly integrated U.S. transportation system, move rail-hauled Wyoming coal from St. Louis, Missouri to utilities along the inland waterways. Tens of millions of tons of petroleum refined along the Gulf move to consumers along the Atlantic coast. The navigable waterways are publicly managed to a large degree because water is a public resource. Water is not easily subjected to conventional property rights because it flows in space and time. Water simultaneously supports many uses in addition to navigation, thereby making public water management an integral part of water transportation decision making.

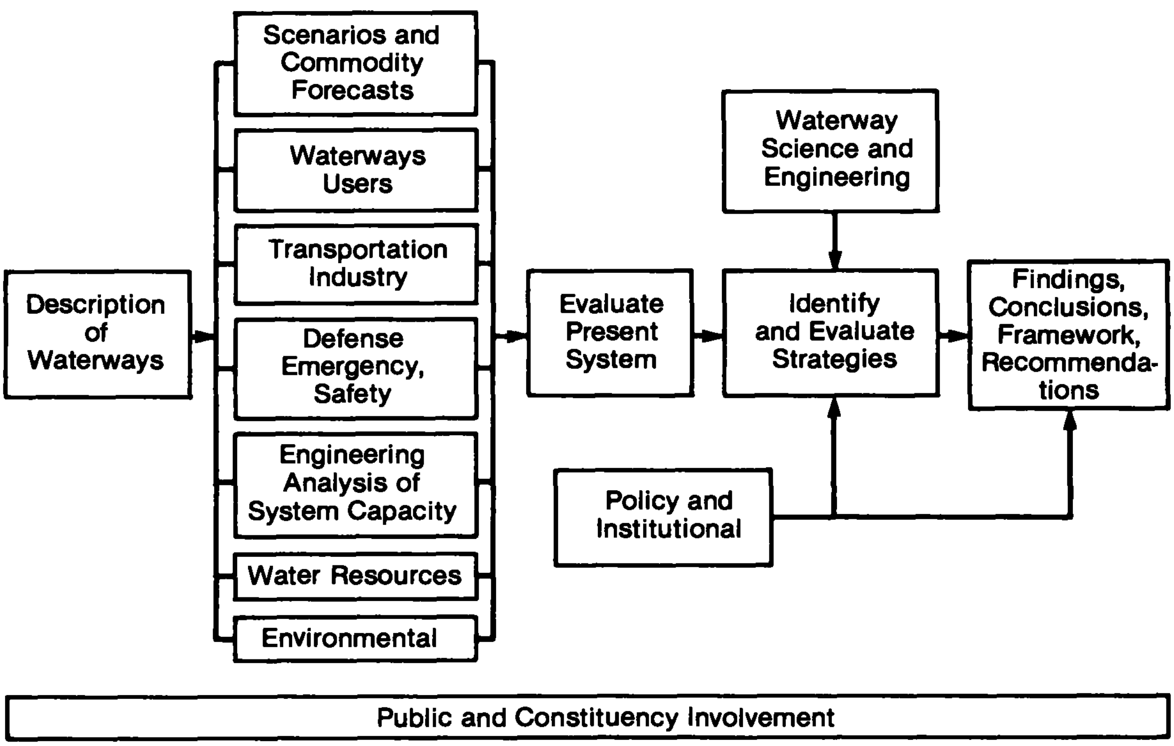
MAJOR ELEMENTS OF STUDY AND THE METHODOLOGY

The study methodology evolved in two documents: the *Plan of Study* (March 1978) and the *Workplan* (July 1979). The *Plan of Study*, set forth basic study requirements—scope, study management, and organization. The *Workplan* developed the details of the study framework and proposed the detailed study to meet the working objective. The major elements of the study and how they fit together are graphically displayed in Figure II–4. These included describing the waterway system, conducting technical research, integrating that research into the analysis of the existing system and strategy development-evaluation, and formulating a framework program.

DESCRIPTION OF WATERWAYS

This element was initiated in April 1978, following approval of the *Plan of Study*. Most all physical and operational data considered necessary for evaluating the national waterways system were placed in a computerized data base. The principal objective was to have all essential data prepared from common definitions, including the time period. The second step was to prepare a concise description of both the physical components and their current traffic characteristics. The initial

Figure II-4
NATIONAL WATERWAYS STUDY ELEMENTS



description consisted of a set of 19 maps, completed by the U.S. Geological Survey in 1979, and later expanded to include 24 maps (Appendix G).

TECHNICAL RESEARCH

Nine specialist teams conducted tasks defined in the *Workplan*. These tasks provided input to related technical research and framework development.

Commodity Forecasts and Scenarios

Seven commodity forecasts, based on various scenarios—sets of assumptions concerning future events—were produced. Basic inputs to the forecasts were:

1. Four sets of macro-economic conditions.
2. Criteria used to select transport mode.
3. Carrier and port responses to changes in the transportation environment.
4. Defense/emergency scenario assumptions.

Waterways Users

Commercial users (i.e., shippers) are the principal decision makers who determine the amount and type of waterway navigation usage, given the capability of the navigation system and its competing transportation modes. In the final analysis the success or failure of waterways plans depends on how accurately the shipper's needs and requirements are assessed. Results of this research were used in developing commodity flow projections.

Transportation Industry

Research focused on specific issues of the waterway transportation industry (water carriers, ports and terminals, shipbuilders and others), as well as key issues related to ports and to rail, truck and pipeline transportation. The three primary purposes of this element were to provide the transportation industry perspective to issues and factors which affect commodity flow analysis; to provide a current understanding of transportation operations and equipment utilization which were used in the evaluation of the system capability; and to provide insight and understanding of transportation industry's perception of policy issues for later formulation of waterways development and management strategies.

National Defense, Emergency and Safety

The movement of commodities on the waterways of the United States is vital for national defense and security. The major thrust of this research was to define the appropriate considerations of national defense and emergency requirements, as well as safety issues which contribute to the development of national waterways strategies.

Engineering Analysis of System Capacity

Engineering analysis of the waterways system focused on how to accommodate different types and volumes of traffic. The analysis included evaluating present waterways system capacity, examining future potential for structural and nonstructural modifications, developing methodologies for estimating responses of the physical waterway system to selected strategies, developing and presenting cost models to estimate investments and operation and maintenance costs associated with waterway modification procedures.

Non-Transportation Water Resource Use

The development and use of waterways for navigation both complement and conflict with other water resource uses. The relationship between navigation and other uses was explored. The purpose of the work was to provide measures of the impact of navigation improvements and operation of the waterways on other water uses. This work provided quantitative input to the capacity analysis for each segment where there are identified space or waterflow constraints. The assessment of the future demands by other water uses contributed to the determination of the waterways' capability for navigation.

Environmental Aspects

Environmental aspects of construction, maintenance, and use of U.S. waterways were considered in the development of alternative strategies. The information was primarily drawn from the body of knowledge developed by project-level environmental studies and major research projects prepared or conducted by the Corps of Engineers and other agencies.

Institutional and Policy Analysis

The part of the study devoted to institutional and policy analysis included a review and analysis of selected regulations and policies that influence the use, operation and development of the waterways and ports. This information contributed to the development and evaluation of alternative strategies and development of the proposed framework.

Waterway Science and Engineering

This research was directed toward determining the highest level of technology available for: channel design, lock and dam design, dredging, river training, waterflow, and other engineering considerations. Technological trends, particularly those that have succeeded in the United States and other countries, were assessed for their potential application and potential impact for improving the capability of the national waterways system.

This technical research played an important role in determining the problems and opportunities likely to confront the navigation system in the next 25 years. The products from this research were reviwed widely by both the public and government. Reports associated with this work are listed in Appendix H.

INTEGRATION

The evaluation of the existing system's capability to meet future needs and the development of strategies to meet the needs involved a process called integration. It involved four steps:

1. Creating scenarios (sets of assumptions about the future). These were used to generate forecasts of waterways traffic.
2. Estimation of future waterways traffic for each scenarios, for each segment of the waterway, and for each commodity group.
3. Assessing capability based on system capacity, efficiency, reliability and safety. Each category had one or more associated measure:
   - —Capacity, the physical ability to accommodate projected traffiic, was estimated for each reach and was based on the degree of facility utilization. Capacity was measured in tons.
   - —Efficiency was based on the cost of operating vessels in each segment serving the estimated future traffic.
   - —Reliability of the structures and channels in each reach was based on age, level of use, and condition of the structures and the predicted adequacy of depths.
   - —Safety was evaluated in terms of accident potential based on known hazards, history of accidents, physical conditions, and traffic characteristics.
4. Strategies, management philosophies and policies for meeting the problems related to waterway capability discussed in 3 above, were formulated to reflect policies such as funding limitations, replacement timing, and resource allocation prioritization. Four strategies were developed and the costs and impacts were evaluated to determine what would happen to system capability. These results enabled the development of a framework of improvements and maintenance required to meet national needs, including emergency and defense.

FRAMEWORK FOR DECISION MAKING

Development of a framework approach to waterways development and management decision making was the NWS response to conclusions drawn from the assessment of the capability of the waterways system, the evaluation of four alternative management philosophies and policies (strategies) applied to meet the system needs, and technical research findings. The framework was formulated to identify early action phases for waterway maintenance (rehabilitation or replacement) or improvement projects. Its value over the long run was the process used in shaping the choices coming before decision makers. It emphasized how choices could be made, thereby gaining a resiliency needed for a general guide for waterway initiatives.

SECTION III

PHYSICAL CHARACTERISTICS OF THE EXISTING WATERWAYS SYSTEM

PHYSICAL CHARACTERISTICS OF THE EXISTING WATERWAYS SYSTEM

INTRODUCTION

The navigable waterways and harbors throughout the world are the result of natural conditions, generations of study, and decisions made to enhance trade and transportation. Many nations have contributed to the art and science of waterway development, which includes the design of vessels appropriate to specific transport requirements and to the character of the streams, lakes, canals, coastal waters, and harbors to be utilized. To understand the evolution of the waterways over time and their unique value in transportation, it is necessary to have a knowledge of the character of the system in its natural state and how and why it has been altered.

HISTORICAL DEVELOPMENT

The number and distribution of safe harbors, and the presence of several great rivers which led deep into the heart of the continent, no doubt contributed to the growth of the American colonies in the 17th and 18th centuries.

The coastal ports were the first to be developed. They were generally established on estuaries which were deep enough and provided natural protection for the ships of the day. As ship drafts increased, commerce suffered at ports which could not properly service the larger ships. The problem was partially overcome by lighters and by having ships enter and leave on the high tide. Lighters are smaller ships or boats onto which larger vessels can unload their cargo offshore from a port that is too shallow for the larger vessel to safely enter. Naturally, such inconvenience cost shippers more money; and insurance rates went up because of the potential danger to ships entering and exiting shallow ports. Those ports established in deeper water bodies with ready access to the nation's interior have survived and flourished. However, from their very inception, most U.S. ports have required dredging and training works to help maintain and/or improve navigable depths.

As the continent was explored it was found that the abundant rivers and lakes did not always easily lend themselves to commercial transport. In their natural state they were often swift, shallow, subject to dangerous flooding, and, above all, filled with obstructions of many types from dangerous rapids to log jams made up of fallen trees and brush. In order to take advantage of the potential of these natural transportation arteries, the colonists drew upon European technologic experience and their own innovation to overcome the obstacles encountered.

THE ERA OF CANAL BUILDING

Faced with the hazards of river navigation, the colonial settlements found that the slackwater canal offered the prospects of safe and reliable commercial navigation for both goods and passengers. European countries were experimenting with canals for commercial transport, and the American colonies and later the new states embraced the concept with enthusiasm as a way of developing the vast resources of the American frontier communities.

The era of canal building began in the late 1700s and was mainly a result of state-level initiatives. The canal development period essentially ended by the middle of the 1800s having peaked and begun an abrupt decline in the 1830s when the State of Pennsylvania went bankrupt. During the 1850s about 4,000 miles of canal were in use (see Figure III–1); few canals were planned following the Civil War. Many of the ante-bellum canals were of only local importance, but a few were phenomenal successes and had a truly national importance. Among these, the Erie Canal is outstanding, linking New York City with Lake Erie near Buffalo. With the discovery of anthracite coal in Pennsylvania, a whole series of canals were built to carry coal to the ports of the Atlantic seaboard. Millions of tons of coal and grain were moved in this way and the canals contributed, at a crucial period, to the rapid increase in the strength of America as a trading nation and as a growing world power.

FEDERAL ROLE AND DEVELOPMENT OF THE NATIONAL WATERWAYS

The rapid growth in railroad development before and immediately after the Civil War brought the canal building era to a rapid close. The steamboat revitalized navigation on the natural rivers. Fortunately the engineering talent developed during the era of canal building was available for work on the difficult task of developing the natural rivers for navigation, work which continues today.

In 1779, the Corps of Engineers was formed to provide engineering in support of the national defense. In 1787, the Northwest Ordinance was passed, establishing national oversight and control of the navigation system in order to promote interstate trade, settlement, and economic development. In 1790, the Revenue Cutter Service was formed. One of its duties was to serve as the Federal maritime police agency.

While private corporations and individual states were building canals to promote trade and development, much of the early Federal interest in the navigation system had been related to safety and to the improvement of natural harbors, lakes and rivers. In 1791, the first Federal investment in navigation structures was made in a lighthouse on the Atlantic coast at Cape Henry, Virginia. In 1802, the Corps of Engineers constructed piers in the Delaware River to support foreign and domestic trade. In 1824, the Corps initiated construction of a harbor on Lake Erie and began snagging operations on the Ohio River to remove hazards to navigation. At first, river improvement was largely an effort to remove obstructions and to provide canals for passage around falls or rapids. Later, steps were taken to improve channels for navigation by restricting the flow to one channel in the hope of deepening it and providing additional water for easier passage of river rafts and boats. Today, the inland waterways of the United States are, with a few exceptions, improvements to the natural water courses.

In 1884, Congress gave the Corps authority to reconstruct existing navigation structures whenever, in its engineering judgment, such replacement was necessary for safe and effective operation. For new water projects (which continued to require congressional authorization), a formal procedure was first established in 1899, and continues in much the same form today. At the same time, the Corps was given authority to control the placement of potential obstructions to navigation. In 1909, Congress granted additional authority to the Corps concerning navigation facilities. The 1909 authority permits essential repairs, rehabilitation, replacement or reconstruction of existing navigation structures which do not change the authorized project in scope, scale or location. Thus, the Corps of Engineers, with the concurrent authorization of Congress as appropriate, has been largely responsible for the broad framework of the national navigation system as we know it today.

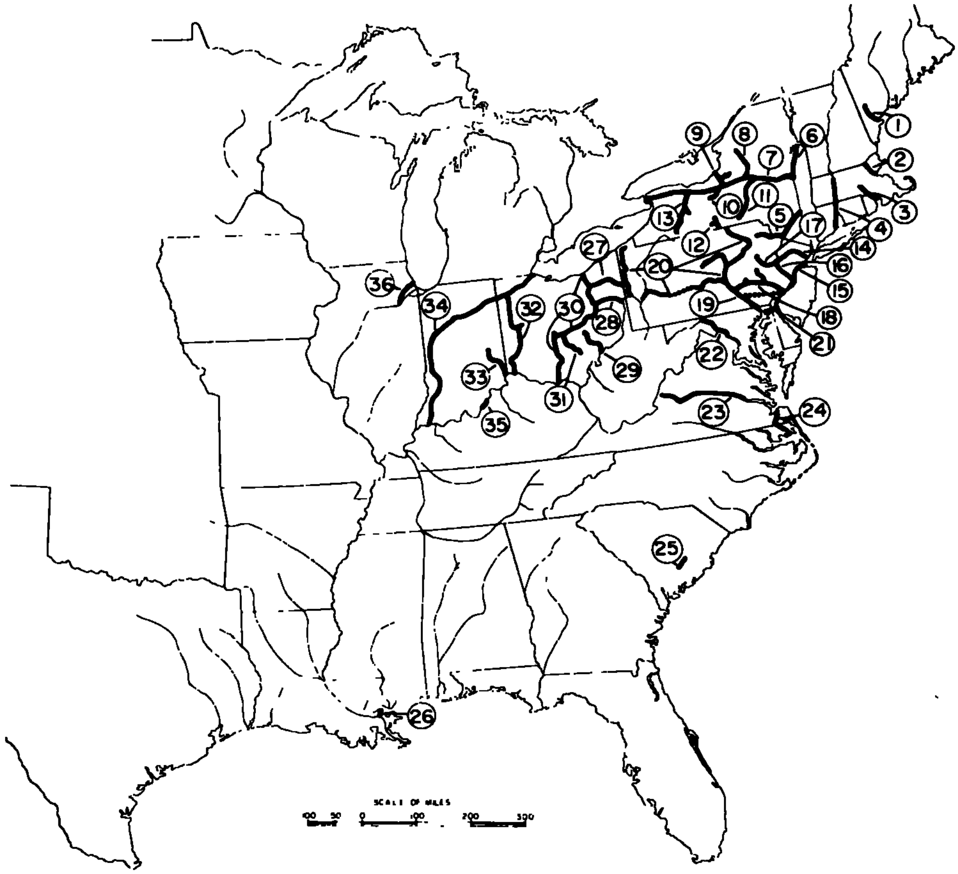
Because few rivers in their natural state meet modern requirements for commercial navigation, the Federal government, acting through the Corps of Engineers, has implemented engineering solutions. There are three basic methods for improving a river for navigation—channelization (open rivers or channels), canalization (locks and dams), and land-cut canals. Open-channel methods seek to improve the existing channel to the point where navigation is feasible through a combination of river training works and dredging. Training works help to direct natural currents in such a way as to aid in the maintenance of navigable depths. In canalizing a river segment, dams are used to create a series of slackwater pools through which waterway traffic can move, with locks to lift the vessels from one pool to the next. Land-cut canals provide a totally new channel cut by artificial means around an otherwise impassable obstruction or between two navigable bodies of water. (For more details about the methods of improvement for navigation, see Appendix B.)

In recent decades, the improvement of a waterway for navigation has often been coupled with other multipurpose objectives. In most instances these objectives do not conflict with each other, according to NWS research. Careful planning and implementation allow a project to provide a vareity of uses, including not only commercial navigation, but also recreational boating and shore based recreation, fish and wildlife habitat, flood control, hydropower, water supply storage for municipal and industrial uses, and the maintenance of water quality. Aspects of other water uses, and some of the conflicting demands that may occasionally arise, are further elaborated in Appendix B.

The inland waterways and Great Lakes systems carry about one billion tons—more than one-quarter of the total intercity freight traffic moving by rail, pipeline and water. The coastal ports handle practically all of the nation's exports and imports. Energy and agricultural commodities are major elements of waterborne traffic. The waterways system is a relatively efficient and low-cost mover of goods which has developed, like all other modes, by an active partnership between the Federal, state and local governments and private enterprise. Public replacement costs (in 1977 dollars) for the inland and coastal waterways, Great Lakes and seaways and coastal ports would be on the order of $52 billion, operations and maintenance costs are in excess of $300 million and other costs, including the U.S. Coast Guard, are significant. Investment by the non-Federal public and private sectors in landside transfer, storage, and processing facilities is many times the Federal investments in the waterways system. Private investment in the towboat and barge fleet alone on the inland waterways is about $11.5 billion. (All costs are expressed in terms of 1977 dollars unless otherwise stated.) For more details about the commercial waterborne carrier fleet of the inland, coastal and Great Lakes areas, see Appendix B.

Figure III-1

CANALS AND ASSOCIATED RIVER IMPROVEMENTS OF EARLY AMERICA (1786—1851)



Legend:

1 Cumberland & Oxford
2 Middlesex
3 Blackstone
4 New Haven & Northhampton
5 Delaware & Hudson
6 Champlain
7 Erie
8 Black River
9 Oswego
10 Cayuga-Seneca
11 Chenango
12 Chemung
13 Genesee Valley
14 Morris
15 Delaware & Raritan
16 Delaware Division
17 Lehigh Navigation
18 Schuylkill Navigation
19 Susquehanna & Tidewater
20 Penn. State Canal
21 Chesapeake & Delaware
22 Chesapeake & Ohio
23 James River & Kanawha
24 Dismal Swamp
25 Santee & Cooper
26 Carondelet
27 Ohio & Penn.
28 Sandy & Beaver
29 Muskingum
30 Ohio & Erie
31 Hocking
32 Miami & Erie
33 Whitewater
34 Wabash & Erie
35 Louisville & Portland
36 Illinois & Michigan

THE SHALLOW DRAFT AND COASTAL WATERWAYS

Map No. 1 of the NWS *Waterways System and Commodity Movement Maps* (Appendix G) shows the location of waterways and ports in the inland waterway system. This map presents a breakdown of navigable depths by waterway and port, as well as 1976 foreign and domestic waterborne commerce at major inland and coastal ports. A map of the U.S. waterways system is also provided in Figure I–1. The following section discusses the shallow draft waterways of the United States in terms of their history and development, as well as current physical characteristics of individual components of the system. More details about the physical characteristics are provided in Appendix D.

HISTORY AND DEVELOPMENT

The first shallow draft waterways were the previously noted canals constructed in the Northeast and Midwest in the late 1700s and early 1800s. The first commercial navigation on the rivers was by canoe, flatboat, and keelboat. This allowed primarily downstream transportation of agricultural and trade goods (such as furs). In 1807, the first steamboat operation appeared on the Hudson River in New York and its development eventually allowed upstream as well as downstream navigation using paddlewheel technology. Shallow draft steamboats extended to all of the other major navigable rivers as those areas of the country became populated. For example, the first steamboat is recorded on the Columbia River in 1850. Steamboats carried passengers, mail, general cargo, and bulk goods (primarily in bags, barrels, and bales) and were the major source of domestic freight transportation. Coal was carried downriver as a bulk commodity in open-topped barges, either floating free or towed by a steamboat. In the 1850s, towboats were specifically designed to push loaded barges lashed together as a single unit. This was a major technological innovation and an advance in the large-scale handling of bulk cargoes.

One of the major problems with these wooden hulled steamboats was "snagging" on stumps and logs in the river. Thus, a provision to remove snags from the navigable rivers to improve safety was included in the Corps' initial civil works program in 1824. In 1825, the Corps introduced dredging to remove sandbars and keep channels clear.

By the time of the Civil War, railroads had emerged as the dominant mode of transportation for passengers and general cargo. They were generally considered safer and faster than steamboats and could, of course, travel inland from navigable waterways. The resulting decline of the steamboat for general transportation left the waterways primarily carrying bulk grain from St. Louis to New Orleans for shipment to the East Coast and Europe and coal for domestic heating, industrial factory power, and as a boiler fuel for transportation.

In 1879, the Mississippi River Commission was formed to oversee flood control and navigation improvements on the Mississippi River. The commission's responsibilities included planning and prioritizing projects and obtaining local support for Federal projects. The Corps of Engineers designed and constructed the authorized navigation improvements.

Also in 1879, the first dam, with lock, was constructed from shore to shore across the Ohio River. Aids to navigation such as channel markings and lights were established to improve safety.

During World War I, the sinking of Allied shipping off the Atlantic and Gulf coasts by U-boats resulted in increased attention to the protection of the Atlantic and Gulf intracoastal commerce (mostly petroleum). World War I also found the railroad industry deficient in its ability to handle wartime materiel to and from ports for overseas deployment. As a result, the Secretary of War was authorized in 1920 to promote inland water transportation to compete with rail and formed in 1924 a new barge carrier, the Inland Waterways Corporation, which became Federal Barge Lines when it was sold to private interests in 1953.

By the beginning of World War II, 9-foot navigation channels had been completed on the Ohio, the Mississippi, and Illinois waterways. The 9-foot project on the Tennessee River became fully operational in 1944.

Since World War II, Congress has authorized and the Corps has constructed or is completing various extensions to the navigation system. These include a 9-foot channel in the Missouri River to Sioux City, Iowa; the Arkansas Waterway system to near Tulsa, Oklahoma; the Columbia-Snake Waterway; various rivers feeding the Gulf of Mexico; and (most recently) the Tennessee-Tombigbee Waterway to link the Tennessee River with the Black Warrior and Tombigbee rivers at Demopolis, Alabama, and the Red River navigation project in Louisiana.

INLAND AND COASTAL WATERWAYS

The major inland river transportation network of the United States is the Mississippi River and Tributaries, which include the Ohio River System, the Illinois Waterway, and the Arkansas and Missouri rivers, among others. In this system, shown on NWS Map No. 17, there are about 9,000 miles of improved navigable channels, 65 percent of which have 9-foot navigable controlling channel depths or more.

In contrast to the north-south orientation of the Mississippi River and Tributaries, the Gulf Intracoastal Waterway (GIWW) parallels the coast for 1,099 miles from Carrabelle, Florida to Brownsville, Texas, on the border with Mexico. The GIWW is a series of natural waterways linked by canals which intersects the Mississippi River at

New Orleans. To the east of New Orleans, the GIWW carries waterway traffic from the Mobile River and its tributaries and the Apalachicola-Chattahoochee-Flint system along with that from a number of smaller streams and channels. To the west, waterway traffic also enters at many points, among these, a branch of the GIWW which extends to the Mississippi River at Baton Rouge (known as the Baton Rouge-Morgan City Bypass or the GIWW: Port Allen Route), the Atchafalaya River, the Houston Ship Channel, and a number of other smaller canals and channels.

This network of inland and coastal waterways, the Mississippi River and Tributaries and the GIWW, connects some of the largest Gulf Coast ports—New Orleans, Houston, Baton Rouge, Beaumont, Corpus Christi and Mobile—with some of the largest inland and Great Lakes ports—Greater St. Louis, Greater Pittsburgh, Huntington, Cincinnati, Memphis, Chicago, Duluth/Superior, and Detroit. It also provides the setting for one of the world's greatest networks of towboat operations. And, in that section of the Mississippi River from Baton Rouge to the Gulf of Mexico, a controlling depth of 40 feet allows ocean shipping to join the barge traffic, making this segment of the inland waterway system vital to both the domestic and foreign trade of the United States.

The majority of Atlantic Coast waterborne commerce is found on deep draft waterways adjacent to the major ports of the coast. These include the Cape Cod Canal; the Cape Fear River below Wilmington; Chesapeake Bay; the Chesapeake-Delaware Canal; Delaware River and Bay; Hudson River below Waterford; and the James and Potomac rivers.

A number of shallow draft waterways connect Atlantic Coast ports and deep draft channels with areas further inland. Due largely to geography, most of these rivers are not very long and serve only a limited area. Among the improved shallow draft waterways of the Atlantic Coast area are the Cape Fear above Wilmington, the Connecticut, Kennebec, Penobscot, Rappahannock, Roanoke, St. Johns and Savannah rivers.

The Atlantic Intracoastal Waterway is a combination of protected coastal waterways and connecting canal segments which run parallel to the coast between Norfolk, Virginia and Jacksonville, Florida. Another section, known as the Intracoastal Waterway, continues from Jacksonville southward to the Florida Keys. There is also an unprotected stretch of the Atlantic Intracoastal Waterway along the Atlantic side of the Demarva Peninsula and along the coasts of New Jersey and Long Island.

The inland and coastal waterways of the Pacific Coast are few. Shallow draft waterways include the Columbia-Snake Waterway and the Willamette River above Portland, Oregon; the Sacramento River above Sacramento, California; the San Joaquin River above Stockton, California; and a few very short navigable river stretches along the Washington and Oregon coasts, such as the Siuslaw, Smith and Yaquina rivers. As on the Atlantic Coast, deep draft channels carry most of the waterborne commerce. These include the Columbia River below Portland, Puget Sound, the Sacramento and Stockton Deep Draft Ship Channels, and San Francisco Bay.

Mississippi River and Tributaries

The Mississippi River and Tributaries drain 1,244,000 square miles in all or parts of 31 states and two provinces of Canada (see Figure III–2). The Mississippi River itself is the largest and one of the most highly developed components of the inland waterways of the United States. Improvement of the Mississippi system for navigation by the Corps of Engineers began soon after the purchase of Louisiana from France in 1803. Navigation was facilitated first by clearing and snagging, then by channel improvements to provide shorter, safer routes. More recently, revetment, cutoff of bends, and reservoir construction furthered navigation. In the early 1900s the Federal Government began a series of permanent navigation structures on the Mississippi with a lock and dam.

Lower Mississippi River

Open-channel navigation exists between the mouth of the Mississippi and Baton Rouge, Louisiana, and between Baton Rouge and Cairo, Illinois, at the mouth of the Ohio River. The channel above Baton Rouge is presently maintained to the 9-foot depth by channel stabilization works and dredging; however, a 12-foot depth is available during most of the year. An authorized width of 300 feet is also currently maintained.

Between Baton Rouge and the mouth of the Mississippi, a deepwater channel is maintained to a 40-foot navigable depth, permitting oceangoing vessels to navigate 233 miles upstream to the Louisiana capital. The combination of deep and shallow draft waterborne commerce makes this river reach the most densely trafficked commercial waterway of the inland system, carrying nearly 350 million tons in 1977. The major ports of Baton Rouge and New Orleans play very significant roles in transhipping of both barge freight to oceangoing vessels and vice versa.

The Lower Mississippi between Cairo and Baton Rouge is perhaps the most significant of the shallow draft inland waterways. This 723 mile reach carries heavy traffic in both directions between deepwater at Baton Rouge and New Orleans and important upriver coal and grain producing areas on the Ohio, Illinois and Upper Mississippi rivers. Commerce between Cairo and Baton Rouge exceeded 120 million tons in 1977.

The Yazoo River, a tributary of the Lower Mississippi, is a 9-foot shallow draft project authorized in 1968. The authorization provides for a 9-foot navigation channel from the mouth of the Yazoo River at Vicksburg to Greenwood, Mississippi. The Yazoo is currently open to navigation, but has yet to be improved to full project specifications.

Lower Upper Mississippi River

The Lower Upper Mississippi extends 220 miles from the mouth of the Ohio River at Cairo, to the mouth of the Illinois River. There is an open-channel section from Cairo to Lock and Dam 27 near St. Louis. Above this point the river is canalized to the head of navigation near Minneapolis, Minnesota. Lock and Dam 26 (L&D 26), just downstream from the junction of the Illinois and Mississippi rivers, is currently the major constraint to traffic flow in the Mississippi system and a single 1200-foot replacement lock is under construction. Dredging and locks and dams are used to maintain authorized channel dimensions of 9 feet by 300 feet in the Lower Upper Mississippi. However, occasional low river flows may reduce navigation depths below 9 feet in the open river section below the mouth of the Missouri River. If future flows of Missouri River water are diverted for increasing irrigation and water supply needs, the problem of inadequate depth may increase.

Over 77 million tons of commerce moved on this river reach in 1977. Congestion at L&D 26 is a problem for most all the waterborne commerce. The downstream movement of agricultural products for export is steadily increasing in importance. The predominant southbound tonnage at L&D 26 is grain and grain products. The predominant northbound movements are coal, petroleum and petroleum products.

The open-channel design of most of the Lower Upper Mississippi involves the use of stone dikes, bank revetment for stabilization, and dredging for maintenance of navigable depths. In recent years, efforts have centered on improving designs and selecting optimum locations for the stone dikes and, in this way, to minimize dredging operations which are costly and which usually have only short-term effects. In conjunction with Missouri and Illinois conservation interests, alternative dike designs by which the fish habitat in this reach may be maintained and improved are also being considered.

The Kaskaskia River is a tributary of the Lower Upper Mississippi which is being improved for navigation upriver for 50 miles from the mouth of the river near Chester, Illinois. The improvement of the Kaskaskia, authorized in 1962, consists of a 9-foot navigable depth and 225-foot width upriver to Fayetteville, Illinois. It includes a single lock and dam less than a mile from the junction with the Mississippi River.

Upper Mississippi River

Navigation on the Upper Mississippi River extends 637 miles north from the mouth of the Illinois River to Minneapolis, Minnesota. The project navigable depth of 9 feet is provided by a series of 27 locks and dams, together with channel regulating works and dredging. Winter ice conditions limit the general navigation season to 8 months above Hannibal, Missouri, near Lock and Dam 22. Navigation improvements on the Upper Mississippi were initiated in 1824 with snagging and clearing operations. The modern canalized system of locks and dams began with authorization in 1930 of a series of higher locks and dams between Alton, Illinois and Minneapolis, Minnesota. Initial construction began in 1934 with Lock and Dam 26, on the Lower Upper Mississippi.

Dredging is also required in order to maintain a 9-foot navigation channel on the Upper Mississippi. Environmental concerns over dredged material disposal have reduced volumes in recent years. However, considerable progress is being made through the GREAT (Great River Environmental Action Team) River Study of the Mississippi River Main Stem to find new and more acceptable uses for these materials which are both economically and environmentally feasible.

Ohio River System

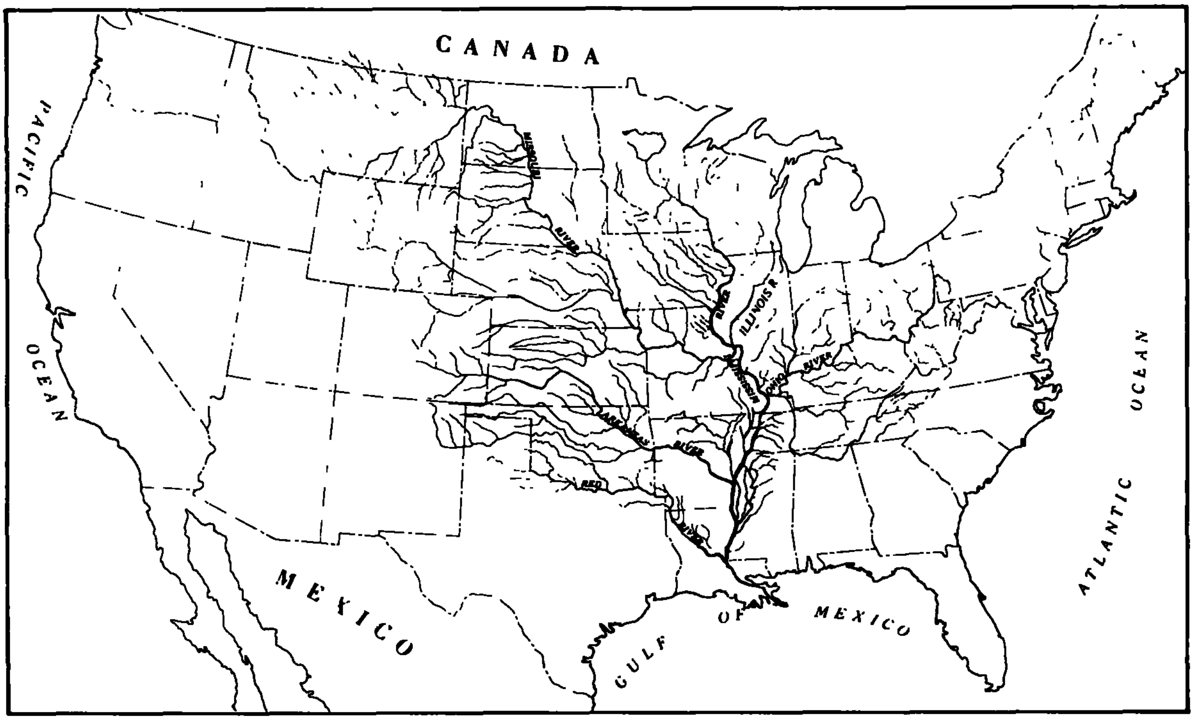
In terms of total waterborne commerce the Ohio River is the most important tributary of the Mississippi. In 1977, the Ohio carried over 180 million tons of traffic.

The Ohio River, formed by the confluence of the Allegheny and Monongahela rivers at Pittsburgh, Pennsylvania, flows generally southwesterly 981 miles to join the Mississippi near Cairo. The Ohio drains a great industrial, agricultural and coal producing basin of 204,000 square miles. The major rivers in the Ohio River basin which have been improved for navigation and other purposes, and the length of each, include the Ohio River itself, 981 miles; the Cumberland, 381 miles; the Green and Barren rivers, 150 miles; the Kanawha, 91 miles; the Allegheny, 72 miles; and the Monongahela, 129 miles. There are more than 200 manmade reservoirs in the basin providing over 40 million acre-feet of storage and over 2,656 square miles of water surface. Between 2 and 3 million acre-feet of storage is specifically reserved for low flow augmentation, primarily to meet water quality objectives, although navigation is also enhanced.

Prior to navigation improvements, the Ohio River annually experienced low water, limiting navigation depths to 16–20 inches for periods up to 6 weeks. The earliest major navigation improvement project was the Louisville and Portland Canal, in 1830, which allowed river traffic to avoid the falls at Louisville. Other than the canal, the primary means of improving navigation until 1900 was channel clearing and excavation. In 1910, Congress authorized a 9-foot navigation project of 53 locks and dams on the Ohio from Pittsburgh to Cairo, to be completed in 1929.

Modernization of the navigation facilities on the Ohio River commenced during the 1950s, and the 9-foot navigation channel depth is now provided at 20 sites by locks and dams. The modernization project was designed to provide more efficient service and to reduce maintenance costs. Fewer locks with higher lifts provide longer slackwater pools; larger lock chambers eliminate the need for double lockages; and new emptying/filling systems

Figure III-2
MISSISSIPPI RIVER WATERSHED



reduce lockage times. Thirteen high-lift locks replaced 39 old low-lift locks and dams. Most elements of the modernization project are either complete or under construction. The exceptions are three upstream locks, Gallipolis Lock and Dam near Huntington, West Virginia and permanent replacements for Locks 52 and 53, near Paducah, Kentucky. Gallipolis is becoming an increasingly serious congestion point for waterborne commerce on the Ohio. The three lock and dam projects furtherest upstream—Emsworth, Dashields, and Montgomery Island—are the smallest and among the oldest on the Ohio River.

Today the Ohio River's importance as a major transportation artery for the movement of coal is increasing as it helps meet the mushrooming demand, both in the United States and abroad, for this energy resource. Coal is used widely within this reach for electric utilities, industrial power plants and coke ovens. Delays associated with Gallipolis Lock therefore have an impact not only upon the coal industry, but also on electric utilities and the steel industry.

The six major tributaries of the Ohio River, noted above, have been improved by means of locks and dams to provide 9-foot navigation channels. Appendix D shows the physical and operating characteristics of these rivers. They are important conduits for commodities moving on the Ohio itself and are especially crucial in providing navigation access to major coal production areas in Pennsylvania, West Virginia, Ohio and Kentucky.

Other tributaries of the Ohio which have been improved for navigation include the Kentucky, Big Sandy and Muskingum rivers, all of which carry relatively small amounts of traffic. The Big Sandy and the Muskingam rivers are maintained at a navigation depth of 9 feet for 7.5 miles and 5 miles, respectively, from their mouths, while the Kentucky River is maintained at less than a 9-foot depth. Navigation on the Kentucky is provided by a series of 14 locks and dams between the junction with the Ohio River and Beattyville, Kentucky, 259 miles upstream. Commercial navigation after 1982 will be limited to the lower 82 miles and 4 locks and dams. The upper 10 locks will be closed.

Tennessee River

The Tennessee River, one of the major tributaries of the Ohio (but discussed separately for NWS purposes), originates at the junction of the Holston and French Broad rivers just above Knoxville, in eastern Tennessee. From that point, it flows 652 miles in a southwesterly direction through the state of Tennessee into northern Alabama where it turns to the northwest and flows into the northeast corner of Mississippi. There it swings north, again crosses Tennessee, and continues across Kentucky to where it enters the Ohio River near Paducah, 46 miles above the junction of the Ohio and Mississippi rivers.

The development of the Tennessee basin by the Corps of Engineers has not been extensive due to the creation of the Tennessee Valley Authority (TVA) in 1933. Of the nine existing multipurpose projects on the main stem of the river, only one, Wilson Lock and Dam in Alabama, was built by the Corps. The Corps, however, has the responsibility of operating and maintaining the locks associated with these projects.

Slackwater navigation from the mouth of the Tennessee River to Knoxville, a distance of about 650 miles, is currently provided by 13 locks and 9 dams. The project depth is 9 feet, which was completed over the full length of the waterway in 1948. Navigation is also provided on the Clinch River from its junction with the Tennessee River to the vicinity of Clinton, Tennessee, a distance of about 60 miles. Melton Hill Lock and Dam, which allows navigation on the Clinch, was also constructed by TVA.

Traffic developed quickly after completion of the TVA locks and dams, reaching 3.1 million tons in 1941. After declining during the World War II, traffic resumed its growth and was over 26 million tons in 1977. Commodities moving on the river consist chiefly of coal, grain, stone, sand and gravel, as well as petroleum products.

Illinois Waterway

The second most significant of the tributaries of the Mississippi River in terms of waterborne commerce is the Illinois Waterway, which is located entirely within the state of Illinois. This waterway, which carried over 60 million tons in 1977, connects Lake Michigan with the Mississippi River.

The Illinois Waterway is part canal and part canalized river. It leaves Lake Michigan at Chicago from two points, the Chicago River and the Calumet River, and then flows 326 miles in a southwesterly direction to enter the Mississippi River about 38 miles above St. Louis. Total length of the project is 357 miles, which includes the separate channels to Lake Michigan. In 1827 the state of Illinois built the first canal connecting the Chicago River with the Illinois River; the idea, however, had been discussed much earlier by Louis Joliet, a French-Canadian explorer, in 1673. Various congressional acts, beginning in 1917, have resulted in construction of a 9-foot by 300-foot navigation channel for most of the Illinois Waterway by means of eight locks and six dams, lateral canals and dredging.

McClellan-Kerr Arkansas River Navigation System

The Arkansas River rises in the Rocky Mountains and flows southeastward through Colorado, Kansas, Oklahoma and Arkansas to join the Mississippi 599 miles above its mouth. Federal improvements in the Arkansas River date from 1832 when channel maintenance was authorized by Congress. Subsequent statutory enactments authorized snagging and clearing, dredging, revetment works, channel modifications and removal of bars. There were significant lapses of time, however, when work ceased due to lack of funding. In 1946 Congress approved a multipurpose development plan for the Arkansas for navigation, flood control, hydroelectric power generation, water supply, sediment control, recreation, and fish and wildlife. After 24 years of planning, designing and construction, the McClellan-Kerr Arkansas River Navigation System was opened to waterborne commerce in December 1970, and was officially dedicated in June 1971. The project provides a 9-foot navigation channel, 100 to 300 feet wide and about 448 miles long, on the White, Arkansas and Verdigris rivers to Catoosa, Oklahoma, near Tulsa. A lift of about 420 feet is achieved by 17 locks and dams. Three upstream lakes were authorized as part of the multiple purpose project in 1946. Over 15 lakes are now operated for multiple purposes, including navigation. The Arkansas River carried over 9 million tons of commerce in 1977.

The White River above the junction with the McClellan-Kerr system is also maintained for navigation up to Augusta, Arkansas. The existing project was authorized in 1892. Currently a minimum depth of 4.5 feet and bottom width of 100 feet are maintained through snagging, dredging and some contraction works. Waterborne commerce in 1977 amounted to over 660,000 tons.

Missouri River

The first vessels of non-native explorers known to have ascended the Missouri River were those of the Lewis and Clark Expedition in 1804. By 1856 steampowered vessels, already in service on the Mississippi and Ohio and other eastern rivers, were also in service on the Missouri as far as Sioux City, Iowa. The Missouri River Commission, created in 1884, undertook construction of revetments and clearing and snagging operations until 1902, when the commission was dissolved. A 1907 survey report served as the basis for the authorization in 1912 of a permanent 6-foot navigable channel from Kansas City to the mouth of the river. Twenty years later this objective had not been achieved, although much work had been undertaken.

The Missouri River has since been developed for hydroelectric power, flood control, navigation, irrigation, and other uses by means of six major upstream multipurpose reservoirs. The navigation project is 735 miles long from Sioux City, to the mouth. A 300-foot wide by 9-foot deep navigable channel is authorized and generally an 8 to 9-foot depth is maintained except during low flow periods. Navigation is open-channel, and the water level is maintained by releases from the upstream lakes. The navigation project is operated over an eight-month season due to limited availability of water from upstream reservoirs and winter ice.

Currently there is no reservoir storage space authorized exclusively for navigation on the Missouri River. Studies performed in 1971 indicate that the present operational plan would have been capable of providing a full eight-month navigation season only 66 of the 71 years of record. While flows released for hydroelectric power generation are generally compatible with navigation, consumptive offstream uses such as irrigation and water supply are competitive. Future reduction of available flows on the Missouri may adversely affect the length of the navigation season, as well as contributions to the Lower and Lower Upper Mississippi River.

Other Tributaries

There are several smaller rivers in various stages of improvement for navigation which connect with the Mississippi River system.

The Atchafalaya River is a relatively new natural stream in the process of self-creation. The formation of the Atchafalaya dates from sometime in the 15th century when an enlarging loop or bend of the Mississippi River broke into the basin of the Red River. By 1940, the Atchafalaya provided a route to the sea possessing a slope advantage over the old mainstream Mississippi River channel flowing past New Orleans; it was no longer necessary to dredge the Old River, as the connection between the Mississippi and the Atchafalaya is commonly known. The channel in the Atchafalaya continued to enlarge. The Mississippi River Commission indicated that the capture of the Mississippi by the Atchafalaya channel was only a matter of time. The congressional act of September 3, 1954, provided for a control structure at Old River which effectively transformed the Atchafalaya into a controlled floodway system. This control system also included a navigational lock to provide access for river commerce between the Mississippi and the Red and Atchafalaya rivers.

The channel in the Atchafalaya River, a 12-foot navigation depth and a bottom width of 150 feet, extends from the Gulf Intracoastal Waterway at Morgan City, Louisiana to the Mississippi River. Use of the 162-mile Old and Atchafalaya rivers shortens the distance between the Gulf of Mexico and the Mississippi by 172 miles and eases congestion in the Port of New Orleans. In 1977, the Atchafalaya and Old rivers carried nearly 6 million tons of waterborne commerce.

The improvement of the Ouachita and Black rivers was first authorized in 1871. Work on the original project was completed in 1926, and provided a navigable depth of 6.5 feet from the mouth of the Black River in Louisiana to Camden, Arkansas, a distance of 351 miles.

The River and Harbor Acts of 1950 and 1960 modified the original project to increase the navigable depth to 9 feet beginning at the mouth of the Red River, which joins the Atchafalaya, and extending to Camden, on the Ouachita River. Work on this navigation project is underway. Eventually four new locks and dams will replace the six obsolete structures. The Jonesville and Columbia locks and dams were placed in operation in June 1972 and provide a 9-foot navigation channel from the mouth of the Red River to old Lock and Dam 6 near Felsenthal, Arkansas, upstream from the Louisiana-Arkansas state line. Replacements for the two remaining locks, 6 and 8, are presently under construction at Felsenthal and Calion. Currently a 9-foot channel exists on the Ouachita for 208 miles upriver from the junction of the Old and Red rivers.

The Red River Waterway, to improve navigation between the Mississippi River and Shreveport, Louisiana, was authorized under the River and Harbor Act of 1968. The act provided for a slackwater channel 9 feet deep, 200 feet wide and 210 miles long, utilizing five navigation locks and dams. Construction was initiated in 1973 and includes channel realignment and stabilization work, as well as the beginning of construction of Lock and Dam 1, which is currently scheduled for completion in 1985.

Gulf Coast Waterways

Several shallow draft waterways which parallel the Gulf Coast connect with the Mississippi River system, as well as with inland ports in the Southeast.

Gulf Intracoastal Waterway (GIWW)

The idea of building a protected waterway along the Gulf Coast originated in the 19th century. Because the Gulf is subject to severe and sudden storms that create real dangers for small crafts, early settlers along the Gulf used the numerous bays and sounds for long distance movements and for safe anchorages. The acquisition of Florida from Spain in 1819 created the potential for east-west regional trade. Connecting the Atlantic trade and that of Pensacola, Mobile and New Orleans with the Mississippi River and its vast hinterland, proved an attractive commercial idea.

The River and Harbor Act of 1873 authorized a survey between Donaldsonville, Louisiana, on the Mississippi River above New Orleans, and the Rio Grande River on the Mexican border. The report, completed in 1875, proposed a 6 by 60-foot canal from the Mississippi River to the Rio Grande. The project was justified almost entirely on potential future development which might result from the proposed waterway improvement. Because of this, and the cost associated with the project, Congress took no further action at that time. Small-scale projects were, however, constructed in Texas and, with the purchase of a privately constructed canal in 1902, a continuous channel was available from Galveston Bay to the Brazos River.

The River and Harbor Act of March 3, 1905 authorized new surveys in Louisiana and Texas, but the waterway took form only in separate pieces. In 1908, Congress authorized a 5 by 40-foot channel between Bayou Teche, near Franklin, Louisiana, and the Mermentau River, and, in 1910, an extension of the waterway was authorized from the Mermentau to the Sabine River. In 1923, several channels with various dimensions had been authorized and constructed between New Orleans and the Sabine River and between Galveston and Corpus Christi. Studies conducted in 1923 and 1925 furnished the basis for congressional action to authorize the construction of the 9 by 100-foot Louisiana and Texas Intracoastal Waterway between the Mississippi River at New Orleans and Galveston Bay. In 1927, the same dimensions were authorized for the reach between Galveston Bay and Corpus Christi.

But progress on a coastal waterway east of the Mississippi was slow. After many improvements and many delays, the present dimension of 12 by 125 feet was established in July 1942 and construction was carried out. Although its terminus, Carrabelle, Florida, is a remote and relatively small port, the importance of the GIWW was realized during World War II. To cope with petroleum shortages the Federal Government laid pipelines from Carrabelle to Jacksonville, Florida and Chattanooga, Tennessee. Because of German submarine operations along the South Atlantic Coast, gasoline and other refined petroleum products were shipped on the Gulf by barge and inland by pipeline to avoid the dangers in open water experienced by oil tankers

World War II also stimulated construction of the remaining section in Texas. On July 23, 1942, Congress, motivated by national defense considerations, authorized enlargement of the waterway dimensions to 12 by 125 feet and its extension to Apalachee Bay on the east and to the Mexican border on the west. With the extensions, the waterway would protect shipping for 1099 miles; 430 miles between Apalachee Bay and New Orleans, and 669 miles between New Orleans and the Mexican border.

There are nine locks along the main GIWW route, some of which serve functions other than navigation. At New Orleans, the Inner Harbor Navigation Canal Lock, constructed by the Board of Commissioners of the Port of New Orleans in 1923, connects the Mississippi River and the GIWW east of the Mississippi River to overcome differences in water levels between the river and the canal. On the west side of the Mississippi River, Harvey and Algiers locks serve the same function, connecting the Mississippi River and the western section of the GIWW via two alternative routes. Bayou Boeuf Lock, located near Morgan City, Louisiana, is situated in the East Atchafalaya basin protection levee at a point where it crosses the GIWW. This lock provides for navigation through the levee which protects areas east of Morgan City from Atchafalaya Basin floodwaters. Vermilion Lock, near Abbeville, Louisiana, and Calcasieu Lock, near Lake Charles, Louisiana, were constructed and are operated to prevent intrusion of saltwater into the Mermentau River basin. These two locks, in conjunction with the Schooner Bayou and Catfish Point control structures, also regulate the water levels in White and Grand lakes. Similarly, on the Texas coast, the Brazos River floodgates provide flood control to protect the GIWW, while the Colorado River locks provide a mechanism to reduce silt infiltration into the waterway.

The Gulf Intracoastal Waterway also has a number of connecting and side channels associated with it. Among the largest of these is the Baton Rouge-Morgan City Bypass (or GIWW: Port Allen Route), authorized by the River and Harbor Act of 1925, and by subsequent modifications through the River and Harbor Act of 1946. A 12 by 125-foot navigable channel is maintained from Morgan City, Louisiana, on the GIWW, to the Mississippi River at Port Allen, near Baton Rouge. The 64.1 mile alternate route was completed in 1962.

Other important channels connecting with the GIWW include the Mississippi River Outlet (a deep tidewater outlet to the Gulf from New Orleans that is about 37 miles shorter than the Mississippi River route), the Houma Navigation Canal; Freshwater Bayou; Chocolate Bayou; San Bernard River; Colorado River Channel to Bay City; navigation channel to Victoria, Texas and the channel to Harlingen. Besides the Mississippi River Outlet, several major deepwater channels cross the GIWW and serve oceangoing traffic as well as barge traffic. These include the nationally important Houston Ship Channel (the shallow draft Trinity River Channel to Liberty connects with the Houston Ship Channel); the Sabine-Neches Waterway which serves the ports of Port Arthur, Beaumont, and Orange, Texas; the Calcasieu River to Lake Charles, Louisiana; channels to Freeport Harbor, Corpus Christi and Brownsville, Texas; Matagorda Ship Channel; channels to Gulfport and Pascagoula, Mississippi, and to Mobile and Pensacola bays.

Mobile River and Tributaries

Shallow draft navigation is provided on the Mobile River from the Port of Mobile and Mobile Bay upstream to the confluence of the Alabama and Tombigbee rivers. Navigation continues up the Tombigbee to Demopolis, Alabama, and up the Alabama to just north of Montgomery, Alabama. Navigation is provided on the Black Warrior River from its confluence with the Tombigbee at Demopolis upstream to the confluence of Locust and Mulberry forks. Navigation continues for short stretches on both forks and provides access to Port Birmingham, Alabama.

The Tennessee-Tombigbee Waterway, now under construction, will provide through navigation via canal and canalized river segments between the Tennessee River and the Tombigbee River at Demopolis. The Tombigbee River is presently open for navigation to Columbus, Mississippi.

The waterways of the Mobile-Tombigbee-Black Warrior basin played an important part in the history of the area. Records of Mobile Bay go back as far as the early 1500s, when its distinctive outline appeared on charts of early navigators who entered the Gulf of Mexico. Explorers, Indian traders and settlers used the water highways of the basin. During plantation days and later, steamboats from Mobile plied the Tombigbee River far into Mississippi and up the Black Warrior River to Tuscaloosa, and after locks were built, to the Birmingham area.

The first improvement on what is now the Black Warrior-Tombigbee Waterway was a navigation project for the Black Warrior River adopted in 1875. Between 1895 and 1915, 17 locks and dams were constructed between Mobile and Birmingham for steamboat traffic; the dams were later raised to provide sufficient channel depth for barge traffic. A modernization program was started to replace the old low-lift structures, whose number and small lock chambers had become impediments to movement on the waterway, with a smaller number of high-lift locks suitable for present-day barge traffic. The first modernization structure, Oliver Lock and Dam at Tuscaloosa was opened to traffic in 1939, replacing three of the oldest of the original structures. Since that time five additional new structures—Demopolis, Warrior, Coffeeville, Holt and Bankhead—have been completed to replace 14 remaining original structures.

Joining the Tennessee and Tombigbee rivers to provide a new trade route connecting Mobile and the Gulf Coast with the mid-section of the nation has been discussed and studied for many years, both before and after its authorization in 1946. Construction on the huge undertaking was initiated in 1972 and is scheduled for completion in the mid-1980s. The river section will contain a 9-foot navigable channel and the canal and divide sections will be 12-foot channels. The bottom width will be 300 feet, except in the actual divide cut, where it will be 280 feet. The lock chambers will be 110 feet wide by 600 feet long, corresponding to locks on the connecting waterways. The 10 locks will have a total lift of 341 feet. Currently, the lower 115 miles of the waterway is open to navigation.

The Alabama River meanders westward and southwestward from its source at the confluence of the Coosa and Tallapoosa rivers, near Wetumpka, to its junction with the Tombigbee River to form the Mobile River near Calvert, about 45 river miles above Mobile. This is an overall navigable length of nearly 315 miles.

During settlement of the lower river basin, the Alabama was the principal artery of transportation for forest and agricultural products moving to Mobile for export and for imported manufactured goods moving upstream to settlers along the river. Later packet boats provided regular freight and passenger service on the river. Modern improvement of the Alabama and Coosa rivers was authorized in the River and Harbor Act of 1945. Plans envisioned the ultimate development of the entire system for flood control, power development, navigation and other purposes. Development of the Alabama was begun in 1963. It consists of channel improvements from the mouth to Claiborne, and locks and dams at Claiborne, Millers Ferry and Jones Bluff. This development provides a 9-foot navigation channel from Mobile to the vicinity of Wetumpka, a short distance above Montgomery. The entire navigation channel was opened to river traffic with the completion of the Jones Bluff Lock in early 1972.

Apalachicola-Chattahoochee-Flint System

The main stem of the Apalachicola-Chattahoochee-Flint (ACF) system is the Apalachicola River, which flows south across the panhandle of Florida from the vicinity of the Georgia line to the Gulf of Mexico. It is formed by the confluence of the Chattahoochee and Flint rivers in the extreme southwest corner of Georgia. The Chattahoochee flows southwestward from the Blue Ridge Mountains across Georgia and forms the Georgia-Alabama state line for about 170 miles before the junction with the Flint.

Federal work on the Apalachicola began as early as 1828. Earliest work on the Chattahoochee was authorized in 1874, and provided a 4-foot channel for steamboat traffic up the river to Columbus, Georgia. The River and Harbor Acts of 1945 and 1946 approved a comprehensive plan for development of the entire Apalachicola-Chattahoochee-Flint basin which included a 9-foot channel from the Gulf 268 miles to Columbus on the Apalachicola and Chattahoochee rivers, and to Bainbridge, Georgia, on the Flint, 29 miles above the junction with the Chattahoochee. The navigation component of the project was completed in 1963 and includes three locks and dams.

During dry spells navigation on the ACF can be adversely affected by low water conditions.

Atlantic Coast Waterways

The estuaries and rivers of the Atlantic and Pacific coasts were explored by Europeans at about the same time. The streams entering the Atlantic offered relatively easy access to the interior and encouraged settlement and trade. NWS Map No. 16 shows the waterways of the Atlantic area.

The navigable tidal rivers of the Atlantic Coast of the United States with their associated bays, estuaries and sounds, played a crucial role in the settlement of the nation and retain important commercial transportation functions today. The Connecticut and Hudson rivers; the Delaware and Chesapeake bays; the Potomac, Rappahanock, James and York rivers; and the Cape Fear, Savannah, and St. Johns rivers all have an important place in the history of navigation and economic development of the Atlantic seaboard. A number of major ports developed at the mouth of some of these streams, including New York, on the Hudson; Philadelphia, on the Delaware; Baltimore, on Chesapeake Bay; Washington, D.C., on the Potomac; Richmond, on the James; and Savannah, on the Savannah River. The following section highlights some of the major Atlantic Coast rivers and waterways.

Cape Cod Canal

The Cape Cod Canal is a deep draft, sea level canal located about 50 miles south of Boston at the narrow neck of land joining Cape Cod to the mainland. It extends from Cape Cod Bay on the northeast to Buzzards Bay on the southwest.

The canal, with a channel 25 feet deep, was constructed by a private corporation and opened as a toll canal in 1914. It was purchased by the Federal Government in 1928. In 1935 the project was modified to provide for an open canal 32 feet deep, with a width of 540 feet in the 7.7 mile land cut. In addition to commercial functions, the canal is very heavily used for recreation and sport fishing. Commercial tonnage in 1977 was over 11.2 million tons and included petroleum and petroleum products, gypsum, cement, and general freight.

Connecticut River

The Connecticut River rises in northern New Hampshire, flows southward for 409 miles and empties into Long Island Sound at Old Saybrook, Connecticut, 14 miles west of New London. In colonial days this river played a major role in the economy of the region, although it was never easy to navigate due to numerous falls. Hartford, 52 miles by channel from the mouth, is now the head of commercial navigation.

The existing navigation project provides for a channel 15 feet deep and 150 feet wide to Hartford. There are two riprap jetties at the mouth of the river. Dikes, training walls, revetments, and other regulatory works are used along the river. In 1977, the Connecticut carried nearly 2.2 million tons of commerce, largely petroleum and petroleum products.

Hudson River and New York State Waterways

Navigation of the waterways of the Atlantic Coast extends in most cases only as far as the tidal flow. The major exception is the Hudson River, where the New York State Barge Canal System provides navigation northward to Lake Champlain, westward to Lake Erie, and northwestward to Lake Ontario. This canal system has taken the place of the old Erie Canal, originally constructed between 1817 and 1825. The Erie Canal for many years provided the only all-water route from the Atlantic to the Great Lakes. The growth of New York City as a major world port owes much to this canal system, which, in its present form, was started in 1905 and completed in 1968.

This canal system is a network of waterways, some completely manmade and others composed of improved natural water courses. It consists of the Erie, Cayuga-Seneca, Oswego and Champlain canals. With navigable depths of 12–14 feet, these canals were built and are maintained by the state of New York. The project provides for the allotment of Federal funds to the state of New York for expenditure under suitable Federal control and supervision in the improvement of the canal connecting Lake Ontario with the Hudson River.

The Hudson River rises in the Adirondack Mountains and flows southward for 315 miles to New York City, emptying into New York Harbor. The part under improvement by the Corps of Engineers extends from New York City to Waterford, about 156 miles, and includes one lock at Troy. A channel 600 feet wide from New York City to Kingston, and 400 feet wide from there to Albany, is maintained at a navigable depth of 32 feet, with substantially lower channel width and depth to Waterford. Work under the existing project began in 1910 and was operationally completed by 1968. The Federal project for the Great Lakes to Hudson River Waterway, which includes the Oswego Canal and eastern Erie Canal, provides for a depth of 13 feet over lock sills and 14 feet in channels at normal navigation pool level. The eastern section of the Erie Canal contains 23 locks; the Oswego Canal, 8 locks; the western section of the Erie, 12 locks; the Champlain Canal, 11 locks; and between Buffalo and Niagara Falls, one lock.

Chesapeake and Delaware Ship Canal

The Chesapeake and Delaware ship channel, a sea level canal, large and deep enough to carry ocean ships from Chesapeake Bay to Delaware Bay, was initiated in 1919, when Congress enacted legislation for the purchase of the old Chesapeake and Delaware barge canal for $2.5 million. The original canal was constructed during the period 1824–1829 by private interests, with assistance from Pennsylvania, Delaware, Maryland and the Federal Government. The initial Federal work provided for a lock-free canal, 12 feet and 90 to 150 feet wide. In 1935, an enlargement plan was adopted which provided a depth of 27 feet and a width of 250 feet from the Delaware River to the Elk River, and 400 feet in the Elk River and Chesapeake Bay. Approach channels were also added. In 1954 further deepening to 35 feet and widening to 450 feet were authorized. Dredged material disposal concerns delayed implementation of the project for a number of years, but deepening was completed in 1981. Traffic for the year 1977 was 10.8 million tons.

Atlantic Intracoastal Waterway

A partially protected coastal water route along the Atlantic Coast allows commercial tows and other light draft vessels not suited to navigation in the open Atlantic to move between Massachusetts and Florida. Earliest improvement works were completed by private capital and repayed by tolls. This approach resulted in relatively limited and scattered development. In the late 19th century, the Federal Government began to adopt a comprehensive plan, although certain segments were not authorized until 1949.

The Atlantic Intracoastal Waterway (AIWW) begins at Ipswich Harbor in Massachusetts, follows the Annisquam River and Blymen Canal to Gloucester Harbor, crosses Massachusetts Bay to the Cape Cod Canal, then provides passage generally by Long Island Sound, the East River, Upper and Lower New York bays, into the Atlantic Ocean and along the New Jersey shore. Two routes are available to Hampton Roads, Virginia, using either the Chesapeake and Delaware Canal and the open waters of Chesapeake Bay, or following the less protected coastal route along the Delmarva Peninsula. The waterway continues via the Elizabeth River and, southerly, via either the Albemarle and Chesapeake Canal route or the Dismal Swamp Canal route and Albemarle Sound into the mouth of the Neuse River in North Carolina. The waterway includes sounds, streams, and marsh and land cuts along the coasts of North and South Carolina, Georgia, and into the St. Johns River below Jacksonville, Florida. The project then continues as the Intracoastal Waterway along the Florida coast to Miami. The Okeechobee Waterway provides a connection with the Gulf of Mexico and ultimately to Tampa Bay. Portions of the project along the Delmarva Peninsula and along the New Jersey and Long Island coasts are not protected and are not maintained to the same depth as the principal sections between Norfolk, Virginia and Jacksonville, Florida. The length of the AIWW is 739 miles between Norfolk and Jacksonville, and 371 miles between Jacksonville and Miami. The Intracoastal was extended from Miami to Cross Bank in the Florida Keys in 1939. The remaining portion of the waterway from Cross Bank to Key West has been placed in an inactive category.

Other Atlantic Coast Waterways

Numerous other coastal inlets, bays and rivers have been improved to varying degrees and distances for navigation along the Atlantic Coast. Among the more significant of these projects are: the Penobscot River to Bangor, Maine; the Potomac River to Washington, D.C.; the Rappahananock to Fredricksburg, Virginia; the York River to West Point, Virginia; the James River to Richmond, Virginia; the Appomattox River to Petersburg, Virginia; the Chowan, Roanoke, Pamlico-Tar, Neuse, Cape Fear and Northeast Cape Fear rivers in North Carolina; the Savannah River to Augusta, Georgia; the Altamaha-Oconee-Ocmulgee rivers in Georgia; the St. Mary's River to Trader's Hill, Georgia; and the St. John's River to Lake Harney, Florida.

Navigation locks are maintained on the Cape Fear and Savannah rivers. Three locks provide shallow draft navigation to Fayetteville, North Carolina, on the Cape Fear, while New Savannah Bluff Lock and Dam permits navigation on the Savannah River to Augusta, a distance of approximately 200 miles.

West Coast Waterways

The Columbia River and tributaries in Oregon and Washington have been developed for inland navigation and other purposes. A deep draft channel connecting San Francisco Bay through the Sacramento Delta brings ocean shipping to Sacramento, California. Improvements to the San Joaquin River for navigation also permit deep draft vessel traffic between San Francisco Bay and Stockton, California.

Columbia-Snake Navigation System

Commercial navigation along the Columbia River and its tributaries dates from the early 19th century. Fur traders used the waterways extensively. Later, oceangoing vessels reached Vancouver, Washington on the Columbia River, as well as Portland and Oregon City, on the Williamette. Steamboats plied sections of the Columbia River upstream from Vancouver, but rapids and swift currents greatly curtailed waterborne commerce. Two canals which bypassed major rapids upstream of The Dalles were completed in 1896 and 1915, respectively, but were flooded when Bonneville and The Dalles dams were completed.

Currently, a 40-foot deep draft navigation channel is maintained on the Columbia from the mouth to Portland by dredging. Shallow draft navigation is maintained from Portland to Lewiston, Idaho, via the Columbia and Snake rivers, and to Corvallis, Oregon, on the Williamette River. The navigation features were developed and are managed as part of the multiple purpose use of water resources, including hydropower, flood control, recreation, and fish and wildlife enhancement. The Columbia-Snake system above Portland is maintained to a 14-foot navigable depth by a series of eight locks and dams. Waterborne commerce in 1977 was over 40 million tons for the entire 465 mile Columbia-Snake Waterway, including the deep draft segment.

The Williamette River is maintained from Portland to Corvallis, Oregon and includes four locks around Williamette Falls. Navigable depths range from 8 feet between Portland and Oregon City, down to 2.5 to 3.5 feet at Corvallis.

San Francisco Bay Area

San Francisco Bay provides deep draft access to the ports of San Francisco, Oakland, Redwood City and Richmond, California. Deep draft channels extend northward and eastward from San Francisco Bay through San Pablo Bay and to Suisun Bay. The Sacramento Deep Water Ship Channel extends from Suisun Bay to Sacramento, a distance of 43 miles. The channel was formed by widening and deepening existing channels from Suisun Bay to a point near Rio Vista, and by excavating a new channel from that point to Lake Washington, near Sacramento. In addition to the channel, the project includes a harbor and turning basin in Lake Washington and a shallow draft barge canal and navigation lock between the harbor and the Sacramento River. Controlling minimum depths are 13 feet in the barge canal and 30 feet in the ship channel. The project, operationally complete in 1963, permits deep draft oceangoing vessels to proceed directly to the Port of Sacramento. In 1977, total commerce was 1.5 million tons.

The Stockton Deep Water Ship Channel

provides navigation on the San Joaquin River from Suisun Bay to Stockton, a distance of about 40 miles. The controlling navigable depth is 30 feet. Commerce on the deep draft channel was approximately 3.5 million tons in 1977. A shallow draft channel upstream from Stockton to Hills Ferry, a distance of about 85 miles, is not maintained due to absence of traffic. Controlling navigable depths on this upstream stretch range from 6 feet at Stockton to 3 feet at the head of navigation.

INLAND PORTS

Inland ports and terminals are responsible for providing those services which support the inland water transportation industry, and those facilities necessary for the transfer of cargo from one transport mode to another. An efficient waterway system brings cargo as close as possible to the shipper and receiver by water. Terminal, pipeline, rail and truck services within intermediate and shorter haul ranges are then used to complete the intermodal movement. Major inland, coastal and Great Lakes ports are shown in Figure I–2.

Table III–1 lists the principal shallow draft inland ports and shows the major commodities handled by each. (For a discussion of inland waterway terminal facilities see Appendix B.)

Note that 7 of the 13 largest inland ports are on the Mississippi River, mostly handling grain shipments, coal receipts, and petroleum receipts. Five more are on the Ohio River System reach, mostly shipping coal and receiving petroleum products.

GREAT LAKES-ST. LAWRENCE SEAWAY SYSTEM

The Great Lakes-St. Lawrence Seaway navigation system provides a water transportation artery 2,342 miles long, with a 27-foot controlling navigable depth, from the U.S. Midwest and Northeast industrial heartland to the Gulf of St. Lawrence and the Atlantic Ocean. The five Great Lakes, their connecting channels, and a system of 16 locks (23 chambers) operated by the United States and Canadian governments, bring oceangoing ships from the Atlantic Ocean into the Great Lakes. The elevation of each lake surface above sea level is displayed in Table III–2.

The locations of the Great Lakes System waterways, ports, locks and connecting channels are shown on NWS Map No. 18.

The Great Lakes and St. Lawrence shorelines are located along the states of Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania and New York, as well as the Canadian provinces of Ontario and Quebec. Many large cities such as Chicago, Illinois; Detroit, Michigan; Cleveland and Toledo, Ohio; Buffalo and

Table III–1
SHALLOW DRAFT WATERWAYS: PRINCIPAL PORTS

Reach	Port Name	1980 Shallow Draft Commerce (Millions of Tons): Farm and Food Products	Coal	Crude and Petroleum Products	Other	Total
Upper Miss	St. Paul, MN	5.0	2.4	1.0	2.1	10.5
	Minneapolis, MN	1.0	0.5	0.0	0.7	2.2
L. Upper Miss	Metropolitan St Louis	6.5	6.8	6.5	4.7	24.5
L. Miss:	Memphis, TN	2.2	1.6	5.3	2.4	11.5
Cairo to B.R.	Helena, AR	1.3	0.0	0.8	0.6	2.7
	Greenville, MI	0.6	0.0	1.5	0.6	2.7
	Vicksburg, MI	0.6	0.0	2.0	0.8	3.4
Ohio River System	Pittsburgh, PA	0.0	23.8	4.4	8.4	36.6
	Huntington, WV	0.0	13.2	5.4	0.6	19.2
	Cincinnati, OH	1 3	3.2	3.8	2.5	10.8
	Louisville, KY	0.1	1.4	3.6	2.6	7.7
	Mt. Vernon, IN	0.8	0.0	2.9	0.3	4.0
	Nashville, TN	0.0	0.0	0.4	1.3	1.7

Table III–2
ELEVATION OF THE GREAT LAKES AND ST. LAWRENCE SEAWAY

St. Lawrence Seaway at Montreal, Quebec	22 feet
Lake Ontario	248 feet
Lake Erie	572 feet
Lake Huron and Lake Michigan	579 feet
Lake Superior	602 feet

Table III–3
GREAT LAKES AND SEAWAY: PHYSICAL CHARACTERISTICS

Segment	Lock Characteristics					Channel Characteristics	
	Number of Lifts	Total No. of Chambers	Maximum Chamber Width (ft)	Maximum Chamber Length (ft)	Median Age in 1981 (years)	Controlling Depth (ft)	Season Length (months)
St. Lawrence River	7	7	80	766	22	27	8.5
Welland Canal	8	11	80	766	49	27	8.5
Detroit River	—	—	—	—	—	27	12.0*
St Clair River	—	—	—	—	—	27	12.0*
St. Marys River	1	5	110	1,200	53	27	8.5
TOTAL	16	23					

* Year-round navigation is not available at all harbors

Table III–4
GREAT LAKES SYSTEM: PRINCIPAL U.S. PORTS

Port Name	Controlling Navigable Depth	1980 Commerce (Million of Tons)					Total
		Farm & Food Products	Coal	Ore	Limestone	Other	
Duluth-Superior	27	8.8	4.4	26.3	0.7	1 2	41.4
Chicago	27	2.5	7.2	4.4	1 3	17.6	33.0
Indiana Harbor	27	0.0	0.0	10.6	1.9	4.4	16.9
Escanaba	27	0.0	0 2	10.9	0.0	0 1	11.2
Calcite	26	0.0	0.0	0.0	7.4	0.1	7.5
Detroit	27	0.1	5.6	7.6	3.0	3.0	19.3
Ashtabula	27	0 0	5.3	4 1	0.4	0.3	10.1
Cleveland	27	0.1	0 0	10.0	1.4	2.5	14.0
Conneaut	27	0.0	8.0	9.3	1.3	3.7	18.7
Toledo	27	4 8	12.8	2.8	0.1	1.8	22.3

Rochester, New York; Milwaukee, Wisconsin; Erie Pennsylvania; and Duluth-Superior, Minnesota and Wisconsin, are located on the shorelines. Canada's largest metropolitan area, Montreal, Quebec, is located at the entrance of the Great Lakes-St. Lawrence system, and two other large metropolitan areas—Toronto and Hamilton, Ontario—are located on Lake Ontario. The Great Lakes are linked with the inland and intracoastal waterways via the Illinois Waterway, a tributary of the Mississippi River which originates on Lake Michigan at Chicago. There are 23 lock chambers in the Great Lakes system. Between the lakes and the ocean, the constraining width is 80 feet, the length is 766 feet, and the controlling navigable depth is 27 feet. Between the Lake Superior mineral producing areas and the steel mills, the largest lock chamber is 110 feet by 1,200 feet with a controlling navigable depth of 27 feet.

PHYSICAL CHARACTERISTICS

The Montreal to Lake Ontario section of the system is the St. Lawrence Seaway, which is under the jurisdiction of the St. Lawrence Seaway Authority in Canada and the St. Lawrence Seaway Development Corporation in the United States. The U.S. operates two locks and the Canadian government operates five locks on the St. Lawrence. The eight locks of the Welland Canal are all in Canada between Lake Ontario and Lake Erie. The locks of the Welland raise ships 324 feet over the Niagara Escarpment. A lift of 23 feet around the St. Mary's rapids between Lake Huron and Lake Superior is handled by the four Sault ("Soo") Locks operated by the Corps of Engineers, and a fifth operated by Canada. The Canadian lock at Sault Ste. Marie, with a depth of only 16.8 feet, can handle only shallow draft vessels and is used almost exclusively for recreational transits. The median age of the "Soo" locks is 53 years. Season length ranges from 8½ months on the Welland Canal (restricting year-round access to the Atlantic Ocean) to a full 12 months on some local moves in individual lakes and connecting channels. The lock, channel and seasonality characteristics of the Great Lakes system are summarized in Table III–3.

The estimated replacement costs of the American facilities in the Great Lakes and St. Lawrence Seaway are slightly less than $5 billion. Annual dredging is about 7 million cubic yards, costing $15 million. Other operations and maintenance expenses, including lock operation, are slightly more than $9 million, bringing total annual costs of Great Lakes and Seaway operation to $24.5 million for the United States. More details of the physical components of the Great Lakes System are provided in Appendix D.

PORTS

The 10 largest Great Lakes ports shown in Table III-4, in terms of tonnage, basically serve the steel industry. Only Duluth, Toledo and Chicago are significant shippers of grain. The rest of the tonnage is primarily coal, iron ore, and limestone. Other cargoes include petroleum products, steel, and general cargo.

PRINCIPAL OCEAN PORTS

The oceans were often the most effective means of long distance travel available to colonial seaboard cities. As a result, ocean transportation was the major form of commerce during colonial periods. It makes sense, then, that some of the first Federal actions taken to improve the waterways were directed at coasts and coastal ports.

By the late 1830s, clipper ships were being built, which soon handled a great deal of high value foreign trade. The first propeller was developed around 1840 and the first iron-hulled ships equipped with propellers were built in Britain in 1843 as the momentum for oceangoing steam vessels increased. The Federal Government subsidized steamship development in the 1840s and 1850s, but discontinued the practice just prior to the Civil War in 1856.

Intracoastal ocean trade between the Atlantic and Pacific, growing in the absence of an efficient intercontinental land transportation system, was given further impetus by the California gold rush of 1849.

The Civil War saw substantial destruction of the U.S. commercial ocean-going fleet and there was a relative decline in the U.S. merchant marine fleet until World War I. At that time, foreign flag service decreased and there was a shortage of shipping. The U.S. Shipping Board was created in 1916 to reverse this trend, and, during and after World War I, subsidies were provided to shipyards and for the operation of U.S. flag vessels in foreign trade.

In recent times, the major technical thrusts in ocean shipping have been the dramatic increase in size of vessels for both large high-speed container ships and very large (and ultra large) crude petroleum carriers, some of them exceeding 500,000 deadweight tons. Since World War II, containerization—handling of a load of general cargo in sealed units rather than in individual pieces—has had major impacts on both the ships and the operation of ports. The economics of such operations have tended to concentrate cargoes in fewer and fewer ports where large container ships can operate economically. Likewise, large tankers can only be accommodated at a few selected ports where navigable depths are sufficiently deep. Thus most of these tankers, when used, have been unloaded offshore. Large bulk carriers for ores and coal have been built up to 150,000 deadweight tons, requiring a 55-foot depth for operation—depths currently available at very few U.S. ports, such as the deepwater terminal serving the Port of Long Beach, California and at sites in Puget Sound. However, studies are underway to examine the feasibility of deepening several major port areas to depths ranging from 50 to 60 feet.

Total replacement costs of Federal navigation improvements at all U.S. coastal ports together are estimated at over $22 billion. This includes deepening harbors and channels, adding navigation safety features such as channel markers, and a variety of other actions.

Average annual dredging at coastal ports totals around 188 million cubic yards, at an approximate cost of $127 million per year. Other operations and maintenance costs at these ports are about $20 million per year, bringing the total Corps operating costs to approximately $147 million per year.

CHARACTERISTICS OF MAJOR OCEAN PORTS

As can be seen in Table III-5, controlling depths of the major U.S. coastal ports range from 34 feet at Richmond, California to as much as 55 feet at Long Beach. Principal cargoes include export food and farm products (mostly grain), export coal, and imported petroleum and petroleum products. Ocean port tonnages are dominated by the movement of petroleum for import and between refineries and consuming areas domestically. More recently the trend has been toward decreasing petroleum traffic as world demand responds to higher prices, conservation efforts, and the utilization of alternative energy sources.

One of these alternatives—coal—has been increasing significantly in total tonnage at major coastal ports, particularly for export. European and Pacific Rim nations are evincing high interest in obtaining U.S. steam coal; the sudden surge in demand resulted in major port congestion at Hampton Roads and Baltimore in 1980 and 1981. Traffic problems are easing, however, as the market stabilizes and as the ports improve their efficiency in handling the higher tonnages. As can be seen in Table III-5, Hampton Roads handled over 50.1 million tons of coal in 1980. This was up from 26.6 million tons in 1977.

SUMMARY

This section has highlighted physical characteristics of the existing major waterways and ports of the United States. The inland waterways of this nation have been a vital transportation resource since the earliest days of the republic. Together with the Great Lakes and ports of the Atlantic, Pacific and Gulf coasts, the waterways allow efficient movement of commodities which are fundamental to our national economy. In the next section these commodities will be examined in detail in terms of current and projected waterborne traffic.

Table III–5
PRINCIPAL COASTAL PORTS
(Handling Over 15 Million Tons in 1980)

Port	Controlling Depth (feet)	1980 Total Waterborne Commerce (Millions of Tons)				
		Farm & Food Products	Coal	Petroleum	Other	Total
New Orleans, LA	40	82.5	12.6	52.6	29.6	177.3
New York, NY	30–45	6.4	1.0	126.3	33.3	167.0
Houston, TX	36–40	14.8	0.0	61.7	32.4	108.9
Valdez, AK	50+	0.0	0.0	86.0	0.0	86.0
Baton Rouge, LA	40	17.7	0.0	34.7	26.9	79.3
Hampton Roads, VA	35–45	5.5	50.1	10.9	8.3	74.8
Beaumont, TX	40	2.2	0.0	45.0	5.1	52.3
Philadelphia, PA	40	5.0	2.9	32.7	7.3	47.9
Corpus Christi, TX	40–45	3.2	0.1	27.6	8.2	39.1
Tampa, FL	34*	1.6	2.7	11.3	33.0	48.6
Baltimore, MD	40	7.7	15.8	10.9	15.6	50.0
Mobile, AL	40	3.1	12.1	9.1	13.3	37.6
Texas City, TX	40	0.0	0.0	16.9	9.0	25.9
Long Beach, CA	50–55	4.5	0.3	27.1	6.9	38.8
Los Angeles, CA	35–52	2.6	0.7	19.4	7.5	30.2
Port Arthur, TX	40	0.6	0.0	28.2	1.0	29.8
Marcus Hook, PA	40	0.0	0.0	25.7	0.0	25.7
Paulsboro, NJ	37	0.0	0.0	22.8	0.0	22.8
Boston, MA	35–38	0.6	0.0	19.8	1.6	22.0
Lake Charles, LA	36	2.3	0.0	15.1	2.9	20.8
Richmond, CA	17–34	0.6	0.0	16.9	1.1	18.6
Pascagoula, MS	38	4.1	0.0	18.7	2.6	25.4
Portland, OR	39	12.5	0.0	7.5	9.3	29.3
Seattle, WA	30–50	4.0	0.0	6.4	10.9	21.3
Freeport, TX	30–36	0.1	0.0	15.6	4.4	20.1
Tocoma, WA	30	6.7	0.0	2 8	7.6	17.1
Jacksonville, FL	31	0.2	0.0	9.6	5.8	15.6

* Channel deepening to 43 feet for bulk material is scheduled for completion in 1985.

SECTION IV

HISTORICAL AND PROJECTED WATERBORNE COMMERCE

DEFINITIONS

The discussion of waterborne commerce in this section is based on definitions used in *Waterborne Commerce of the United States*, published annually by the U.S. Army Corps of Engineers.

Imports and exports: These terms apply to traffic between the United States and foreign ports, including the Canal Zone. Traffic of U.S. Great Lakes ports with Canada is supplemented by the term "Canadian" to differentiate it from overseas traffic.

Coastwise receipts and shipments: These terms apply to domestic traffic receiving a carriage over the ocean, or the Gulf of Mexico, e.g., New Orleans to Baltimore, New York to Puerto Rico, San Francisco to Hawaii, or Puerto Rico to Hawaii. Traffic between Great Lakes ports and seacoast ports, when having a carriage over the ocean, is also termed "coastwise." The Chesapeake Bay and Puget Sound are considered internal bodies of water rather than arms of the ocean and therefore traffic confined to these areas is "internal" rather than "coastwise."

Lakewise receipts and shipments: These terms apply to traffic between United States ports on the Great Lakes System. The Great Lakes System is treated as a separate system rather than as a part of the inland system.

Internal receipts and shipments: These terms apply to traffic between ports or landings wherein the entire movement takes place on inland waterways. Also termed internal are movements involving carriage on both inland waterways and waters of the Great Lakes; inland movements that cross short stretches of open waters which link inland systems; marine products, sand and gravel taken directly from beds of the oceans, the Gulf of Mexico and important arms thereof; and movements between offshore installations and inland waterways.

Local: Movements of freight within the confines of a port whether the port has only one or several arms or channels, except car-ferry and general ferry, are termed "local." The term is also applied to marine products, sand, and gravel taken directly from the Great Lakes.

Intraterritory receipts and shipments: These terms apply to traffic between ports in Puerto Rico and the U.S Virgin Islands, which are considered as a single unit.

HISTORICAL AND PROJECTED WATERBORNE COMMERCE

HISTORICAL WATERBORNE COMMERCE

Between 1947 and 1980 U.S. foreign and domestic waterborne commerce almost tripled, from 0.77 to almost 2.0 billion tons, as shown in Table IV–1. Today this traffic is almost equally divided between foreign and domestic commerce, but in 1947 foreign waterborne commerce was only one quarter of the total. After 1947, domestic waterborne commerce grew steadily, almost doubling by 1980, from 0.6 to 1.1 billion tons. Foreign trade, however, expanded more rapidly, increasing fivefold in the 1947–1979 period from 188 to 994 million tons. A slight decline to 920 million tons was registered in 1980. The lack of growth for both domestic and foreign commerce for 1978–1980 is due largely to the decline in the movement of crude petroleum and petroleum products.

Figure IV–1 shows the commodity composition of U.S. waterborne commerce in 1980. The commodity groupings are from *Waterborne Commerce of the United States: Part 5, National Summaries,* 1980, by the U.S. Army Corps of Engineers. The leading commodity group is petroleum and products, comprising over 44 percent of the total traffic and similar percentages of the foreign and the domestic traffic. The coal and coke commodity group is 13.6 percent of all commerce, 15.6 percent of the domestic commerce and 11.3 percent of the foreign commerce. In total, the energy commodities comprised almost 58 percent of all U.S. waterborne commerce in 1980. The next ranking commodity groups and the percentage of the total commerce are: iron ore and iron and steel, 6.7; grains, 8.3; sand, gravel and stone, 5.0; chemicals 5.8, logs and lumber, 2.6; sea shells, 0.5; and all others, 13.2. The major differences between the foreign and the domestic commerce, compared with the total commerce, are shown in Figure IV–1. These differences include the significance of grain in foreign commerce and of sand, gravel and stone in domestic commerce.

DOMESTIC WATERBORNE COMMERCE

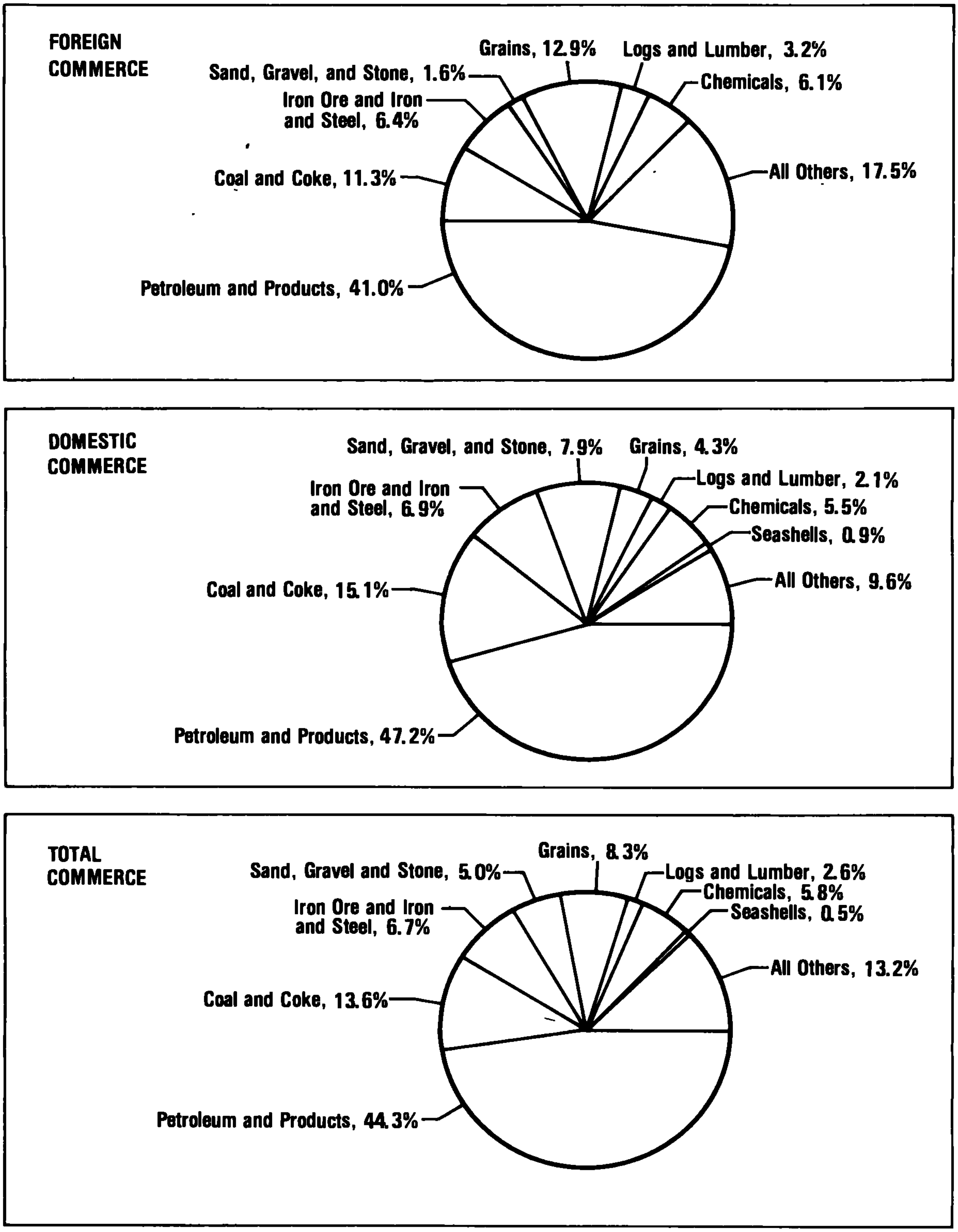
The NWS categories for U.S. domestic waterborne commerce are: (1) internal or inland

Table IV–1
UNITED STATES WATERBORNE COMMERCE, 1947–1980[1]
(Millions of Tons)

Type of Commerce	1947	1950	1952	1960	1970	1977	1978	1979	1980	Annual Compound Rate of Growth 1952–1977[2] (percent)
Total Commerce	767	820	887	1,100	1,532	1,908	2,021	2,074	1,999	3 1
Foreign Commerce										
Total	188	169	227	339	581	935	946	994	921	5 8
Imports	62	102	116	211	339	658	643	633	517	7.2
Exports	126	67	111	128	242	277	303	361	404	3 7
Domestic Commerce										
Total	579	651	660	761	951	973	1,075	1,080	1,078	1.6
Internal	150	191	217	291	472	529	535	535	535	3 6
Coastwise	153	182	184	209	239	248	305	305	330	1.2
Lakewise	163	170	154	155	157	109	143	144	115	—[3]
Intraterritory and Local	113	108	104	105	83	87	92	97	98	—[3]

1 U.S Army Corps of Engineers, *Waterborne Commerce of the United States, Part 5, National Summaries.* Annual
2. The 25–year period 1952–1977 is shown for later comparison with the 25–year projection period, 1978–2003.
3. Decrease percent not shown Data for lakewise traffic not representative in 1977 because of a labor dispute

Figure IV-1
PRINCIPAL COMMODITIES IN U.S. WATERBORNE COMMERCE, 1980



waterways traffic, (2) coastwise traffic between U.S. ocean ports, (3) lakewise traffic between U.S. Great Lakes ports, and (4) intraterritory and local traffic. The annual tonnage of each of these types of traffic for 1947–1980 is listed in Table IV–1 and is graphed in Figure IV–2. The total domestic traffic increased steadily from 579 to 1,078 million tons from 1947 to 1980. Coastwise traffic increased moderately over that period from 153 to 330 million tons. The sharp upturn in coastwise traffic in 1978 was due primarily to Alaskan crude petroleum commerce. Lakewise traffic shows a slight decline from 163 to 144 million tons from 1947 to 1979. Data for 1980 shows a decline to about 115 million tons. This decline was linked to the disruption in the nation's demand for steel. The drop to 109 million tons in 1977 was the result of a labor dispute that interrupted shipments of iron ore, the predominant commodity on the Great Lakes.

INLAND WATERWAYS COMMODITIES

The major commodities which move on the inland waterways are shown in Figure IV–3 and Table IV–2. Coal, the number one tonnage commodity, is followed by petroleum products, grains, and crude petroleum. The coal transported on the U.S. rivers displayed a steady increase from 47.8 to 131.6 million tons between 1952 and 1980. Petroleum products, which include gasoline, jet fuel, distillate fuel oil and residual fuel oil, increased from 50.8 to 112.8 million tons between 1952 and 1977, but decreased to 101.5 million tons in 1980. Grains have shown remarkable growth, increasing more than fifteenfold, from 3.9 to 59.1 million tons, between 1952 and 1980. Crude petroleum increased from 28.5 to 52.6 million tons between 1952 and 1970, but declined to 41.6 million tons in 1980.

FOREIGN WATERBORNE COMMERCE

The rapid rise in foreign waterborne commerce from 1952 to 1977, at an annual rate of 5.8 percent, is due largely to imports growing at an annual rate of 7.2 percent compared to exports at a 3.7 percent rate (see Table IV–1). Trade by major commodities of foreign waterborne commerce, shown in Table IV–3, isolates crude petroleum imports as the principal growth commodity. That commodity increased from 39.1 to 405.6 million tons between 1952 and 1977, but declined to 306 million tons in 1980. Similarly, imports of petroleum products increased rapidly from 22 to 99.5 million tons between 1952 and 1977, then dropped to 54 million tons in 1980.

Exports have increased from 111.4 to 403.9 million tons between 1952 and 1980, as noted in Table IV–3. The selected grains (corn, wheat and soybeans) have displayed a remarkable increase from 14.6 to 130.4 million tons between 1952 and 1980. Grain exports in 1981 were at same level as 1980, according to the U.S. Department of Agriculture, Federal Grain Inspection Service. Coal exports (predominately metallurgical coal) varied annually from a low of 35.6 million tons in 1960 to 65.7 million tons in 1979. The new steam coal market abroad boosted coal exports to 91.3 million tons in 1980 and slightly over 112 million tons in 1981 based on data from the Bureau of the Census,

Figure IV-2
U.S. DOMESTIC WATERBORNE COMMERCE BY TYPE OF TRAFFIC, 1947-1980

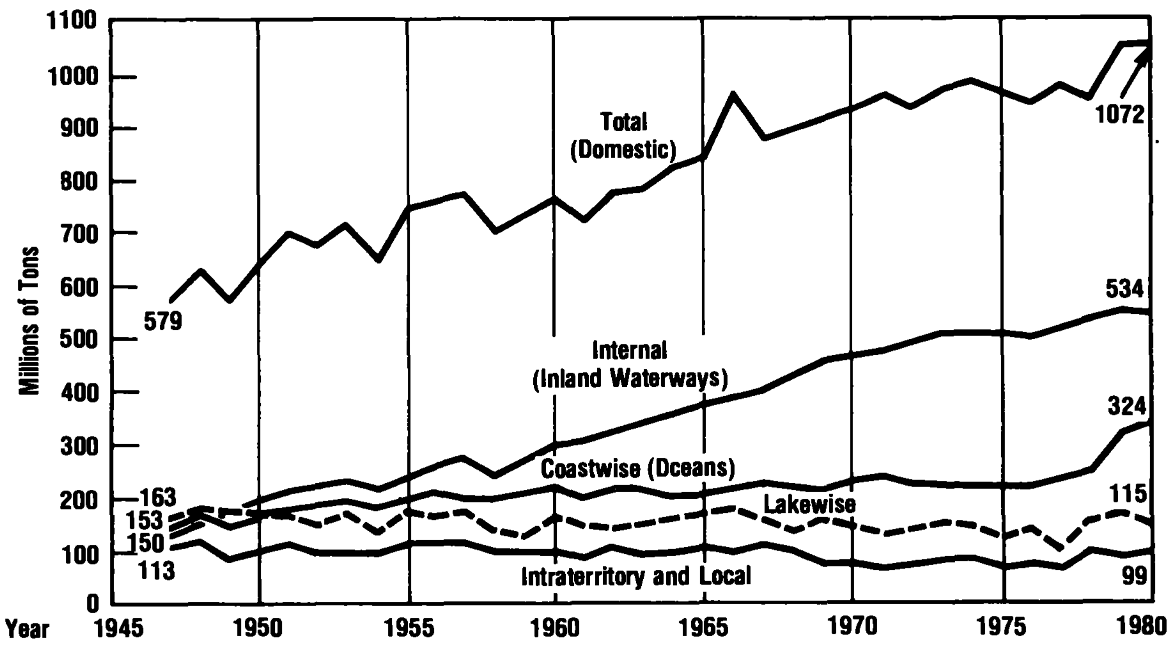


Table IV–2
UNITED STATES INTERNAL INLAND WATERWAYS WATERBORNE COMMERCE: MAJOR COMMODITIES, 1952–1980
(Millions of Tons)

Rank 1980	Commodity	1952	1960	1970	1977	1978	1979	1980
1.	Coal	47.8	73.3	110.1	128.0	114.6	125 7	131.6
2.	Petroleum Products	50.8	62 4	88.6	112.8	110.2	102.5	101.5
	Gasoline	30 1	32.2	36.5	32.1	30.7	28.3	28.7
	Jet Fuel	0	2.5	5.2	4.1	3.9	3.8	4.2
	Distillate Fuel Oil	9.9	14 7	17.4	26.9	24.4	22.8	22.5
	Residual Fuel Oil	10.8	13.0	29.5	49.7	51.2	47.6	46.1
3.	Selected Grains	3.9	9.4	23.5	45.8	49.4	51.0	59.1
	Corn	2.2	4.1	11.3	23 2	25.4	27 9	30.5
	Wheat	1.3	3.1	4.1	10.1	10.0	10.0	12.6
	Soybeans	0.4	2.2	8 1	12.5	14 0	13.1	16.0
4.	Crude Petroleum	28.5	31.6	52.6	49 0	50.5	47.2	41.6
	All Other	85.6	114.7	197.3	193.1	210 3	208.1	201.2
Total All Commodities		216.6	291.4	472.1	528.7	535.0	534.5	535.0

1 U.S Army Corps of Engineers, *Waterborne Commerce of the United States. Part 5, National Summaries*. Annual

Department of Commerce.

Both imports and exports of all other commodities each have increased steadily from 55 to over 180 million tons; a decline to 158 million tons in imports was registered in 1980.

WATERWAYS SHARE OF TRANSPORTATION BY ALL MODES

A specific example of the relationships of the waterways to other modes and to deep draft ports is found in Lowell D. Hill, Mack N. Leath and Stephen W. Fuller's recently completed nationwide survey of grain transportation by all modes; the statistics given in Table IV–4 are from their study. The study shows that trucks dominate intrastate movements of corn and soybeans, although rail, in 1977, carried 54.4 percent of intrastate wheat. On interstate hauls that year, rail handled 57.5 percent of wheat, 47.7 percent of corn and 27.2 percent of soybean movements; barge accounted for 42.2

Figure IV-3
LEADING COMMODITIES IN U.S. DOMESTIC WATERBORNE COMMERCE ON INLAND WATERWAYS, 1952-1980

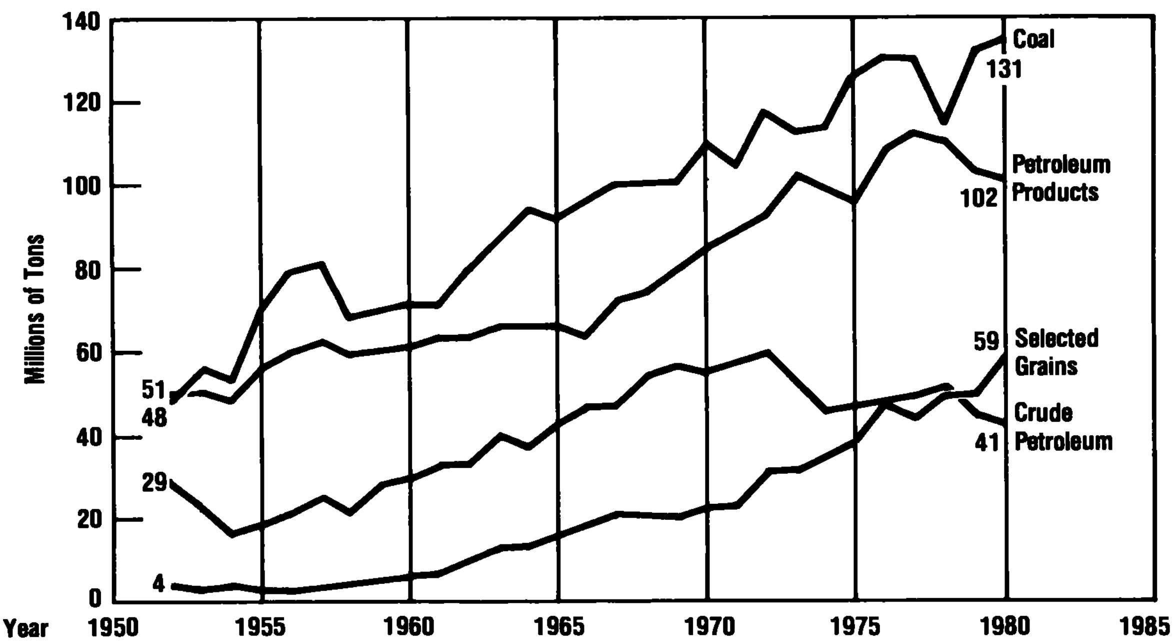


Table IV-3

UNITED STATES FOREIGN WATERBORNE COMMERCE: MAJOR IMPORT AND EXPORT COMMODITIES[1]

(Millions of Tons)

Commodity	1952	1960	1970	1977	1978	1979	1980
Imports							
Crude Petroleum	39.1	67.7	93 6	403.6	387.2	379.1	306.0
Petroleum Products	22.0	39.8	91.0	99.5	74.4	66.7	54.0
Gasoline	0.4	0.5	0 5	3.5	6.2	7.1	6.1
Distillate Fuel Oil	0.5	1.3	2.2	7.8	3.7	4.6	2.3
Residual Fuel Oil	21.1	38.0	88.3	88 2	64.5	55.0	45.6
All Other	54 9	103.8	154 7	155.0	181.6	187.2	157.5
Total	116 0	211.3	339.3	658.1	643.2	633.0	517.5
Exports							
Coal	41.8	35.6	71.3	53.9	40.3	65.7	91.3
Selected Grains	14.6	25.6	47.5	88.2	115.5	124.2	130.4
Corn	2.7	6.1	15.4	44.2	54.9	65.0	67.8
Wheat	11.2	15.1	19.2	26.2	37.5	36.4	39.1
Soybeans	0.7	4 4	12.9	17.8	23.1	22.8	23.5
All Other	55 0	66.8	122.8	135 0	147.1	170.5	182.2
Total	111 4	128.0	241.6	277.1	302.9	360.4	403.9

1. U S Army Corps of Engineers, *Waterborne Commerce of the United States, Part 5, National Summaries*, Annual.

Table IV-4

MOVEMENTS OF CORN, WHEAT AND SOYBEANS BY TYPE OF MOVEMENT AND MODE OF TRANSPORTATION, 1977

Type of Movement and Mode of Transport	Corn[1]		Wheat[2]		Soybeans[3]	
	1,000 Bushels	Percent	1,000 Bushels	Percent	1,000 Bushels	Percent
Intrastate Movements						
Rail	278,802	11.2	619,607	54.4	119,366	12.9
Non-Farm Truck	1,867,768	75 0	454,056	39.9	746,515	80.5
Farm Truck	333,316	13.4	3,208	0.3	90	*
Barge	9,245	0.4	61,561	5.4	60,830	6.6
Total	2,489,151	100.0	1,138,432	100.0	926,801	100.0
Interstate Movements						
Rail	1,277,480	47.7	810,567	57.5	223,786	27.2
Non-Farm Truck	398,710	14.9	235,737	16.7	191,907	23.3
Farm Truck	95,099	3 6	23,833	1.7	58,856	7.1
Barge	904,602	33.8	339,683	24.1	349,657	42.2
Total	2,675,981	100.0	1,409,820	100.0	824,206	100.0
Movements to Points of Exports						
Rail	639,246	36.7	616,119	57.3	145,075	22.8
Non-Farm Truck	195,148	11.2	134,659	12.5	99,276	15.6
Farm Truck	29,301	1.7	12,231	1.1	5,779	0.9
Barge	875,741	50.3	313,191	29.1	385,644	60.7
Total	1,739,436	100.0	1,076,200	100.0	635,774	100.0

*Less than 0 1 percent

1 Lowell D Hill, Mack N. Leath, and Stephen W. Fuller, *Corn Movements in the United States· Interregional Flow Patterns and Transportation Requirements in 1977*. North Central Regional Research Bulletin 275, Southern Cooperative Series Bulletin 253, and Illinois Bulletin 768, Agricultural Experiment Station, College of Agriculture, University of Illinois at Urbana-Champaign, January 1981, pages 11, 12, and 15.

2. Mack N Leath, Lowell D. Hill, and Stephen W. Fuller, *Wheat Movements in the United States: Interregional Flow Patterns and Transportation Requirements in 1977*, North Central Regional Research Publication 274, Southern Cooperative Series Bulletin 252, Illinois Bulletin 767, Agricultural Experiment Station, College of Agriculture, University of Illinois at Urbana-Champaign, January 1981, pages 17, 19 and 23.

3 Mack N. Leath, Lowell D. Hill, and Stephen W. Fuller, *Soybean Movement in the United States. Interregional Flow Patterns and Transportation Requirements in 1977*, North Central Region Publication 273, Southern Cooperative Series Bulletin 251, Illinois Bulletin 766, Agricultural Experiment Station, College of Agriculture, University of Illinois at Urbana-Champaign, January 1981, pages 12, 14 and 17.

percent of soybeans, 33.8 percent of corn and 24.1 percent of wheat. For export movements, barge accounted for 60.7 percent of soybeans, 50.3 percent of corn and 29.1 percent of wheat; rail accounted for 57.3 percent of wheat, 36.7 percent of corn and 22.8 percent of soybeans.

In summary, corn, soybeans and wheat movements by barge to points of export were 46.7 percent of all such movements by all modes and accounted for 17 percent of the total U.S. production of those grains in 1977. The movements to points of export of corn, wheat and soybeans by all modes, and relationship to grain production, is depicted graphically in Maps No. 21–24 of Appendix G.

Based upon the data compiled by the U.S. Department of Energy, the waterborne share of U.S. domestic coal movement is 12 to 13 percent of the shipments from the mines. Some of the coal that leaves the mines by rail and truck is later transferred to water transportation. This increases the waterborne share, at the final destinations, to 22 to 25 percent. The waterborne coal movements are dominated by transport on the rivers, followed by that on the Great Lakes and along the U.S. coasts.

The long term significance of the waterways to the nation's total transportation system is documented in Table IV–5, which shows that the traffic on U.S. rivers and the Great Lakes accounted for 15 to 16 percent of the nation's ton-miles of traffic since 1950.

WATERWAYS SYSTEM AND COMMODITY MOVEMENT MAPS

A set of 24 maps depicting the physical characteristics of the nation's commercial waterways and ports, and commodity movements by water and other modes, are contained in Appendix G. Physical characteristics shown on five of the maps include channel and harbor depths and lock locations and names. One of these maps is of the entire nation and four maps show more detailed information for four regions: Atlantic, Mississippi River System and Gulf, Great Lakes-St.Lawrence Seaway, and Pacific.

The 19 maps of major commodity movements present cross-sections of waterborne traffic for one year as an aid in understanding the extent, the traffic densities, and the interrelationships of the components of waterways system. Several also provide information on areas of production and consumption, as well as the states of origin of exports and destination of imports of waterborne foreign trade. For added insight, movements by all modes are shown for petroleum, coal and grain. An 8-page booklet with the maps discusses trends in waterborne commerce; a brief description of the origin, movement and destination of the commodity flows; and technical notes about the maps.

COMMERCIAL USERS OF THE WATERWAYS SYSTEM

The commercial users of the nation's waterways and ports are those industries and economic sectors that are the producers or consumers of the commodities discussed earlier in this section and depicted in the maps in Appendix G. A discussion of the system users is contained in the NWS contractor-prepared report entitled *Findings and Conclusions*, pages 53–83. Additional information on the system users is discussed later in this section.

Table IV–5

UNITED STATES VOLUME OF DOMESTIC INTERCITY FREIGHT, BY TYPE OF TRANSPORT: 1950 TO 1978[1]

Type of Transport	1950	1960	1970	1977	1978
			Billions of Ton-Miles		
TOTAL	1,094	1,330	1,936	2,307	2,436
Railroads[2]	628	595	771	834	868
Motor Vehicles	173	285	412	555	602
Inland Waterways[3]	163	220	319	368	375
Oil Pipelines	129	229	431	546	586
Domestic Airways[4]	0.3	0.8	3.3	4.2	4.6
			Percent Distribution		
TOTAL	100.00	100.00	100.00	100.00	100.00
Railroads[2]	57.44	44.73	39.83	36.15	35.63
Motor Vehicles	15.80	21.46	21.28	24.06	24.71
Inland Waterways[3]	14.93	16.56	16.46	15.95	15.39
Oil Pipelines	11.81	17.19	22.26	23.67	24.06
Domestic Airways[4]	0.03	0.06	0.17	0.18	0.19

1. Adapted from U.S. Bureau of the Census, *Statistical Abstract of the United States. 1980* (101st Edition), Washington, D C , 1980, table 1094, page 639.
2 Includes electric railways. Beginning 1970, freight traffic excludes mail and express
3. Includes Great Lakes. Freight traffic includes Alaska for all years and Hawaii beginning 1960
4 Revenue service only for certificated route and charter carriers Includes express mail and excess baggage.

FUTURE WATERBORNE COMMERCE

The following paragraphs discuss the assumptions and the methodology used to develop the forecasts of waterborne commerce. A comparison of forecasts of all modes of transportation is also included. All forecasts are "unconstrained" by possible limitations in waterway capacity. The sources of the projections are the technical reports prepared by the contractors for this study. Specific references for additional information will be listed at the end of each subject.

ASSUMPTIONS ABOUT THE FUTURE

Because the future is uncertain, a planning study based on a single forecast would inevitably be compromised by the passage of time and the occurrence of unexpected events. Therefore, seven alternative sets of forecasts, each set based on a selected scenario (a set of assumptions about the future), were prepared. The major variables of each scenario were:

1. *Baseline*. This scenario calls for continuation of presently well established trends and discernable conditions. The Baseline is not a "most likely" scenario, but is a benchmark against which variations among scenarios can be judged. Past trends are unlikely to continue unchanged.
2. *High Transportation Use*. This scenario assumes that basic underlying economic conditions and government policies are those that tend to stimulate greater demand for transportation. Specifically, it assumes that there is a decline in construction of new nuclear power plants, increasing the consumption of coal. It also assumes that coal exports increase and that phosphate exports continue at a high rate.
3. *Low Transportation Use*. This scenario reflects a combination of economic events and government policy that tend to depress the demand in industries which are major users of water transportation. Specifically, it assumes that the government sector's rate of growth increases at a rate higher than the overall economy; that crude oil imports are substantially below the level in the Baseline scenario; that few synfuel plants are actually constructed; that there is a relaxation of environmental emission standards affecting the coal sourcing decisions of utilities; that agricultural crop yields are stable rather than growing; and that steel imports gain a greater share of the U.S. domestic market.
4. *Bad Energy*. This scenario hypothesizes an energy crisis in the mid-1980s with a resulting impact on the economy of the nation. Specifically,oil prices rise faster than in the Baseline scenario; foreign crude oil supplies are tighter; imports of foreign crude drop precipitously; coal exports are greater than in the Baseline scenario; additional synfuel plants are constructed along the waterways; and seven coal slurry pipelines are built.
5. *High Coal Exports*. This scenario is a variation of the High Use forecast. It assumes that the U.S. will dramatically increase its coal exports over the next 20 years to nearly 300 million tons in 2003. This forecast is based in part upon data provided by the National Coal Association and is consistent with the *Interim Report of the Interagency Coal Export Task Force*, January 1981.
6. *Defense*. This scenario is also a variation of the High Use forecast and assumes that the U.S. is engaged in a five-year conventional war from 1986 to 1990. At the height of the conflict in 1990, the U.S. is engaged on two fronts, both of which are overseas. This forecast is based on data provided by the Federal Emergency Management Agency.
7. *Miscellaneous*. In addition to the six scenarios listed above, adjustments to the High Use scenario were tested to determine if they affected study conclusions. Underreporting of base-year traffic was corrected for the Ohio River System reach and at the Inner Harbor Navigation Canal Lock. These corrections in turn resulted in modification to many connecting reaches. Arkansas River forecasts were increased in the Miscellaneous to mirror the results of traffic forecasts prepared for the Ozark Regional Commission. Similarly, based on locally prepared studies, projected sand and gravel forecasts on the Columbia-Snake Waterway were increased under this scenario. These adjustments were made at the suggestion of the Corps of Engineers and the general public as a result of the public review of the basic forecasts. Table IV–6 summarizes the principal assumptions included in the first six scenarios.

FORECAST METHODOLOGY

The basic forecasting methodology involved the following steps:

1. The national economy was modeled using the Data Resources Inc. (DRI) macroeconomic models. Different model assumptions are embodied in each set of forecasts. Assumptions about the likely trends in U.S. population growth were based on the latest U.S. Bureau of the Census information and were the same for all scenarios.
2. A detailed analysis was performed of each of the major industries which significantly affect water transportation tonnage. These analyses used both field

Table IV–6

THE NATIONAL WATERWAYS STUDY PRINCIPAL ASSUMPTIONS FOR NWS SCENARIOS[1]

Principal Assumptions	Baseline	High Use	Low Use	Bad Energy	Defense	High Coal Exports
1 Macroeconomic	Trendlong	Trendlong	Larger Government	Bad Energy	Wartime Economy[2]	Trendlong
2. Corn Yields by 2003 (Bushels per Acre)	121	121	110	121	121	121
3. West Coast Share of Farm Products Exports (Percent)	14	14	14[3]	14	Overall Decline During Conflict	14
4. Phosphate Exports	Decrease After 1985	Constant After 1985	Decrease After 1985	Decrease After 1985	Constant After 1985	Constant After 1985
5 Steel Imports (Percent of Total Consumption)	Decrease After 1990 from 17 to 15	Decrease After 1990 from 17 to 15	Increase to 26 by 2003	Decrease After 1990 from 17 to 15	Decline Sharply During Conflict	Decrease After 1990 from 17 to 15
6 Crude Oil Prices (Average Annual Price Increase-Percent)	3.8	3.8	3.8	4 8	3 8	3.8
7. Crude Oil Imports by 2003 (Millions of Tons)	290	290	240	200	Decline of 100 Million Tons per Year During Conflict	290
8. Coal Exports by 2003 (Millions of Tons)[4]	107	156	107	156	156	290[5]
9. Gulf Coast Share of Total Coal Exports in 2003 (Percent)[4]	19	23	11	23	23	35
10 Domestic Coal Consumption by 2003 (Millions of Tons)	1,794	2,360	1,625	1,728	2,360	2,360
11. Synfuel Plants on Water (Coal Consumption in Millions of Tons by 2003)	10 (50)[6]	11 (61)	6 (30)[6]	15 (81)	11 (61)	11 (61)
12. Coal Slurry Pipelines	None	None	None	7[7]	None	None
13 Eastern Coal Use (Lake Erie Loadings of Coal by 2003 in Millions of Tons)	Present Technology and Regulations (20)	Present Technology and Regulations (22)	Increased Use in Great Lakes Area (24)	Present Technology and Regulations (20)	Present Technology and Regulations (22)	Present Technology and Regulations (22)

1. The Miscellaneous scenario incorporates all the assumptions of the High Use scenario The adjustments are made to account for data base errors (Ohio and Gulf Coast-East reaches) or to introduce alternative regional forecasts (Arkansas and Columbia-Snake Waterway reaches).
2 Based on Federal Emergency Management Agency forecast
3. Great Lakes share drops 10 percent
4. Overseas and Canadian destinations.
5 Based on National Coal Association high forecast and modified by Data Resources, Inc (DRI)
6 An additional demonstration plant (not included in these numbers) on the Monongahela River is assumed in operation from 1983 to 1990 and consumes 3,000,000 to 6,000,000 tons of coal each year. However, after 1990, it is discontinued
7 One of these seven pipelines (ETSI) will divert 4 5 million tons of coal from the waterways by 2003

interviews and ongoing DRI industry studies and models.

3. Industry forecasts were regionalized to estimate future production and consumption in specific geographic areas. These projections were based in part upon analysis of historical industry data.

4. Each industry's logistics decision process was analyzed to identify the likely transportation decisions which would be made. Waterborne projections were based in part upon correlations between broad economic and industry factors and the waterborne flows for 1969 to 1977, as well as on full consideration of likely shifts in logistics systems by industry due to new plant locations or new product introductions.

5. The industry analysis, production and consumption regions, and logistics decision process for each industry were adjusted to reflect the effects of the individual scenario assumptions shown in Table IV–6.

The resulting seven sets of forecasts of potential waterborne commodity flows were developed using the base year 1977 and five-year increments from 1980 to 2003 for 14 commodity groups and 22 reporting regions. These forecasts were aggregated from more detailed forecasts made for 45 commodity groups and 62 waterway segments and were "unconstrained" by any shortfall in the waterway capability to handle the traffic. Thus, the seven sets of projections represent the probable cargo levels available for water transportation under each of the sets of assumptions. The present navigation system's ability to accommodate these forecasts flows is discussed in a later section.

Additional information regarding the assumptions, scenarios and methodology of developing the forecasts of future waterborne commerce is contained in the following NWS technical reports described in Appendix H: *Traffic Forecasting Methodology: Evaluation of the Present Navigation System*, including Appendix A; and *Findings and Conclusions*

FORECASTS BY COMMODITY GROUPS

The forecasts were developed as discussed in the preceding paragraphs, utilizing the commodity groupings shown in Table IV–7. The detailed listing of commodities in each group is shown in Appendix C, Table C–1. The forecasts for commodity groups are summarized in Table IV–7 for the year 2003 for six forecasts (excluding the Defense scenario which is the same as the High Use scenario for 2003). The maximum and minimum forecasts for U.S. total and U.S. foreign waterborne commerce for each major commodity group are graphed in Figures IV–4 through IV–11.

1. *Petroleum*. This number one tonnage commodity group is forecast to decline from 958 to a low of 602 million tons from 1977 to 2003, as shown in Figure IV–4. Other scenarios show a high of about 726 million tons in 2003. The reductions are primarily due to projected decreased imports and greater use of pipelines to distribute petroleum products.

2. *Coal*. As the second ranking tonnage commodity in 1977 coal traffic is forecast to almost quadruple from 212 to 805 million tons between 1977 and 2003, as noted in Figure IV–5. This maximum is based on the High Coal Export scenario. The minimum (Low Use) forecast shows coal more than doubling to 476 million tons by 2003. Domestic and export markets are projected to increase as coal is substituted for petroleum. Much of the increased production will occur in western U.S. coal fields using the rail mode.

Table IV–7
UNITED STATES WATERBORNE COMMERCE BY COMMODITY GROUP, 1977 AND FORECASTS FOR 2003[1]
(Millions of Tons)

Major Commodity Group / Commodity Sub-Group	1977	Forecasts: 2003					
	Base Year	Baseline	High Use	Low Use	Bad Energy	High Coal Export	Misc.
1. Petroleum	958.2	722.8	722.8	646.8	602.1	622.8	725.9
Crude	488.7	423.6	423.6	369.3	335.6	423.6	423.7
Petroleum and Coal Prod.	469.5	299.2	299.2	277.5	266.5	299.2	302.2
2. Coal	211.8	513.7	642.8	475.9	578.3	805.2	677.4
3. Agricultural Products	202 3	458 6	458.6	418.7	463.0	458.6	461.7
Farm Products	158.1	366.2	366.2	339.3	389 5	366.2	368.8
Food and Kindred Prod.	44.3	92.4	92.4	79.4	73 5	92 4	92.9
4. Metals and Ores	149.6	302.7	302.7	278.5	294.9	302.7	305.0
Metallic Ores	115.3	244.3	244.3	203.5	234.7	244.3	245.4
Primary Metals Prod.	34.3	58.4	58.4	75.0	60.2	58.4	59.6
5. Chemicals/Fertilizers[2]	77.7	139.2	139.2	133.6	136.2	139.2	142.4
6. Forest Products	64.4	70.5	70.5	70.5	70.5	70.5	70.6
Lumber and Wood Prod.	52.6	54.2	54 2	54.2	54.2	54.2	54.2
Pulp, Paper and Allied Prod.	11.8	16 3	16.3	16.3	16.3	16.3	16.4
7. Other	250.8	378 1	390 6	355.9	369.4	390.6	406.2
Nonmetallic Minerals	159.0	197.3	209.8	187.8	194.4	209.8	217.6
Stone, Clay, Glass, Concrete Prod.	16.2	32.8	32.8	27.1	28.8	32.8	33.2
Waste and Scrap	21.8	29.2	29.2	29.1	28.9	29.2	29.3
Other Commodities	53.8	118.8	118 8	111.9	117.3	118.8	126.1
Total	1914.8	2585.6	2727.2	2379.9	2514.3	2889.6	2789.2

1. Foreign and domestic commerce
2. Phosphate rock and natural fertilizer materials not elsewhere classified are included in the nonmetallic minerals commodity sub-group.

Figure IV-4
U.S. WATERBORNE PETROLEUM, 1977-2003

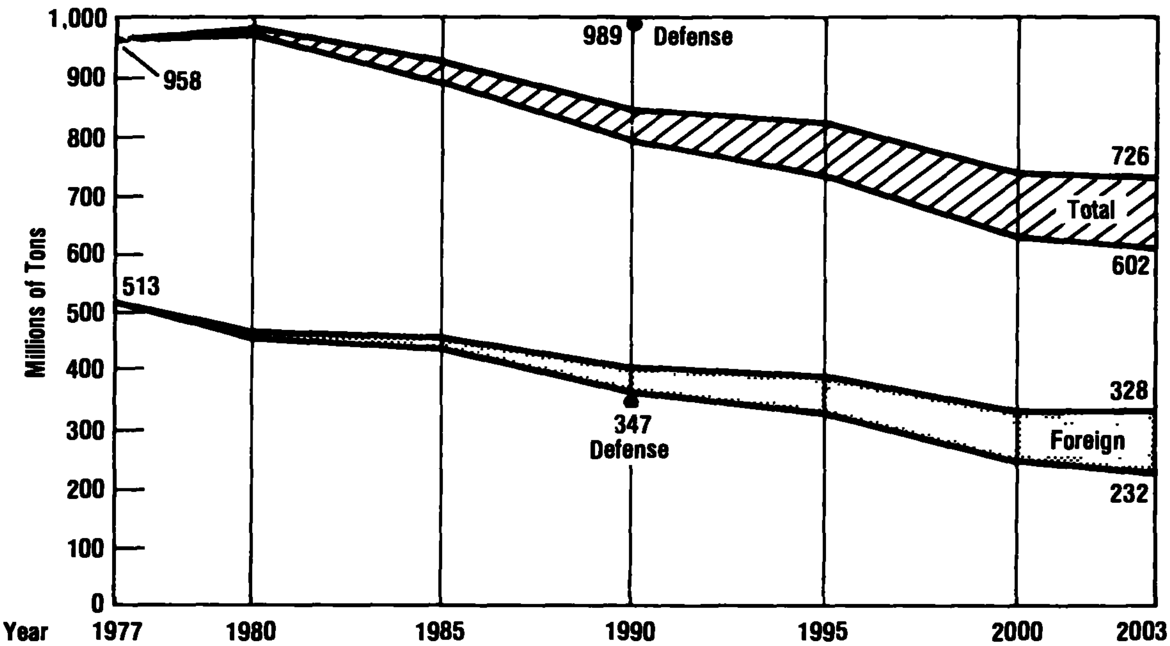
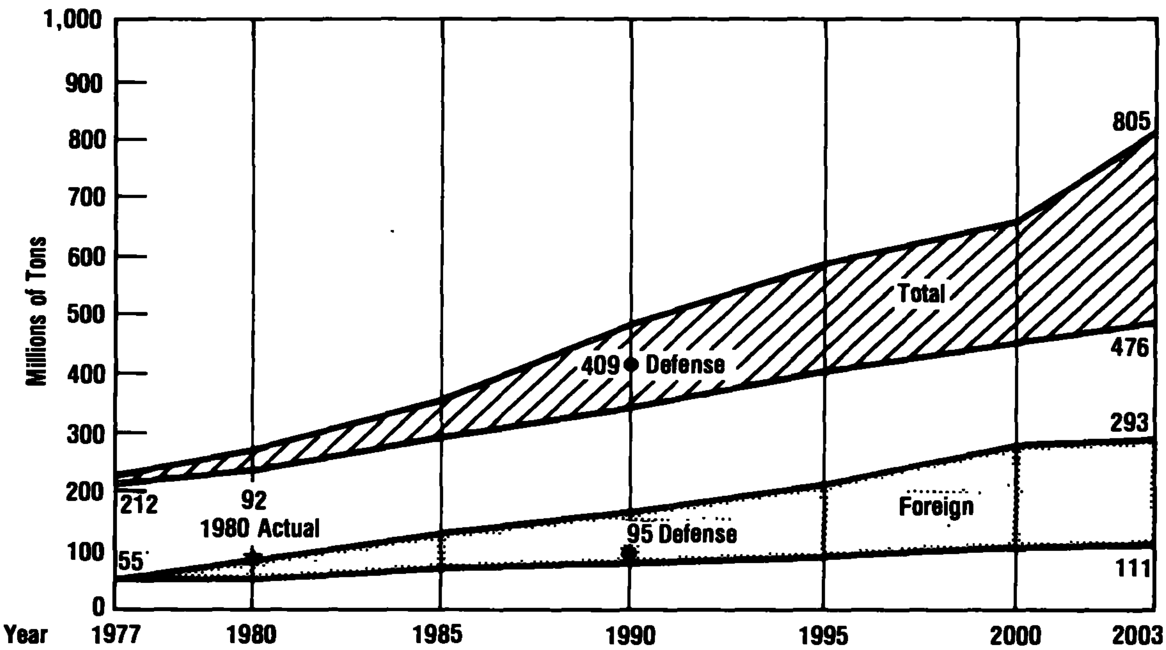


Figure IV-5
U.S. WATERBORNE COAL TRAFFIC, 1977-2003



3. *Agricultural Products*. Farm products and food and kindred products are forecast to increase by a factor of 2.3 times from 202 to a high of 463 million tons between 1977 and 2003. The Low Use forecast shows a doubling by 2003 to 419 million tons. The greatest contributors to this growth are corn, soybeans and wheat in the farm products group. Figure IV–6 depicts the strong foreign trade growth component for agricultural products and the negative impact of a Defense emergency on this trade.

4. *Metals and Ores*. This group, which includes metallic ores and primary metal products, is forecast to double in traffic from 150 to 305 million tons, based on the highest forecast from 1977 to 2003. Metallic ores are forecast to increase at a slightly greater rate than primary metal products. Figure IV–7 displays the relationship of foreign trade to the total forecast and particularly the impact of the hypothetical Defense scenario.

5. *Chemicals and Fertilizers*. As displayed in Figure IV–8, this group is forecast to increase from 78 to a maximum of 142 and a minimum of 134 million tons between 1977 and 2003.

6. *Forest Products*. This group has the lowest rate of increase of all the commodity group forecasts, by increasing only 10 percent from 64 to 71 million tons between 1977 and 2003, as shown in Figure IV–9. Pulp, paper and allied products are forecast to increase slightly more rapidly than the lumber and wood products, the other component of the forest products group.

7. *Other*. The total of this group shown in Figure IV–10 is forecast to increase from 251 to a maximum of 406 million tons from 1977 to 2003. The forecast minimum for 2003 is 356 million tons. A wide diversity of rates of growth prevails within this group. Waste and scrap increases very slowly from 22 to 29 million tons for 1977–2003. In contrast the "other commodities" category, which includes general cargo, is forecast to increase 133 percent from 54 to 126 million tons between 1977 and 2003.

8. *Total*. Total U.S. waterborne is forecast to increase from 1915 to a minimum of 2380 and maximum of 2890 million tons between 1977 and 2003. Figure IV–11 displays traffic growth estimates through the year 2003.

GROWTH CURVES: HISTORICAL AND FORECAST

To add perspective to the above forecasts, historical and forecast changes in traffic of predominant commodities in waterborne commerce are shown graphically in Figures IV–12 through IV–15. Major domestic commodities are shown in Figure IV–12, with coal the number one commodity in growth rate and quantity in the future. Petroleum products have been declining since the late 1970s and are forecast to continue that decline. Crude petroleum had been declining in the early 1970s, but the Alaskan crude petroleum movement brings an increase until the mid 1980s, when a slight decline is forecast to occur to 2003. Metallic ores have been declining but are forecast to increase in the future. Grains have shown strong growth and

Figure IV-6
U.S. WATERBORNE AGRICULTURAL PRODUCTS, 1977-2003

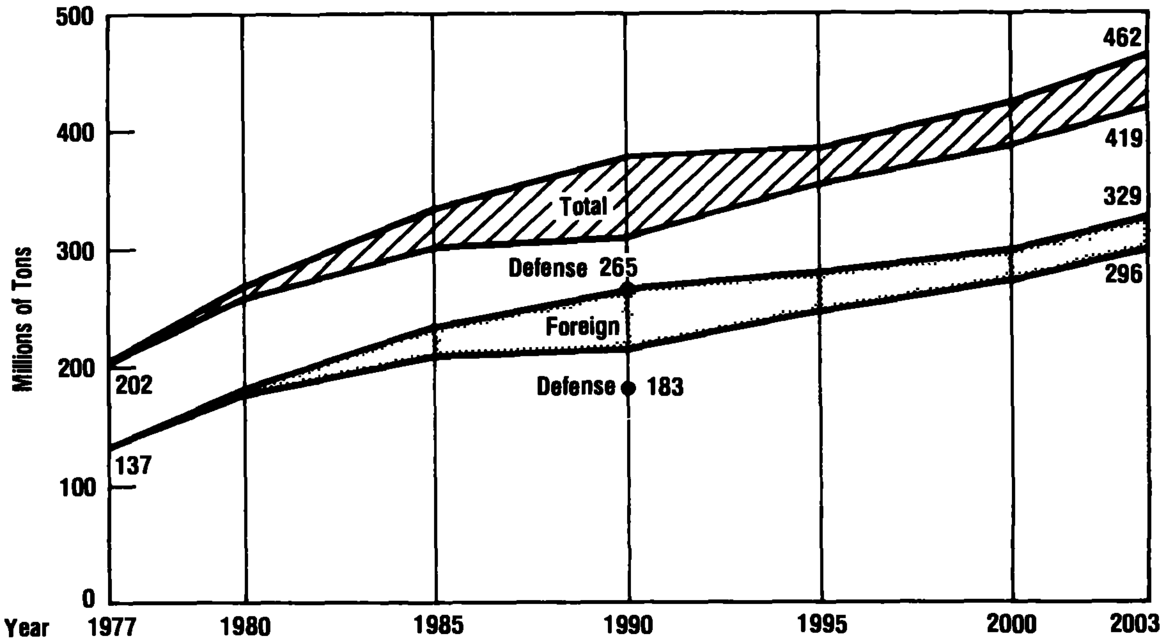


Figure IV-7
U.S. WATERBORNE METALS AND ORES, 1977-2003

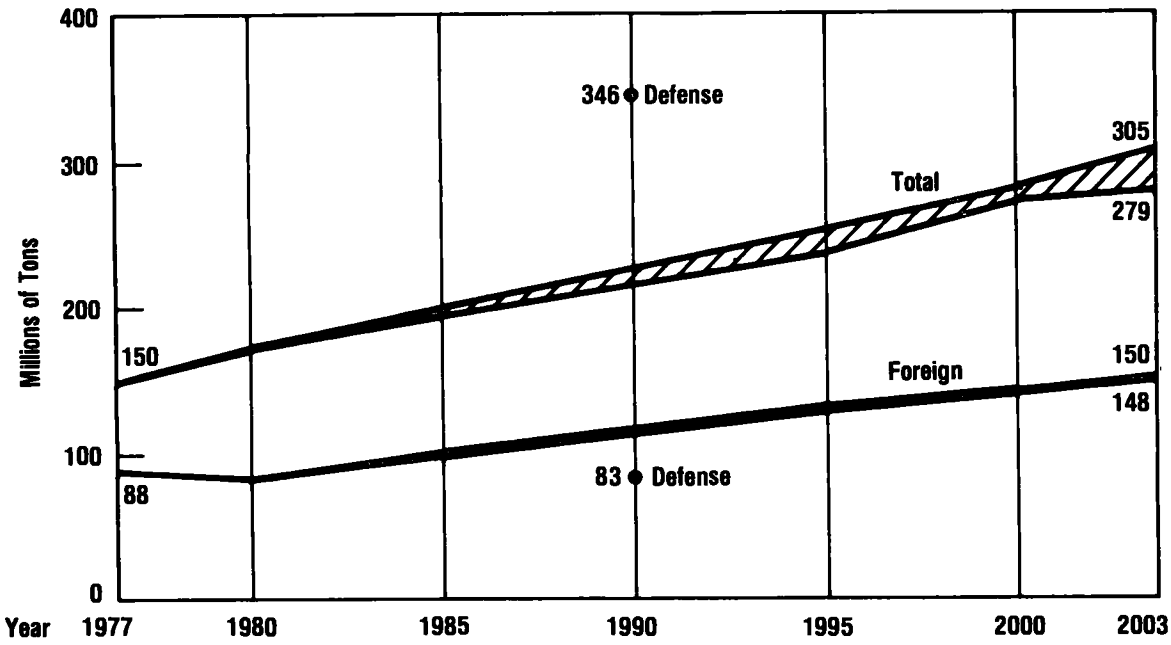


Figure IV-8
U.S. WATERBORNE CHEMICALS AND FERTILIZERS, 1977-2003

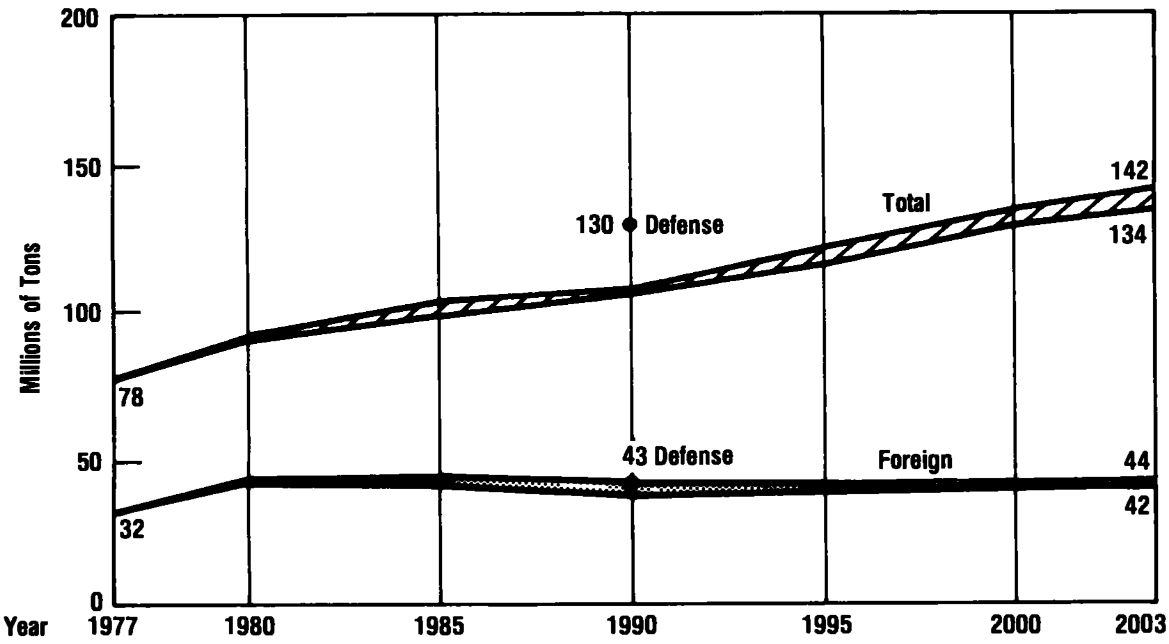


Figure IV-9
U.S. WATERBORNE FOREST PRODUCTS, 1977-2003

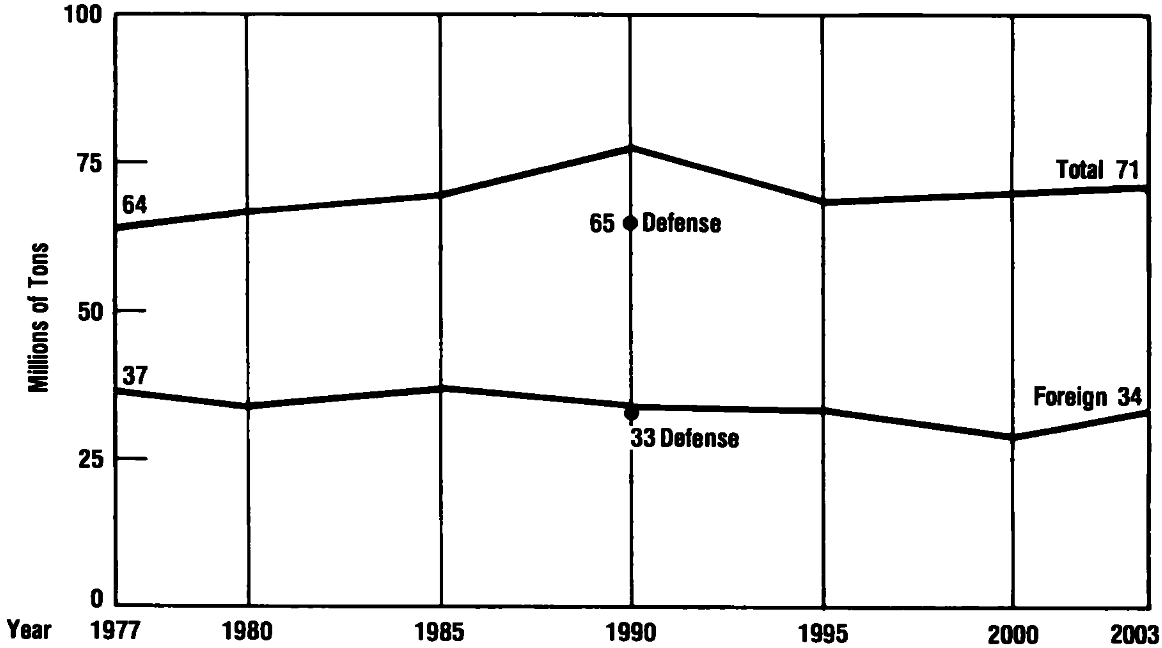


Figure IV-10
U.S. WATERBORNE, OTHER PRODUCTS, 1977-2003

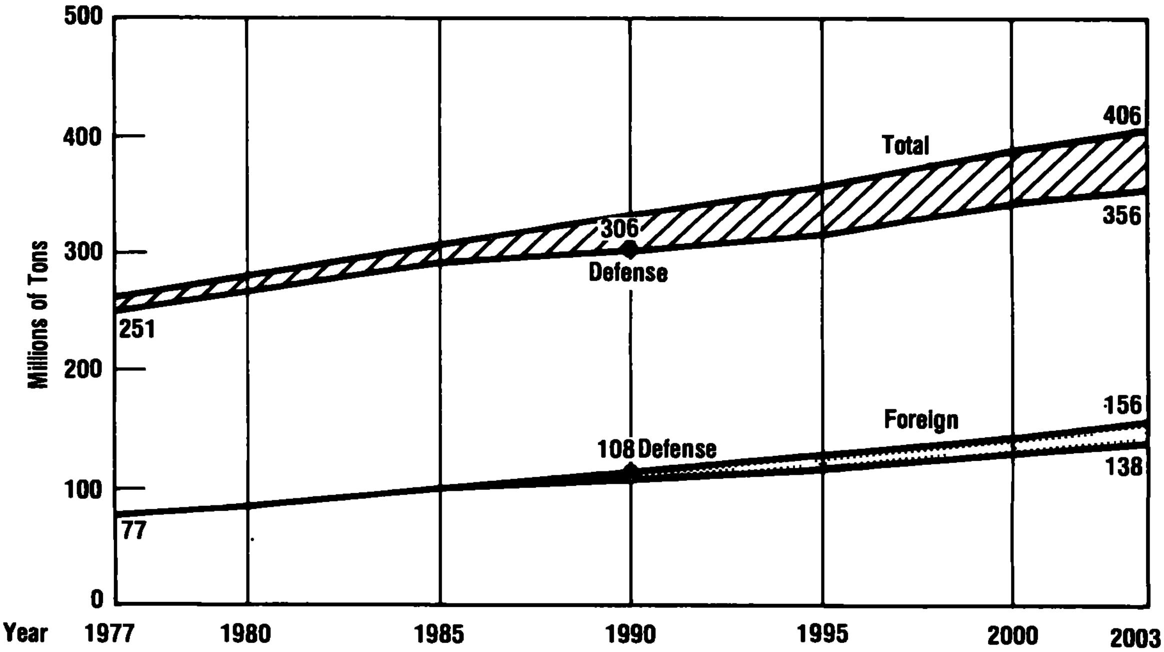


Figure IV-11
U.S. WATERBORNE COMMERCE, 1977-2003

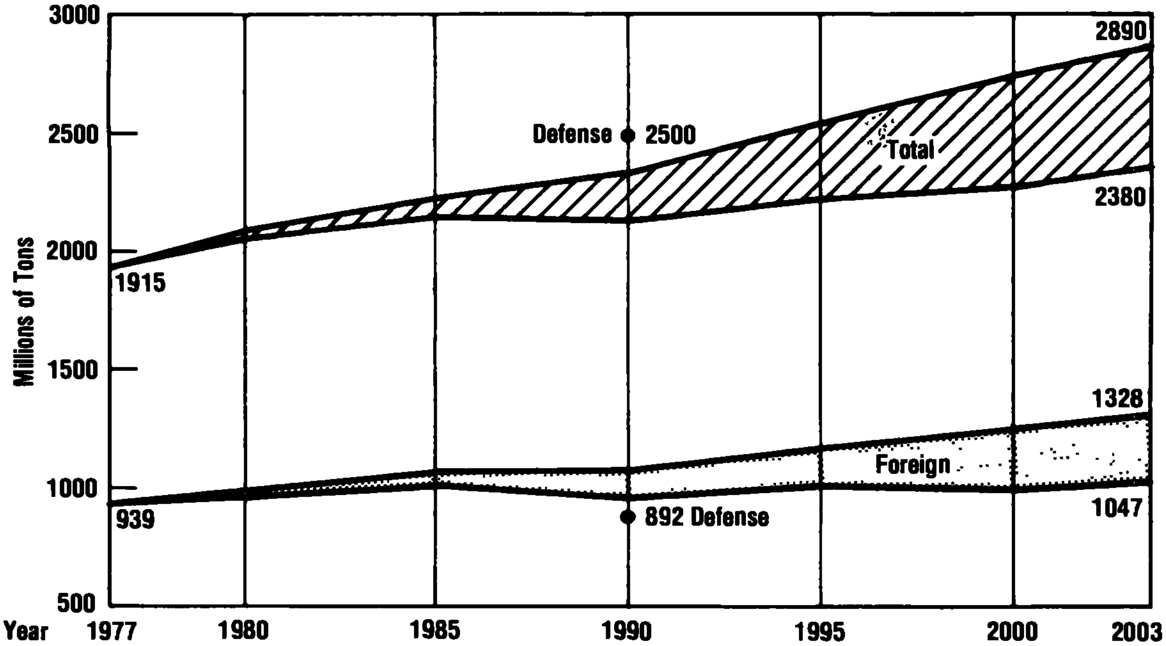
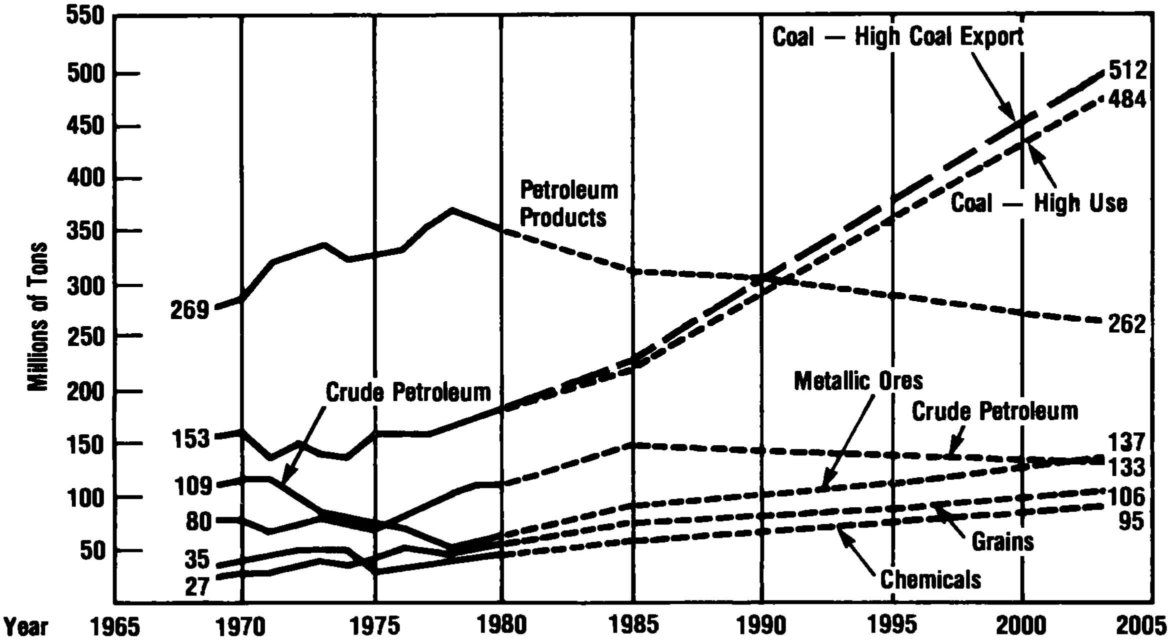


Figure IV-12
MAJOR COMMODITIES IN U.S. DOMESTIC WATERBORNE COMMERCE HISTORICAL AND PROJECTED (HIGH USE AND HIGH COAL EXPORT SCENARIO), 1969-2003



are forecast to continue that trend. Chemicals have fluctuated in the 1970s, but are forecast to increase steadily in the future.

Waterborne exports of grains and coal are depicted in Figure IV–13. Historically coal has had lows of about 30 and highs of about 70 million tons annually until the addition of the new foreign steam coal market increased coal exports to 91 million tons in 1980 and 112 million tons in 1981. The forecasts are for a continued growth in coal exports to 290 million tons in 2003, with a strong steam coal export market shown as the High Coal Export scenario. Exports of selected grains (corn, wheat and soybeans) have increased very rapidly from 15 to 130 million tons between 1952 and 1980. Forecasts call for those grain exports to reach 219 million tons by the year 2003.

Imports of crude petroleum and petroleum products, which are graphed in Figure IV–14, show past increases, recent declines, and a forecast for further declines to 2003. Crude petroleum imports increased at a slow rate until a highly accelerated growth from 90 to 404 million tons occurred from 1970 to 1977. That traffic dropped to 306 million tons in 1980 and is projected to further decline to 280 million tons or less by 2003.

The totals for all commodities are shown in Figure IV–15 for domestic, foreign and total traffic for the historic period 1947–1980 and the forecast period 1980 to 2003. The domestic commodity curve is forecast to continue to be fairly consistent with the amount of increase shown by the historic curve. Foreign waterborne commerce is forecast to increase much less than in the past, primarily because of decreasing petroleum imports.

FORECASTS OF FREIGHT BY WATER, RAIL AND PIPELINE

A summary of the 1977 base year and the 2003 forecast freight tonnage to be carried by rail, water and pipeline is shown in Table IV–8 for the Baseline forecast. The compound annual rate of growth in percent is as follows: rail, 2.6; domestic water, 1.6; pipeline, 0.7; and foreign waterborne commerce, 0.8. The more rapid rate of growth of rail is due, to some extent, to the increase in coal to be hauled by railroads from western origins where water transportation is not available. The waterways are forecast to continue to carry approximately the same percentage of traffic by all modes in 2003 that they carried in 1977, about 26 to 28 percent. Rails are forecast to increase their percentage of the total traffic, whereas pipelines are forecast to decline.

FORECASTS BY REACHES

The total traffic for each of the 22 reaches is shown in Table IV–9 for 1977 and six forecasts for 2003. Forecasts for each commodity group by reach are displayed in Appendix C, Tables C–2 through C–8. The percentage changes for the maximum and minimum forecast for each reach are reported in Table IV–10. Those tables show reach growth patterns: those with rapid growth, those with slow growth, and those with traffic losses forecast for the future. The fastest growing traffic areas are the Mississippi River and Tributaries and the Mobile River and Tributaries, which includes the Tennessee-Tombigbee Waterway presently under

Figure IV-13
U.S. WATERBORNE EXPORTS OF GRAIN AND COAL, HISTORICAL AND PROJECTED, 1952-2003

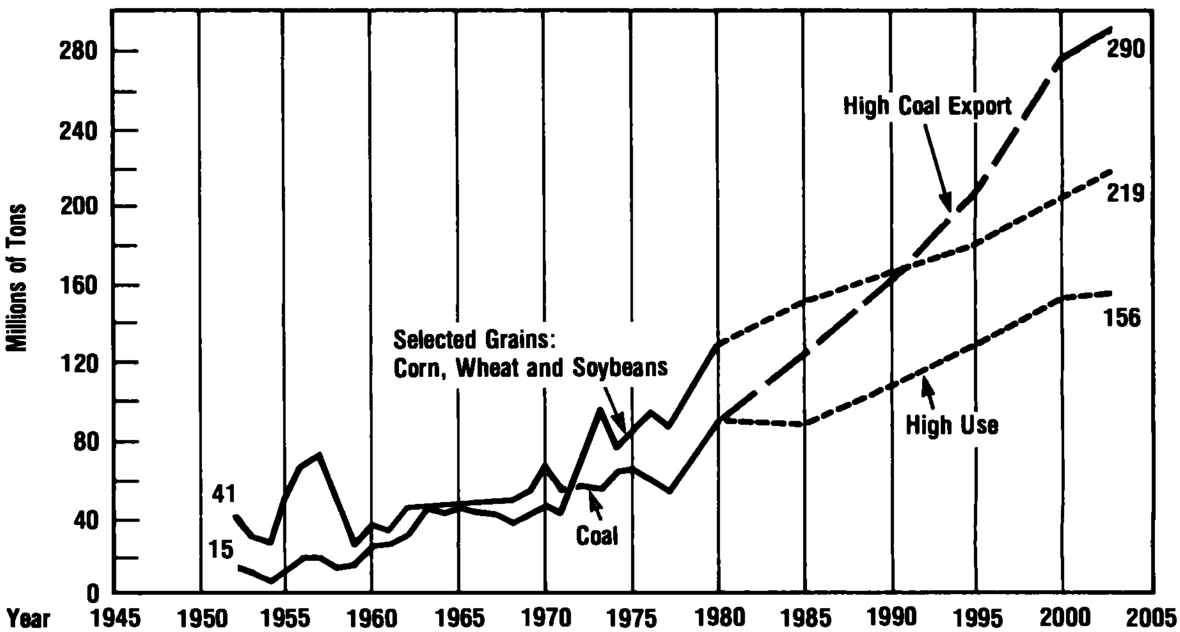


Figure IV-14
U.S. WATERBORNE IMPORTS OF CRUDE PETROLEUM AND PETROLEUM PRODUCTS HISTORICAL AND PROJECTED (HIGH USE SCENARIO), 1952-2003

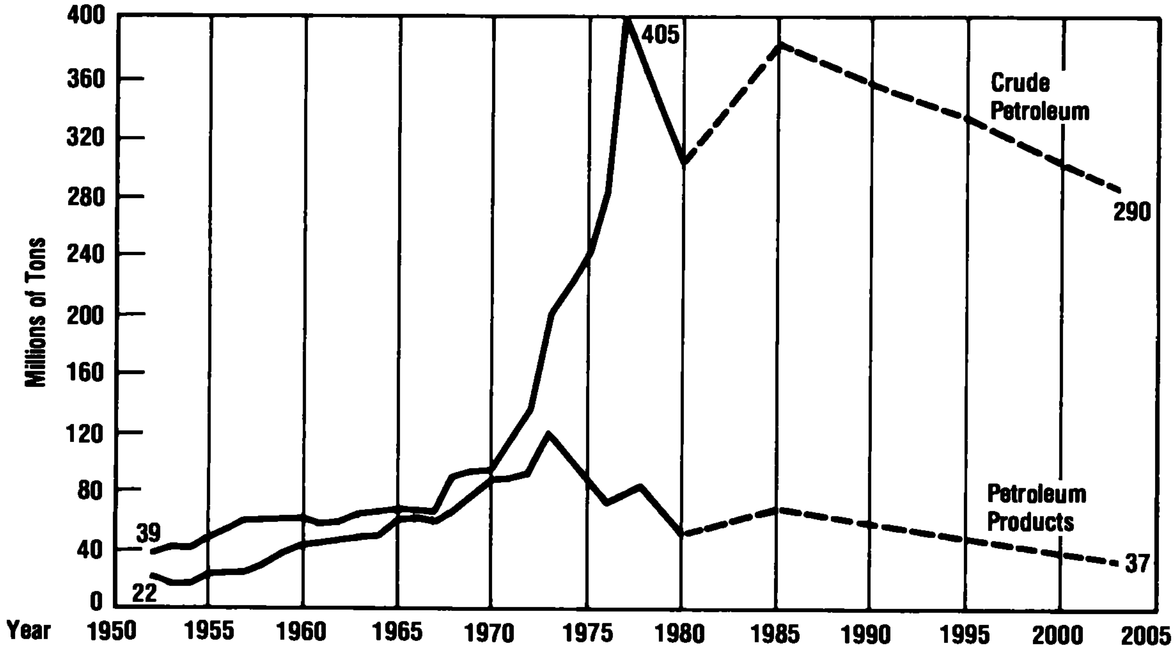


Figure IV-15
TOTAL U.S. WATERBORNE COMMERCE, HISTORICAL AND PROJECTED, 1947-2003

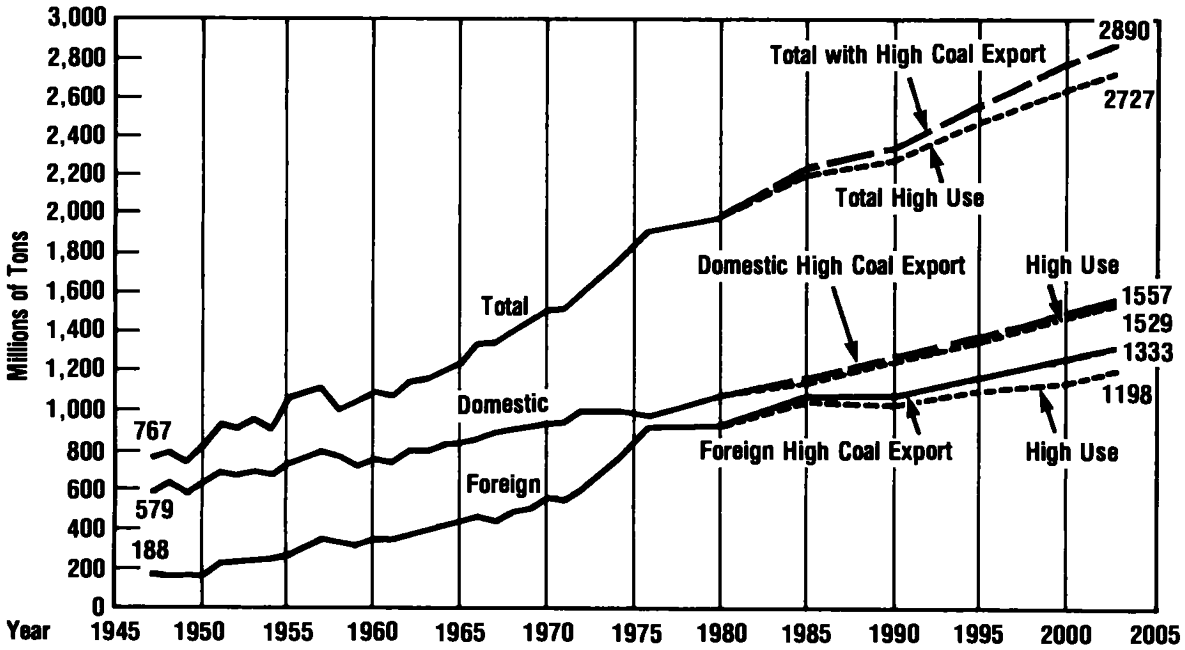


Table IV–8

FREIGHT CARRIED BY RAIL, WATER, AND PIPELINE, 1977 AND FORECASTS FOR 2003[1]

Mode	Total Amount (Millions of Tons) 1977	2003	Change 1977 to 2003 (Millions of Tons)	(Percent)	Compound Annual Rate of Growth (Percent)	Domestic Traffic Percentage Distribution 1977	2003
Rail	1391	2619	1228	88	2.6	39	48
Water—Domestic[2]	976	1448	472	48	1.6	28	26
Pipeline	1172	1401	229	19	0.7	33	26
Subtotal	3539	5468	1929	55	1.8	100	100
Water—Foreign[2]	939	1133	194	21	0.8		
Total	4478	6601	2123	47	1.6		

1 Data Resources, Inc , 1980
2 Baseline scenario National Waterways Study

Table IV–9

WATERBORNE COMMERCE: TOTAL OF ALL COMMODITIES BY REACH, 1977 AND SIX FORECASTS FOR 2003[1]

(Millions of Tons)

Reach	1977 Base Year	Forecasts: 2003 Baseline	High Use	Low Use	Bad Energy	High Coal Export	Misc.
Upper Miss.	30.9	66.0	68.7	58.8	67.9	68.7	69 4
Lower Upper Miss.	77.5	162.0	167 3	147 7	163 3	169.6	170.7
L. Miss: Cairo to B.R.	123.6	222 3	231.0	190 7	235 9	246.6	248.4
L. Miss: B.R. to Gulf	344 4	534 9	548.7	492 1	543 7	591.4	570.4
Illinois Waterway	60.4	103.5	106.4	95.6	108.4	106 4	107.2
Missouri River	6.7	7.8	7 8	7.4	7.0	7.8	7.9
Ohio River System	172.5	307.5	345.2	280.3	324 5	359.6	382.9
Tennessee River	26.5	66.9	79.5	61.7	67.3	86.4	81.4
Arkansas River	9.4	14.4	15 0	10 8	16.5	15.8	26 2
Gulf Coast-West	341.3	385.7	389.0	376.9	362.2	404.1	391.5
Gulf Coast-East	108.7	152 1	168.2	141.3	140.5	168.5	177.9
Mobile River and Trib	43 7	119 0	137.4	108.9	120 4	177.6	141.5
South Atlantic Coast	69.8	69.6	71 1	65.1	63.8	71.1	71.1
Middle Atlantic Coast	436.8	438 0	469.2	409.8	427.5	514.7	469.2
North Atlantic Coast	87 4	68 9	68.9	64.6	63.0	68.9	68.9
Great Lakes System	189.9	385.7	411 1	345.2	392.7	411 1	411.3
Washington/Oregon Coast	68.4	121.2	121.2	109.4	113.0	132.9	121.2
Columbia-Snake Waterway	43.5	58.6	58 6	57 9	54 6	58.6	63 7
California Coast	138.3	143 6	143.6	115.0	113.3	153.4	143.6
Alaska	28.8	86.2	86.2	86.4	95.4	86.2	86.2
Hawaii	15.3	21.5	21.5	20.9	21.1	21.5	21.5
Caribbean	89 8	74.5	74.5	49.4	68.0	74 5	74 5
Total[2]	1,914.9	2,585.6	2,727 2	2,379.8	2,514 3	2,889 6	2,789 2

1 Unconstrained forecasts of waterways tonnage
2 These figures reflect national totals, not the sum of reaches Reaches are not additive because many individual shipments pass through more than one reach

construction. These are the waterways where grain and coal are the dominant commodities. The annual compound rates of growth of the maximum forecasts range (in percent) from the high of 5.8 for the Mobile River and Tributaries, 4.8 for the Tennessee River, 4.2 for Arkansas River, and 3.3 for the Upper Mississippi River, to 3.2 for both the Lower Upper Mississippi River and the Ohio River System. Alaska also is a high growth area, showing a 4.9 percent maximum based on the relatively new movement of crude petroleum. The Great Lakes System and the Washington/Oregon Coast reaches show forecast growth rates of 2 to 3 percent per year. The Columbia-Snake Waterway and the Gulf Coast-East reaches have forecast growth rates of 1 to 2 percent annually.

The slow growing or declining traffic areas are those with crude petroleum or petroleum products as the dominant commodity traffic. The areas affected the most by the decline in petroleum traffic are the Atlantic coastal reaches, the California coast and the Caribbean. Losses in total traffic are forecast for the North Atlantic Coast and the Caribbean reaches for all the forecasts. The other ocean coastal reaches show very low growth, although increases are forecast in commodities other than the petroleum group.

COMPARISON OF HISTORICAL AND FORECAST RATES OF GROWTH OF WATERBORNE COMMERCE

The forecast 25-year (1978–2003) growth in total U.S. waterborne commerce shown in the last line of Table IV–10 ranges from a minimum of 0.9 to a maximum of 1.7 percent annually. These are much slower rates than the past (1952–1977) growth rate of 3.1 percent reported in Table IV–1 for total U.S. waterborne commerce. The level of crude petroleum imports is the major factor in the differences in those rates of growth. Domestic waterborne commerce historically displayed a 1.6 percent annual rate of growth between 1952 and 1977 (Table IV–1), which is identical to the forecast domestic rate using the Baseline forecast (Table IV–8). The compound annual percent rates of growth of domestic waterborne commerce for forecasts other than the Baseline forecast differ slightly and are as follows:

1.	Low Transportation Use	1.2
2.	Bad Energy	1.5
3.	Baseline	1.6
4.	High Transportation Use	1.8
5.	High Coal Exports	1.9

Table IV–10
WATERBORNE COMMERCE: TOTAL OF ALL COMMODITIES BY REACH, 1977 AND CHANGE BASED ON MINIMUM AND MAXIMUM FORECASTS FOR 2003

		Change: 1977 to 2003 Forecasts[1] (Percent)				
	Total 1977 (Millions	Total Change		Compound Annual Rate		Highest Three Ranking
Reach	of Tons)	Min	Max	Min	Max	Commodity Groups 1977[3]
Upper Miss	30.9	90	125	2.6	3.3	Grain, Coal, Pet.
Lower Upper Miss.	77.5	91	119	2.6	3.2	Grain, Coal, Pet.
L. Miss: Cairo to B.R.	123.6	54	101	1.7	2.8	Grain, Pet., Chem.
L. Miss: B.R. to Gulf	344.4	43	72	1.4	2.2	Pet., Grain, Chem.
Illinois Water	60.4	58	79	1.8	2.4	Grain, Met. & Ores, Coal
Missouri River	6.7	10	18	0.4	0.7	Sand/Gravel, Grain, Chem.
Ohio River System	172.5	62	122	1.9	3.2	Coal, Pet., Chem.
Tennessee River	26.5	133	226	3.4	4.8	Coal, Grain, Chem.
Arkansas River	9.4	15	181	0.6	4.2	Pet., Sand/Gravel, Grain
Gulf Coast-West	341.3	6	18	0.2	0.7	Pet., Chem., Ag. Prod.
Gulf Coast-East	108.7	29	64	1.0	2.0	Pet., Coal, Chem.
Mobile River and Trib.	43.7	149	306	3.7	5.8	Coal, Steel, Pet.
South Atlantic Coast	69.8	–9	2	–0.4	0.1	Pet., Chem., Ag. Prod.
Middle Atlantic Coast	436.8	–6	18	–0.2	0.7	Pet., Coal, Ag. Prod.
North Atlantic Coast	87.4	–28	–21	–1.3	–0.9	Pet., Ag. Prod., Chem.
Great Lakes System	189.9	82	117	2.4	3.1	Met. & Ores, Coal, Grain
Washington/Oregon Coast	68.4	60	94	1.9	2.7	For. Prod., Pet., Grain
Columbia-Snake Waterway	43.5	26	46	0.9	1.5	For. Prod., Pet., Grain
California Coast	138.3	–18	11	–0.8	0.4	Pet., Ag. Prod., For. Prod.
Alaska	28.8	202	231	4.5	4.9	Pet., For. Prod., Chem
Hawaii	15.3	37	41	1.3	1.4	Pet., Ag. Prod., For. Prod.
Caribbean	89.8	–45	–17	–2.4	–0.8	Pet., Chem., Ag. Prod.
Total[2]	1,914.9	24	51	0.9	1.7	

1 Based on maximum and minimum forecast for each reach (Table IV–9)
2. Based on national totals, not the sum of reaches. Reaches are not additive because many individual shipments pass through more than one reach.
3 Based on tons of waterborne commerce

6 Miscellaneous 1.9

As discussed above, the forecast traffic growth for high tonnage barge transport reaches, such as the Mississippi, Ohio, Tennessee and Mobile Rivers, ranges from a minimum of 1.7 to a maximum of 5.8 percent annually. Most of those reaches have maximum forecasts of 2.8 to 3.3 percent annually (Table IV–10). These rates are slightly below the historic annual rate of 3.6 percent for internal (inland waterways) traffic (Table IV–1).

ADDITIONAL INFORMATION ABOUT REACHES

Appendix D with this report contains additional information for each of the 22 reaches including:

a. Map of each reach and vicinity showing locations and names of locks and dams;
b. Graphs of base year and maximum and minimum forecasts of waterborne commerce, 1977–2003;
c. Bar charts based on traffic composition by commodity groups, 1977 and 2003 using the High Use forecast;
d. Profiles of most reaches which have locks and dams;
e. List of locks and dams, dimensions, year opened to traffic and lock capacity; and
f. Brief descriptions of physical characteristics, dredging statistics, linkage with other reaches, type of vessels, recreational and other water uses, environmental concerns, status of the waterway, and capability and constraints of the waterway.

A matrix showing the 1977 traffic linkages between reaches is in Appendix D and provides added information about the characteristics of the traffic of each reach. These characteristics allow categorizing the traffic in the reach as local, interreach, or movement to points of export.

Detailed projections by the 14 commodity groups, by reach for each of the seven forecasts are contained in the National Waterways Study technical report entitled *Evaluation of the Present Navigation System*, March 1982. A complete set of tables is contained in the 768-page Appendix A to that report, which shows 1977 waterborne commerce and forecasts by five-year increments to 2003 for domestic waterborne shipments and receipts and foreign waterborne imports and exports. Supplemental tables in that Appendix show the total domestic traffic in tons and in ton-miles for the Mississippi River and Tributaries, the Gulf Intracoastal Waterway and Tributaries, and the Great Lakes System.

SECTION V

CAPABILITY EVALUATION OF THE EXISTING SYSTEM

DEFINITIONS

Capability: The ability to handle commercial waterborne traffic (capacity), and to handle it safely, efficiently and reliably.

Capacity: The maximum physical ability of a lock or channel to handle commercial navigation, measured in tons per year.

- — Constraining Lock (Constraint): A lock site which restricts traffic growth beyond its physical capacity—100 percent utilization
- — Primary Constraining Lock: A lock site which restricts traffic growth on one or more closely interrelated waterways.
- — Secondary Constraining Lock: A lock site which restricts traffic growth on one or more interrelated systems after additional capacity is provided for at the primary constraining lock site.
- — Congested Lock: When annual lock utilization is equal to or exceeds 80 percent of physical capacity. This is the approximate point where delays begin to increase rapidly.

Efficiency: Maximizing use of resources per unit of output of performance. Relative linehaul cost per ton-mile for commercial carriers is used as a measure of efficiency.

- — Linehaul Cost: Operating cost per ton mile of vessel or tow operation between ports or given points.

Reliability: The ability of a segment or reach to serve traffic with assurance of continuous service.

Safety: Sites hazardous to vessels due to physical factors such as inadequate clearance conditions.

CAPABILITY EVALUATION OF THE EXISTING SYSTEM

This section describes the approach used to evaluate the capability and safety of the existing water transportation system under both peacetime and hypothesized wartime conditions. It then summarizes the results of that evaluation, and discusses the impact on the national goals of economic growth, energy self-sufficiency, export of agricultural products and coal, and national defense. The following paragraph briefly reviews forecasts of commodity growth which provide the foundation for the evaluation of the existing system.

Previous sections discussed how U.S. waterways and ports play key roles, through the movement of basic commodities, in the U.S. economy and the strengthening of the nation's defense. In order to continue their significant contributions to the nation's balance of payments through the agricultural and coal exports; to the nation's energy self-sufficiency through movement of energy commodities; and to provide transportation conditions essential for the nation's defense and security, assurance of their capability and safety is essential. The commodity groups which are forecast to experience the greatest percentage increases are coal, agricultural products, and metals and ores, in that order (Table V–1 displays these commodity groups and their potential growth with respect to other waterborne commodities.) Currently important, these commodity groups are projected to attain greater national significance over time. The importance of these commodities in terms of waterway system capability is a function of where the commodity traffic growth occurs in relation to each and all other commodities. Figure V–1 displays the regional dispersion of domestic traffic for the inland waterways, Gulf Coast and Great Lakes.

ANALYTICAL APPROACH

The key factors involved in evaluating the capability of the waterways were capacity, efficiency, reliability and safety. These are discussed below.For further detail refer to the NWS technical report, *Evaluation of the Present Navigation System,* referenced in Appendix H.

ASSUMPTIONS

Evaluation of waterway capability incorporated three basic assumptions:

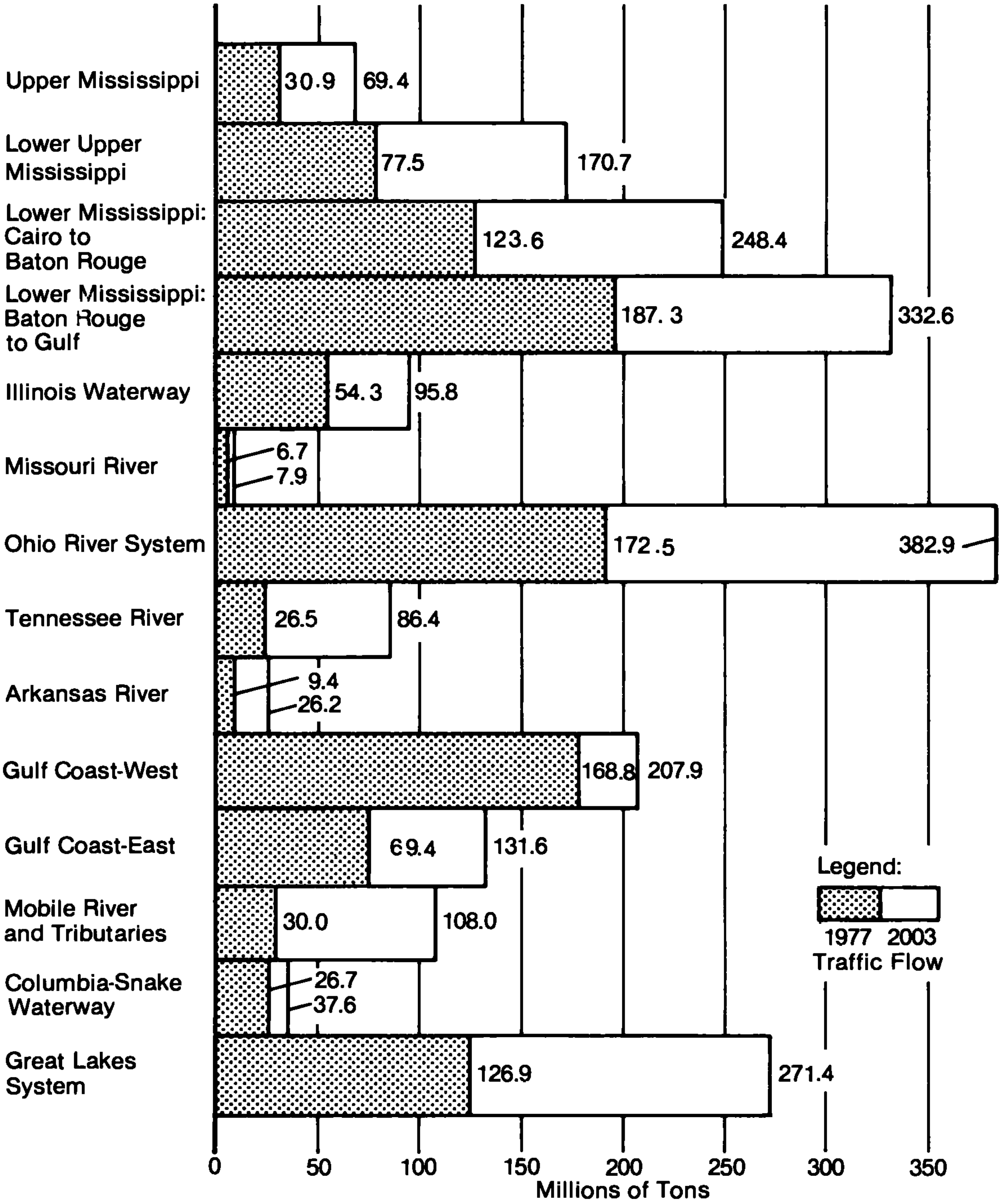
1. On-schedule completion of the existing system—Projects currently under construction were included in the system analysis as of the date they are scheduled to be in full operation. Since forecasts are in five-year increments, their operation will be reflected at the five-year reporting point following their completion date. For example, the new Lock 26, on the Lower Upper Mississippi, was evaluated on the basis that it would be operational by 1990.
2. Lock evaluation—Lock utilization and estimated capacities were based on traffic specific to that lock and on the physical characteristics of that structure. Locks generally determine the maximum traffic volume of a waterway and, therefore, serve

TABLE V–1
WATERBORNE COMMODITY GROWTH AND SHARES, 1977–2003

Commodity	Base Year 1977 (Millions of Tons)	Range of Growth 1977–2003 (Percent)		Commodity Share of Total (Percent)	
		Minimum	Maximum	1977	2003
Agricultural Products	202	107	127	11	17
Chemicals/Fertilizer	78	72	83	4	5
Metals and Ores	150	76	112	8	11
Coal	212	125	280	11	24
Petroleum	958	–37	–24	50	26
Forest Products	64	9	0	3	3
Other	251	42	62	13	14
Total	1915	24	51	100	100

Figure V-1

DOMESTIC TRAFFIC GROWTH, 1977 TO 2003: INLAND WATERWAYS, GULF COAST AND GREAT LAKES[1]



1. The forecast depicted is for the maximum level achieved across all six peacetime forecasts. Domestic traffic flows are between U.S. points of origin and destination.

both individually and collectively to limit the traffic carrying capacity.
3 Validity of traffic forecasts—Seven traffic forecasts were used. Six were based on peacetime conditions and one was based upon a five-year defense mobilization. Forecast traffic was converted into tow configurations based on current and predicted practices in each waterway segment.

CAPABILITY COMPONENTS AND MEASURES

The four evaluated factors of waterway reach capability—physical capacity, efficiency, reliability and safety—are influenced by one or more of the following:

1. Primary commodity and mix of commodities in segment traffic flow.
2. The amount and share of hazardous commodities projected for each segment.
3. Density of traffic at a point or segment of the waterway.
4. Vessel and tow characteristics—dimensions (length, width and draft), horsepower and cost.
5. Maximum lock capacity.
6. Lock utilization.
7. Physical conditions—channel dimensions, channel configuration, currents, weather (fog, heavy weather, winds), ice, floods and drought.
8. Technological status of structures—dimensions and alignment are indicators.
9. Physical integrity of structures—age is an indicator.

The evaluation methodology for each of the four capability factors discusses both the approach to the analysis and the individual measures applied.

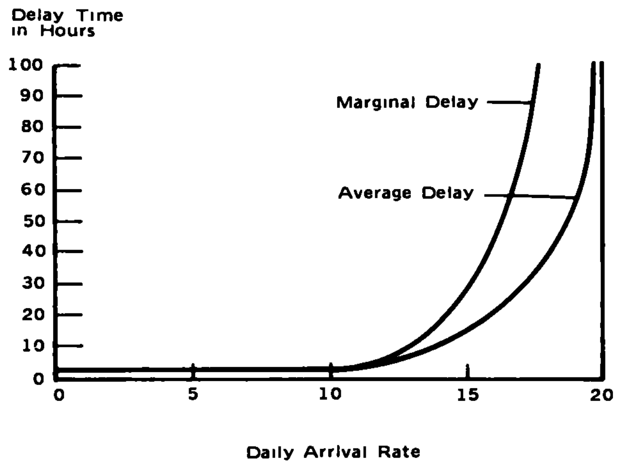
Capacity

Locks are the primary capacity constraint in the inland, intracoastal and Great Lakes systems. Other causes of delay, such as fleeting areas, bends and restrictive bridges, do not generally restrict total throughput, though they slow traffic. Coastal channel dimensions limit access by large bulk carriers, and thus the substantial economic benefits of this vessel size are sharply reduced at U.S. ports. Capacity is both an economic and a physical problem, however, NWS evaluated only the physical.

Fleets of barges powered by towboats (tows) move commodities on the inland and intracoastal waterway systems. Constraints on these systems limit the numbers of tows passing each day. Lines of waiting tows develop at locks when the arrival rate, the number of tows desiring lockage during the day (week or month), approaches the rate at which tows can be served. If a lock can service 20 tows per day and 10 arrive, the potential for a long line is small. However, as the arrival rate increases, the length of wait, delay per tow, increases. Figure V-2 displays this graphically. When the service limit (or capacity) is approached, the waiting time approaches infinity. Delays create added costs. Most expenses (except fuel)—labor, equipment rental, administrative overhead—continue whether a vessel is moving or not. Also, inventory costs are incurred on the product carried. The result of delays is increased use of resources, both labor and capital, per ton transported.

Some tows made up of specific commodities can, and will, be capable of incurring greater delays

Figure V-2
DELAY CURVES



than others. Decisions about choice of route and mode in the short run and resource supply and plant location in the long run are part of the entire production function of each shipper buying the service of a tow. Limited lock capacity inflicts increasingly higher costs upon all customers served. These delay costs occur well below the theoretical capacity. Thus, delay costs become a significant burden on those who pay for transport service long before the maximum physical capacity is reached.

The NWS evaluated lock capacity and congestion. Locks which would theoretically exceed their physical capacities under the forecast traffic levels were defined to be constraints. Locks reaching 80 percent of this physical capacity were defined to have reached a point of significant congestion. When traffic forecasts exceed the 80 percent lock utilization some shippers' products will be diverted, in the short run, to alternative modes or routes.

The NWS team developed lock-specific forecasts of both traffic and capacity. Capacity levels at locks generally increased over time. This was, in part, because of the assumption of nonstructural and minor structural measures being applied to expand the capacity; thus, each lock evaluation included an increase in capacity of usually 15 to 20 percent. Additionally, changing commodity mixes, flow patterns and flotilla (towboat with barges) sizes and configurations, all contributed to changing capacity over time. The capacity calculation gave commercial traffic absolute priority over recreation craft.

Several locks and dams operate open or navigable passes during high flow periods. Tows move over the dams (wickets are first lowered) in these periods, but must lock through in low flow periods. Lock capacity is relevant during the periods when the passes cannot be used. LaGrange and Peoria Locks on the Illinois Waterway and Locks 52 and 53 on the Ohio River System were evaluated under the low flow assumption, because of their impact on other waterways and the level of strategic materials and export commodities moving on these two reaches.

Each potentially congested lock was evaluated independently. Capacity measured in tons was determined. Whenever the traffic forecast exceeded the capacity, the lock was identified as a constraint under that particular forecast.

Efficiency

Efficiency is affected primarily by lock congestion. However, channel dimensions and configuration of some segments contribute to inefficient vessel operating characteristics—small tows, shallow drafts, and slow speeds. These inefficiencies also affect the optimum use of locks. Lock and channel efficiency is estimated by linehaul costs incurred by operators. As traffic levels increase and lock capacity is approached, delays develop at increasing rates; and, as stated above, the NWS defined a lock to be congested when traffic levels exceed 80 percent of its physical capacity. Delay costs due to congestion increase transport costs and thus the delivered price of both domestic and export commodities.

Reliability

An important element of waterway capability is the reliability of service. Shutdowns or slowdowns because of weather, flow conditions, or repairs influence the linehaul costs of shippers. Uncertainty associated with service availability translates into additional costs due to increased inventories required to hedge against shipment delays. Two principal features of the physical system, structures and channels, along with management of ice conditions, contribute to reliability.

Structures

The measures applied as indicators of reliability are age, physical condition, modern dimensions relative to the system, and utilization. Deferred maintenance would be an appropriate measure; however, data are incomplete. Navigation structures (locks, dams, jetties, breakwaters and dikes), like all manmade products, wear out with use and age. While normal maintenance will prolong the useful life of structures, there almost always comes a time when major repairs are necessary to preserve the integrity and safety of the structure. In cases when an old, physically deteriorated, and particularly a technologically obsolete structure cannot be repaired, then replacement is necessary.

Channels

Channel reliability depends on the predictability of depth and width. Dependable channel dimensions are maintained by dredging and river training techniques. The need for dredging is influenced by the movements of sediment in the channel and the flow regime. Water flow availability depends on hydrologic conditions and on water use demands which compete for water with navigation. Navigation channels are dredged when the traffic volumes warrant it; when the funds are available; and when environmental restrictions permit it. When dredging is deferred for these or other reasons, the reliability of the channel is reduced. For the National Waterways Study, hydrologic records were evaluated and competing water uses documented to determine whether dependable navigation depths could be maintained under low flow conditions.

Ice Management

Significant physical factors affecting the navigability of inland and Great Lakes channels include ice, fog and other weather hazards. Navigation on the Great Lakes and many northern waterways is sharply limited by winter ice. The Upper Mississippi River, Missouri River, and Great Lakes System provide normal operations for about 9 months during the year. The Illinois Waterway and the Ohio River System experience substantial ice at infrequent intervals creating hazardous operating conditions, slowing and, in some years, stopping traffic. Ice and other weather conditions slow or halt traffic and accelerate structural deterioration. The NWS evaluated the impact of these conditions on incidence of delays, vessel damage, and amount of traffic served seasonally.

Safety

Many factors of structural and channel design and operations contribute to safety. Bridges and other structures may adversely affect the safe operation of navigation systems. The NWS undertook a systematic documentation of safety hazards and evaluated their likely impact on projected traffic flows. The NWS technical report *Review of National Defense, Emergency and Safety Issues Affecting the Waterways* provides a broad survey of the historical records; another report, *Evaluation of the Present Waterways System,* evaluates the safety needs in view of future traffic flows.

Accidents involving inadequate vessel control comprise 60 percent of the reported accidents. These include groundings, rammings and collisions and are related to the physical marine environment and levels of traffic. An NWS study of factors contributing to vessel control accidents on inland rivers found that the river segments with a high level of these accidents had one or more of the following characteristics in common:

1. One or more bridges.
2. One or more locks.
3. Bend or intersection with another channel.
4. Narrow channel width.

Overall, levels of congestion are deemed relatively more important in ports compared to inland river segments. NWS analysis concluded that obstructions to navigation such as bridges and locks (particularly bridges and locks which restrict traffic and cause delays) contribute to safety problems. Bridges are the most common characteristic cited in safety problem areas. Likewise, restrictive channel dimensions and unreliable channels (i.e. channels with frequent shoaling) increase the burden on operators. Other factors contributing to the magnitude of safety problems include traffic growth, increases in tow and/or vessel delay at locks, increasing tow sizes and high levels of hazardous cargoes.

Four types of safety problems were identified in the analysis. These included bridges, locks, channel congestion and channel configuration. The measures applied to determine safety problem areas included one or more of the following:

1. Historical record of accidents.
2. Narrow bridge clearance, horizontal and/or vertical.
3. Lock approach, channel configuration and dimensions.
4. Density of traffic, measured in absolute tons.
5. Amount and share of hazardous commodities, measured in tons and percent.

CAPABILITY EVALUATION

The evaluation of waterways' capability—based on the factors discussed previously, the ability to handle commercial waterborne traffic and to handle it safely, efficiently and reliably, under peacetime conditions—is discussed in the following paragraphs.

CAPACITY ANALYSIS

The capacity analysis focuses on locks which were determined to be the dominant physical constraining feature on a waterway under peacetime conditions. The importance of a lock constraint to the nation is measured by that portion of the forecast traffic which the lock cannot handle. To place this traffic into a national goal context, the evaluation identified traffic by the commodity group which would probably be most affected. Table V–2 statistically presents the analysis results for each inland and Great Lakes System reach summarized below:

1. Constraining locks which present physical barriers to traffic growth are projected to occur under one or more of the six peacetime scenarios in nine different reaches. Twenty U.S. lock sites and eight Canadian sites would constrain projected traffic growth.
2. Over 100 million tons of traffic would not be accommodated because of these constraining sites. While this is about 7 percent of the total projected domestic waterborne traffic, its impact measured by congestion costs would be substantial. The impact on commodity groups under peacetime conditions, as indicated by the maximum level not served nationally, is shown in Table V–3. Coal and agricultural products are the commodities most affected by constraints.
3. The inland and Great Lakes System reaches responsible for most of the nation's coal and agricultural product flows cannot handle all projected traffic. The new 1200-foot Lock 26 on the Lower Upper Mississippi would limit forecast traffic on both the Upper Mississippi River and Illinois Waterway reaches. These reaches collectively originate more than half of the waterborne agricultural product shipments. The Ohio River System, which originates more than half of the waterborne coal shipments, is forecast to have constraints at seven locks by the year 2003. Nine reaches have capacity limitations. Eight of these have coal as the dominant commodity (defined as 20 percent of reach traffic) and four have agricultural products.

EFFICIENCY ANALYSIS

The impact of lock congestion and limited channel dimensions on linehaul costs was evaluated for all reaches.

Locks and Inland Channels

Factors influencing linehaul costs are channel dimensions and configuration, existance of locks, commodity types and volume. Channel dimensions and the configuration, for example, influence linehaul costs by limiting the size, draft, and speed of vessel and/or tows operating on a reach. Table V–4 displays the depths available, maximum tow size and the average speed for the inland waterways in 1977. The methodology used to estimate linehaul costs is discussed in the technical report *Evaluation of the Present Navigation System*. Several problem areas are readily apparent in high volume and high growth reaches. The Gulf Coast-West moves predominately hazardous cargos within a narrow 125-foot channel. Configuration problems (bends) restrain tow sizes on the high traffic growth Mobile River and Tributaries reach.

Table V–2

EVALUATION OF INLAND WATERWAYS AND GREAT LAKES REACHES FOR EFFICIENCY AND CAPACITY

Reach	System Traffic Characteristics			
		Millions of Tons		
	Dominant Commodity Groups in 2003[1]	Base Year Traffic 1977	Maximum Forecast Year 2003[2]	Defense Increment Year 1990[3]
Upper Miss[11]	Ag Prod Coal	31	69	0
Lower Upper Miss	Ag Prod Coal	78	171	1
L Miss Cairo to B R	Ag Prod Coal	124	248	4
L Miss B R to Gulf	Ag Prod Pet	344	591	–6
Illinois Waterway[10]	Ag Prod Coals Metals & Ores	60	108	19
Missouri River	Ag Prod Other	7	8	0
Ohio River System	Coal	173	383	29
Tennessee River	Coal	27	86	3
Arkansas River	Coal	9	26	1
Gulf Coast-West	Pet.	341	404	25
Gulf Coast-East	Other Coal Pet	109	178	6
Mobile River and Tribs	Coal Metals & Ores	44	178	–1
Great Lakes System	Metals & Ores. Coal Other	190	411	120
Columbia-Snake Waterway	For Prod Ag Prod.	44	64	–1
National Total	Pet Coal	1915[14]	2890[14]	203

1 A dominant group makes up at least 20 percent of total domestic and foreign commodity movement by 2003 in that reach
2 Forecast shown is based on greatest total flow for that reach—domestic plus foreign
3 Defense increment is the net change in traffic flow under the Defense Scenario over peacetime conditions
4 A constraining lock restricts traffic beyond its physical capacity—100 percent utilization is assumed A primary constraining lock restricts traffic growth on a closely interrelated system
5 Earliest Year denotes the first year under any one of six peacetime forecasts in which a lock constrains
6 A secondary constraining lock restricts traffic at other system locks after additional capacity is provided for at the primary constraining locks
7 Congestion at a lock is assumed to begin at 80 percent average annual utilization—some locks are congested earlier some later depending on annual traffic distribution and type of traffic
8 Six peacetime forecasts were used to evaluate constraints and congestion This number means the lock was congested or constraining by year 2003 under that number of forecast conditions The single asterisk reflects congestion in 1990 with a hypothetical defense emergency Double asterisks reflect a constraint condition due to the defense emergency in 1990 The number of constraints would increase if the emergency occurred later than 1990

		Lock Evaluation			System Evaluation		
						Linehaul Costs[9]	
Primary Constraint[4] (Earliest Year)[5]	Secondary Constraint[6] (Earliest Year)[5]	Congested Locks by 2003[7]	No of Forecasts Lock is Congested or Constraining by 2003[8]	Age of Most Recent Lock at Site by 2003	Maximum Traffic Not Served by 2003 (Millions of Tons)	Base Year 1977	Increase by year 2003
					14	7.5	3 7
	Lock 22		6	65			
	(2003)	Lock 18	1	66			
		Lock 20	1	67			
		Lock 21	5	65			
		Lock 24	5	63			
		Lock 25	5	64			
					31	8 1	3 6
Lock 26-new			6*	15			
(1990)		Lock 27	5	50			
					30	5 0	1 8
					29	5 7	2.4
					18 5[10]	7 2	2 2
	LaGrange (2000)[11]		6*	64			
	Peoria (2000)[11]		6*	64			
	Marseilles (2000)		6**	70			
		Starved Rock	6*	70			
		Dresden Island	3	70			
		Brandon Road	6*	70			
		Lockport	6*	70			
					0	16 2	6 7
					65 2[12]	8.7	1 6
Gallipolis (1995)			6**	66			
Uniontown (2000)			6	28			
	Newburgh (2003)		6	28			
	McAlpine (2000)		6*	42			
	Lock 52 (2000)[11]		6	34			
	Lock 53 (2000)[11]		6	23			
	Montgomery (2003)		5*	67			
		Dashields	1	74			
		Emsworth	6*	82			
					18	9 7	.5
	Kentucky (2000)		6	59			
					1	14 4	3 1
					7	11 4	5 2
		Harvey	6*	69			
		Algiers	6*	47			
					10	10 8	3 8
Inner Harbor (1985)			6*	80			
					16	10 8	3 0
Oliver (1990)			6*	64			
	Warrior (2000)		6	46			
	Demopolis (2000)		6	49			
	Coffeeville (2000)		3	43			
	Holt (2000)		6	37			
		Bankhead	1	28			
					17	26 0	4 0
Welland (1985) (Canadian)			6*	70	67 Domestic[12] 4 Foreign[12]		
		Sault Ste Marie	6**	34			
					6	8	3 7
Bonneville (1990)			1[13]	65			
14–6 U S 8 Canadian	14 U S	16 U S	44–36 U S 8 Canadian (Total Locks)		106 69[12]	8 3 (Inland)	2 6 (Inland)

9 Linehaul costs include real fuel cost escalation from 1977–2003 as well as costs associated with added delays Costs are shown in mills—1 mill = $ 001 Increase shown reflects highest level increase across all forecasts
10 The Illinois and Upper Miss are constrained by the Upper Lower Mississippi primary constraint—Lock 26
11 Congested and/or constraining during low water conditions The existing temporary lock structures evaluated by NWS are designed to satisfy lockage capacity needs on an interim basis, pending a permanent solution
12 Traffic not served under the defense emergency hypothesized and evaluated under 1990 conditions If this emergency occurred at year 2003, the traffic not handled could approach the peacetime level not handled in 2003 plus the net defense traffic per reach shown in Column 4
13 Application of NWS growth rates to actual 1981 traffic shows Bonneville as congested under all six forecasts
14 National totals are not the sum of reaches Reaches are not additive because many individual shipments pass through more than one reach

Table V-3
MAXIMUM POTENTIAL COMMODITY TRAFFIC NOT HANDLED BY YEAR 2003[1]

Commodity Group	Traffic Not Handled (Millions of Tons)
Coal	49.3
Agricultural Products	25.0
Metals and Ores	11.3
Chemicals/Fertilizer	8.8
Other	6.9
Petroleum	6.5
Forest Products	0.7

1 This table reflects the greatest possible traffic diversion caused by physical constraints under the six peacetime forecasts

Lock performance is measured by the level of lock utilization. A total of 44 locks (36 U.S. locks and 8 Canadian locks) are projected to exceed 80 percent capacity by 2003 under one or more peacetime forecasts and become significantly congested. Five sites exceed the 80 percent capacity level under only one forecast level.

Congestion induced delays coupled with fuel cost increases (four percent real increase annually) lead to an estimated increase in linehaul costs by as much as 37 percent between 1977 and 2003 if no actions other than minor structural and nonstructural measures are taken. Four commodity groups experience greater than average cost increases between 1977 and 2003 reflecting high levels of delay incurred. Agriculture and coal commodities are forecast to incur cost increases of 58 and 56 percent, respectively, while the chemicals/fertilizers and metals and ores groups are forecast to peak at 45 and 43 percent, respectively. These higher than average increases reflect, in part, the lock and channel induced costs of waterways serving these commodities. For example, the agriculturally dominant Upper Mississippi and Lower Upper Mississippi reaches are both forecast to have above average linehaul cost increases.

In 2003 total domestic linehaul costs are forecast to be, depending on the traffic forecast levels, between $1.4 billion and $1.7 billion higher than in 1977. The inland waterway system linehaul cost increases are forecast to range from $900 million to $1.2 billion, whereas the Great Lakes average about $500 million by 2003 over 1977 levels. The inland waterway's cost increase incorporated the assumption of a $0.10 per gallon gas tax in 1985. Both inland and Great Lakes total costs reflect real fuel cost increases as well as cost changes associated with vessel technology, tow configurations, backhauls, and delays at locks.

Coastal Channels

Channel configuration and dimensions can determine the vessels calling at a port and, in international trade, the ability of a vessel to call can influence the U.S. competitive position. Vessel draft and length generally are controlled by the size of the federally maintained channels. If the world fleet requires modified channel dimensions to gain access to U.S. ports, and other competing nations offer ports with sufficient dimensions, U.S. trade share could be reduced. The following paragraphs present an analysis of variables involved in determining deep draft needs: the commodities most susceptible to carriage in large deep draft carriers, the depth of U.S. ports, and the world fleet characteristics.

Commodities and U.S. Deep Ports

Internationally, petroleum and coal dominate the existing and prospective deep draft movements (55 feet and over). The U.S. Gulf Coast, as late as 1981, had one facility to handle petroleum at depths over 55 feet—the LOOP project (a petroleum transfer facility) off of the Louisiana coast. The West Coast ports of Cherry Point (private facility) in Washington and Long Beach, California, are both capable of serving deep draft movements. No East or Gulf Coast port presently offers deep draft service capability. Table III–5 of this report gives the major ports, their depths and the principal commodity groups handled in 1980. Three ports historically dominated the overseas coal exports: Norfolk and Newport News, Virginia and Baltimore, Maryland. The ports along the Lower Mississippi: Baton Rouge to Gulf reach and the port of Mobile, Alabama experienced spectacular surges in their respective coal exports between 1977 and 1981. The Mississippi exports increased from 1.3 million tons in 1977 to 14 million tons by 1981, whereas Mobile exports more than doubled from 3.6 to 7.6 million tons during the same period. Traffic forecasts present the likelihood of significant increases in coal exports and therefore continuing pressure for deeper channels at major U.S. ports.

Commodities and World Vessels

Projections were made in 1977 that show one-third of the world's export coal would move in vessels over 100,000 deadweight tons by 1985, with an additional one-third moving in vessels of between 50,000 and 100,000 deadweight tons. Forecasts discussed in Section IV show that the prospective U.S. share of coal moving in foreign trade could increase from 18 to over 38 percent by the year 2000. A factor influencing this growth will be the ability of the United States to service the efficient deep draft coal carriers. Since the major land side limitations experienced in 1980 and 1981 will be largely removed by 1985, and the transportation efficiency from mine to port terminal is expected to improve, the remaining factor requiring remedy is the depth of channels at ports.

Coastal Reach Traffic Analysis

Collectively four reaches—Lower Mississippi: Baton Rouge to Gulf, Gulf Coast-West, Middle Atlantic Coast, and Great Lakes—are forecast to move three-quarters of all U.S. exports and two-thirds of the imports by year 2003. Table V–5 displays tonnage for 1977 and the maximum 2003 forecast for all coastal reaches and the reach shares of 2003 traffic for all foreign commerce, coal exports, crude petroleum imports, and farm product exports.

Regarding overseas coal exports—the most rapidly growing commodity in waterborne commerce—only six reaches display significant shares by 2003. The Middle Atlantic Coast reach is forecast to move about half of the overseas coal by 2003—47 percent under the High Coal Export forecast and 64 percent under the Miscellaneous forecast The Lower Mississippi: Baton Rouge to Gulf and Mobile River and Tributaries reaches rank as the next highest in shares of coal exports by 2003—17 and 18 percent, respectively, under the High Coal Export forecast. The Gulf Coast-West, the Washington/Oregon Coast and the California Coast are each forecast to handle less than 10 percent of the overseas coal exports. Based on volume alone, the probability of reaping efficiencies for export coal transport in deep draft vessels appears to be greatest for the Middle Atlantic Coast, followed by the other two leading coal export reaches.

Petroleum imports are forecast to decline markedly by the year 2003, however they still will dominate U.S. foreign trade. Three of the leading total foreign trade reaches—Lower Mississippi: Baton Rouge to Gulf, Gulf Coast-West, and Middle Atlantic Coast—are also the leading importers of crude petroleum. The coal export concentration overlaying the petroleum imports heighten the significance of both the Lower Mississippi and Middle Atlantic Coast.

Grain exports, because of the ultimate foreign destinations and their port depths, are not as likely to be moved by deep draft vessels projected for the dry bulk trade. Some grain shipments to such ports as Rotterdam, however, would benefit immediately by using deeper draft vessels.

Table V–4

INLAND SHALLOW DRAFT WATERWAYS: OPERATING CHARACTERISTICS IN 1977

Reach/Segment	Maximum Controlling Depth (Feet)	Common Maximum Tow Size[1]	Average Speed[2] (MPH)
Upper Miss.	9	15	4
Lower Upper Miss.	9	25	4
L. Miss Cairo to B.R.	9–12	45	6
L. Miss. B.R. to Gulf			
Miss. from B.R Downstream	40	45	6
Ouachita-Black and Red Rivers	6–9	2	4
Old and Atchafalaya Rivers	12	4	4
Baton Rouge-Morgan City Bypass	11	5	4 5
Illinois Waterway	9	15	4
Missouri River	8.5–9	9	4.4
Ohio River System			
Ohio	9	15	4.5
Monongahela	9	6	4
Allegheny	9	4	4
Kanawha	9	9	3
Kentucky	6	1	4
Green	9	4	4
Cumberland	9	8	4
Tennessee River	9	15	4.3
Arkansas River	9	9	4
Gulf Coast-West	9–12	5	4 5
Gulf Coast-East	3–12	5	4
Mobile River and Trib.	9	6	4
South Atlantic and Middle Atlantic Coasts			
Atlantic Intracoastal Waterway	4–12	2	4
Great Lakes System			
New York State Barge Canal	14	1	3
Columbia-Snake Waterway	12	5	4

1 Expressed in jumbo (35′ × 195′) barge equivalents
2 This is an average of up and downstream movements, after delays are taken into account

Table V–5
CHARACTERISTICS OF COASTAL REACHES

Reach	System Traffic Characteristics			Share of Foreign Trade by Coastal Reach, 2003 Traffic (Percent)[4]					
		Millions of Tons Total Traffic[2]		All Commodities		Overseas Coal Exports[5]		Crude Petroleum	Farm Product
	Dominant Commodity Groups[1]	1977 Base Year	2003 Maximum[3]	Exports	Imports	Misc	HCX	Imports	Exports
L Miss. B R to Gulf	Agric, Petrol	344	591	24	16	14	17	23	38
Gulf Coast-West	Petrol	341	404	13	21	7	8	34	20
Gulf Coast-East	Petrol; Coal; Other	109	178	5	3	—	—	2	2
Mobile River and Trib.	Coal, Metals & Ores	44	178	4	3	16	18	—	2
South Atlantic Coast	Petrol, Other	70	71	3	3	—	—	—	1
Middle Atlantic Coast	Coal, Petrol	437	515	21	22	64	47	18	12
North Atlantic Coast	Petrol	87	69	—	4	—	—	5	—
Washington/Oregon Coast	Petrol, Forest Prod.	68	133	4	6	—	5	6	4
Columbia-Snake Waterway	Agric, Forest Prod	44	59	3	1	—	—	—	5
California Coast	Petrol; Other	138	153	5	6	—	4	2	5
Alaska	Petrol	29	95	—	—	—	—	—	—
Hawaii	Agric; Other	15	22	—	1	—	—	—	—
Caribbean	Petrol.	90	75	—	6	—	—	10	—
Great Lakes	Metals & Ores, Other	190	411	16	7	—	—	—	11
Total U S.	Petrol, Coal	1915	2890	100	100	100	100	100	100

1. Commodity groups which comprise 20 percent or more of reach commerce in year 2003—Domestic and Foreign Traffic.
2 Domestic and Foreign Traffic
3. Highest level of six peacetime forecasts, High Coal Export (HCX)
4 This is based on the reach share of exports or imports for the Miscellaneous forecast unless otherwise specified.
5. Great Lakes exports are predominately to Canada and are excluded from total. HCX is the High Coal Export forecast of 233 million tons of overseas traffic by 2003. This compares to Miscellaneous level forecast of 100 million tons.

The leading grain export reaches—Lower Mississippi: Baton Rouge to Gulf, Middle Atlantic Coast and Gulf Coast-West—are coincidental with those leading in petroleum imports. The Lower Mississippi and Middle Atlantic are also forecast to be leaders in coal exports. Indications are that the potential for attracting deep draft vessels is greatest in the port reaches handling a mix of export coal, petroleum imports and grain.

RELIABILITY ANALYSIS

The reliability of the physical structures on the waterways or channel dimensions depends on maintenance, structural rehabilitation, and availability of an adequate flow of water unimpaired by ice. Structural reliability is assessed first, followed by flow maintenance and ice management.

Structural Reliability

The structural reliability of the U.S. navigation system is a major control of the capability of that system. Many structures in the present system are at, or are approaching, their design lives. In addition many were designed to reflect the requirements of an earlier technological age. The thousands of navigation structures—dams, jetties, wiers, dikes and locks—can impair system reliability. For NWS purposes, however, only locks were analyzed since they are the principal bottlenecks to the flow of traffic, and involve a relatively small number.

Two hundred and nine lock sites on commercially active waterways were reviewed. Of these, 196 are U.S. owned and operated and 13 are Canadian. Table V–6 describes potentially obsolete locks as they relate to all locks in a reach and the total number of aged locks. The Upper Mississippi, Illinois Waterway, Ohio River and Great Lakes System reaches had 50 (42 U.S.) out of the 56 (48 U.S.) lock sites which are forecast to be heavily used and will have exceeded their design lives by 2003. Thirty (22 U.S. sites) of these would also become congested under one or more forecasts.

Peculiarities of engineering, environmental and use conditions can prematurely contribute to structural obsolescence. While age and use were key factors used in the NWS analysis of locks, periodic engineering reviews of all structures will likely identify additional structures and delete others from replacement consideration. Major rehabilitation at Lock 1 on the Upper Mississippi River was completed during 1981. Although Table V–6 provides a good estimate of the number of replacement lock candidates based on the age and use criteria alone, the degree of structural integrity found through detailed engineering studies should ultimately determine the appropriate replacement or rehabilitation actions.

Channel Reliability

Measures of reliability for maintenance of channel dimensions are much less precise than for a structure. Measures of channel reliability are actual records of depths and the incidence of groundings. Over the longer term, a predictable flow and its adequacy for navigation takes on increased importance in assessing channel reliability. Flow availability assessment is published in both the *Analysis of Navigation Relationships to Other Water Uses* and *Engineering Analysis of Waterways Systems*. These suggest where and when potential problems might occur, but do not attempt to predict localized sites or severity.

Table V-6
SUMMARY OF AGING LOCKS REQUIRING FURTHER STUDY

Reach/Lock Name	Number Of Lock Sites in Reach	Number of Reach Lock Sites Over 50 years by 2003	Number of Old Locks High Use[1]	Year Latest Lock Built[2]	Lock Dimensions in Feet (Width x Length)	Number of Forecasts Showing Lock is Congested
Upper Miss.	27	24	24			
Lock 1			(1)	1932	56 x 400[3]	0
Locks 2-17			(17)	1930-48	110 x 600	0
Locks 18, 20-25			(6)	1936-40	110 x 600	1-6
Lower Upper Miss	3	0	0	—	—	—
L. Miss. B.R. to Gulf	8	1	0	—	—	—
Illinois Waterway	8	7	7			
Lockport, Brandon Road			(2)	1933	110 x 600	6
Dresden Island			(1)	1933	110 x 600	3
Marseilles			(1)	1933	110 x 600	6
Starved Rock			(1)	1933	110 x 600	6
Peoria, LaGrange			(2)	1939	110 x 600	6
Ohio River System	61	36	11[4]			
Dashields			(1)	1929	110 x 600	1
Emsworth, Montgomery			(2)	1921, 1936	110 x 600	6
Gallipolis			(1)	1937	110 x 600	6
Lock 2 on Monongahela			(1)	1953	110 x 720	0
Locks 3&4 on Monongahela			(2)	1907, 1932	56 x 720[3]	0
Locks 7&8 on Monongahela			(2)	1926	56 x 360[3]	0
Winfield & Marmet on Kanawha			(2)	1934, 1937	56 x 360[3]	0
Tennessee River	10	4	1			
Kentucky			(1)	1944	110 x 600	6
Arkansas River	17	0	0	—	—	—
Gulf Coast-West	10	5	2			
Harvey			(1)	1935	75 x 415[3]	6
Calcasieu			(1)	1950	75 x 1194	0
Gulf Coast-East	9	4	1			
Inner Harbor			(1)	1923	74 x 626[3]	6
Mobile River and Trib	19	1	1			
Oliver			(1)	1939	95 x 460[3]	6
South Atlantic Coast	6	5	0	—	—	—
Middle Atlantic Coast	2	2	0	—	—	—
Great Lakes System	17	9	8			
Welland (Canadian)			(8)	1932	80 x 766	6
Washington-Oregon Coast	1	1	0	—	—	—
Columbia-Snake Waterway	13	6	1			
Bonneville			(1)	1937	76 x 556[3]	1
Total Lock Sites	209	105	56	1921-50	—	—
U S.	196	97	(48)	—	—	—
Canadian	13	8	(8)	—	—	—

1. Only lock sites with over 30 percent commercial use by year 2003 are considered
2 The year built is for the most recent lock at a site.
3 Lock dimensions of the most recent lock are incompatible with other segment locks and/or with the modern vessel fleet and its operation
4. The recent temporary structures at Locks 52 and 53 replacing obsolete structures were designed for an interim basis, pending a permanent solution. These two sites, however, are not included in the 11 highly used older locks category.

Dredging

In recent years dredging has been reduced because of environmental issues and funding limitations. This has increased the probability of vessel groundings. The principal concerns regarding reliability of channel dimensions are safety and efficiency.

The magnitude of deferred dredging (scheduled but not performed) is one indicator of the additional dredging which may be required for full reliability. During the period 1973–1977, approximately 30 million cubic yards were deferred. Nearly 90 percent was in coastal reaches. This constituted 10 percent of the nearly 300 million cubic yards actually dredged. The NWS technical report *Evaluation of Alternative Future Strategies for Action* gives quantities deferred by waterway segment. Currently, some of the projects, which are maintained at less than authorized dimensions, are being evaluated to determine if current and projected traffic merit continuation as a Federal navigation project. The projects under study however, would account for 2 of the 30 million cubic yards of deferred annual dredging.

During the 1970s decade the rapid real cost increases in dredging were closely related to increases in fuel costs and to environmental restrictions on dredging and disposal operations. Based on this experience, NWS technical research concluded that future real dredging costs may increase by about 2.2 percent per year. Two major fundamental changes have occurred in the Federal dredging program in the last few years which are likely to restrain cost increases:

1. The Industry Capability Program now puts dredging projects out for competitive bid to private contractors. Correspondingly, the Federal dredge fleet is being reduced to the minimum level of technologically up-to-date vessels required for defense and emergencies. The test period has shown that private firms have the ability to meet dredging needs at reasonable prices.
2. The Dredge Material Research Program completed by the Waterways Experiment Station has reduced many of the environmental uncertainties surrounding dredging operations and placement of dredged materials.

In addition to these two major changes, ongoing research and the application of river training technology continue to minimize levels of maintenance dredging. Similarly, reservoir regulation is effectively used in this regard by adjusting flows to influence bed load movement. These, with the two major changes, may be the principal factors holding down the volume and the unit cost of dredging in the future. Operations and maintenance (O&M) costs shown in the NWS therefore do not reflect real unit cost increases, only the addition of O&M for the projects under construction.

Flow Maintenance

Several waterways or segments are likely to be confronted with increased problems during periods of low flows. These reaches include:

Missouri River and Lower Upper Mississippi River—The Missouri River was developed for multiple purposes by means of several large upstream storage reservoirs and a heavily trained channel below the head of navigation at Sioux City, Iowa. Releases for generating electrical power and other purposes generally provide sufficient navigation flows. However, upstream projects were designed to provide irrigation water. As irrigation and other consumptive uses expand, less water will be available for navigation on the Missouri River and Lower Upper Mississippi River. This could reduce the length of navigation season on the Missouri and the availability of flows on the Mississippi River below the mouth of the Missouri. The rate at which upstream diversions on the Missouri are likely to increase is uncertain. Navigation use, however, has the lowest legal priority on the Missouri.

Apalachicola-Chattahoochee-Flint System—Because of upstream competing use, this system is not able to guarantee a predictable depth all year. This lack of reliability due to seasonal flows coupled with competing upstream use seriously inhibits navigation. Growth of the basin economy is expected to heighten the competition for future water supplies and thus increase the low flow management problem.

Droughts can cause serious navigation bottlenecks on the entire Mississippi River System. Lack of flows on the White River restrict entry to and exit from the Arkansas River. Similar difficulties are experienced on the Mobile River and Tributaries reach. These conditions require emergency dredging operations. Floods as well as droughts can produce severe problems for navigation. Floods increase velocities and create safety problems for waterway operators. The Corps of Engineers, other Federal, state and local agencies and the waterway industry have developed effective and cooperative relationships which increase the probability that the waterway system will perform well under many adverse conditions.

Ice Management

Winter ice on the U.S. inland and Great Lakes reaches requires that the Great Lakes, Upper Mississippi and Missouri reaches all be closed from three to four months annually. Other reaches with ice problems—Illinois Waterway, Lower Upper Mississippi, Ohio River System and Columbia-Snake Waterway reaches—are managed for year around navigation. Ice and other winter hazards periodically stop or slow down traffic during winter months on these reaches. Therefore effective ice management measures can increase the productivity of the waterway system.

Locks

Ice presents several impediments to lock operations. Brash ice, floating pieces of ice up to six feet in diameter, either drifts or is pushed ahead of vessels into lock chambers and can take up so much of the chamber that vessels cannot enter until the ice is locked through. When vessels do enter the chamber, they force ice against the lock walls where it accumulates and effectively narrows the chamber. Floating ice often drifts into the miter gate recesses of the lock where it prevents the gates from closing fully. Both drifting and stationary ice accumulate in the structural niches of lock gates, builds up, overloads gate sills, or prevents secure gate closing.

Management of these conditions is complex and much is still in the research stage. "Bubbler" systems have been set up at lock approaches to deflect floating ice. This reduces the lock ice but does not eliminate it. Special flushing systems are required where the normal procedure of opening valves does not work. Cutters have been utilized to remove ice, and special preventive coatings act to inhibit the buildup of ice on lock walls. These, among other measures, help to reduce maintenance associated with damage resulting from ice.

Channels

On the Ohio River System, ice and channel conditions are relayed to tows through information systems. Similarly, ice and other weather related information in general is transmitted from carrier to carrier, Coast Guard to carrier, and Corps of Engineers to carrier. Normally the carrier on the inland waterways maneuvers his boat to keep open the channels and disrupt ice formation. Also "mule training"—single file operations of vessels—is occasionally practiced during heavy ice conditions. On the Great Lakes, unlike the inland waterways, the U.S. Coast Guard maintains an icebreaking fleet. This fleet is augmented by cooperation among carriers.

Two technical research volumes, *Engineering Analysis of Waterways Systems* and *Waterways Science and Technology*, discuss ice management techniques. Ice, as discussed, seasonally closes three reaches and reduces reliable, efficient, safe operation on three others.

SAFETY ANALYSIS

The safety analysis approach, discussed earlier in this section, relied on a combination of factors to identify potential problem areas. These problems were generally categorized as bridges—major and minor, locks, and channels—congestion and configuration. Figure V–3 and Table V–7 display various problem areas grouped into these categories. The locations and descriptions of safety problems are summarized in Appendix E. The identified problem areas will continue to create hazardous navigation conditions until actions are taken to reduce risks. Existing conditions will become worse as traffic grows, as lock delays mount, as tow sizes increase relative to the maximum that can be accommodated, and as the share of hazardous commodities gets larger.

Two major channel safety problem areas identified are the busiest export reach in the U.S., Lower Mississippi: Baton Rouge to Gulf, and the number one coal origination reach, the Ohio River System. The petroleum dominated Gulf Coast-West and the Illinois Waterway, with its mix of coal, agricultural products and metals and ores, have the majority of major bridge problem sites. Almost all of the responsibility for solving the identified hazards rests with the U.S. Coast Guard; lock approach responsiblity however, resides with the Corps of Engineers.

DEFENSE CAPABILITY EVALUATION

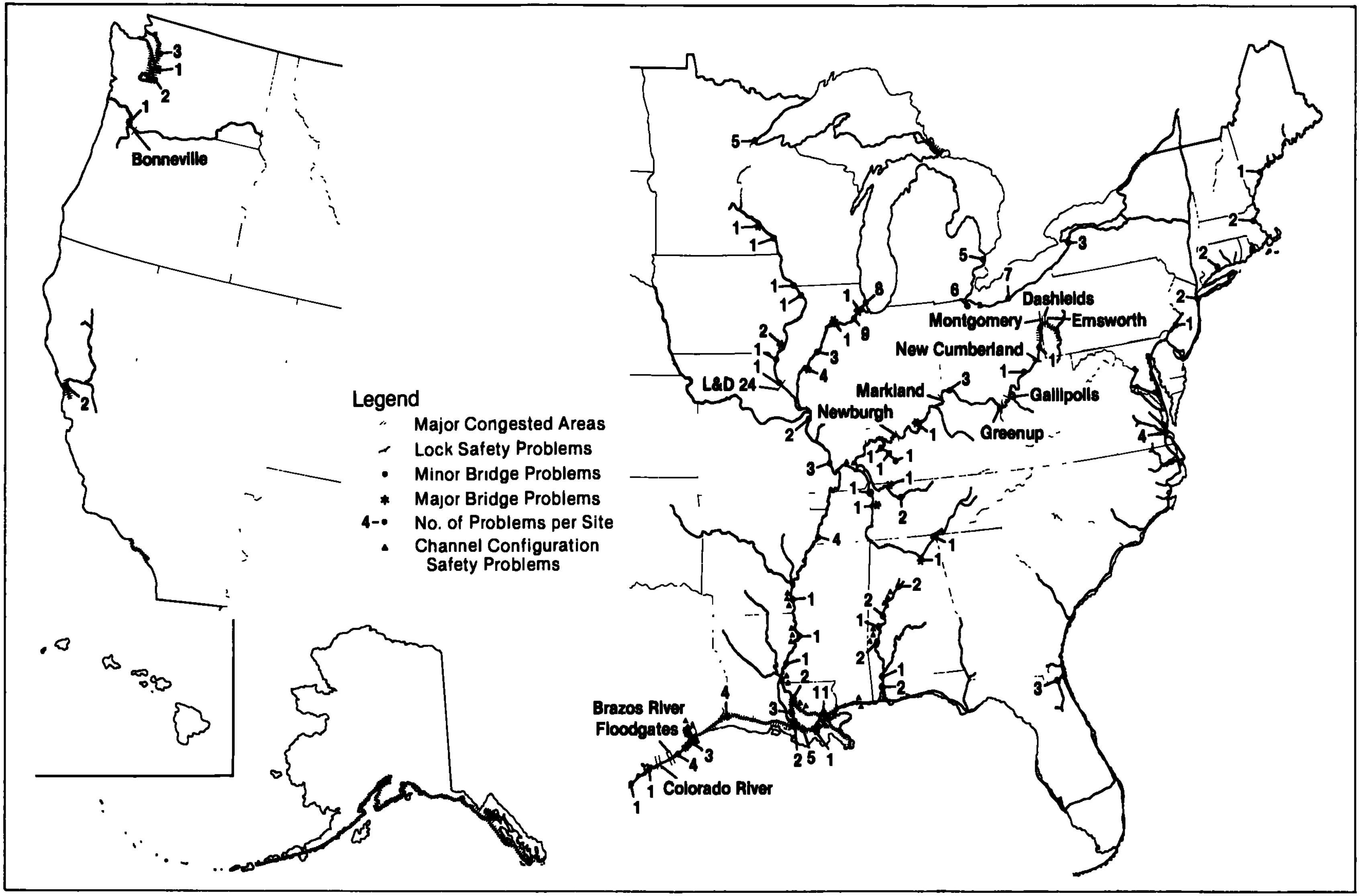
An hypothesized national defense mobilization for a major overseas war on two fronts was utilized to test the ability of the waterways to satisfy national defense requirements. Defense planning is basically a projection of a large number of potential eventualities. A defense scenario which appeared to place the greatest stress on the waterway system

Table V–7
SAFETY PROBLEM SUMMARY
(Number of Areas)

Reach	Channel Configuration	Major Congested Channel Areas	Bridges: Minor	Bridges: Major	Locks	Total Safety Problems
Upper Miss	—	—	5	3	1	9
Lower Upper Miss.	—	—	5	—	—	5
L. Miss: Cairo to B.R.	2	—	7	—	—	9
L. Miss. B.R. to Gulf	3	3	5	—	—	11
Illinois Waterway	—	1	12	6[1]	—	19
Missouri River	—	—	—	—	—	—
Ohio River System	1	6	10	2	8	27
Tennessee River	—	2	2	2	—	6
Arkansas River	—	—	—	—	—	—
Gulf Coast-West	1	2	23	3	2	31
Gulf Coast-East	2	2	5	—	—	9
Mobile River and Trib.	3	—	10	—	—	13
South Atlantic Coast	—	2	3	—	—	5
Middle Atlantic Coast	—	2	7	—	—	9
North Atlantic Coast	—	—	5	—	—	5
Great Lakes System	1	2	34	—	—	37
Washington/Oregon Coast	—	1	5	1	—	7
Columbia-Snake Waterway	—	1	1	—	1	3
California Coast	—	2	2	—	—	4
Alaska	—	1	—	—	—	1
Hawaii	—	—	—	—	—	—
Caribbean	—	—	—	—	—	—
Total	13	27	141	17	12	210

1. Includes Butterfly Dam at Lockport, IL.

Figure V-3
SAFETY HAZARDS



was selected from the range of potential scenarios. The results suggest the importance of the waterway system to defense mobilization requirements and point to the need to take these requirements into consideration in deciding lock and channel actions and their timing.

Section IV of this report discusses the impact of the defense mobilization on traffic forecasts. The five-year mobilization was assumed to peak in 1990. This kind of mobilization requirement could occur at any time. If it occurred later than the 1990 period evaluated, a much greater number of capacity, congestion, reliability and safety problems would be identified. Table V–2 displays the 2003 peacetime traffic problems—many of the congested locks on the defense sensitive reaches would probably constrain flows if the emergency occurred after 1990. Table V–8 summarizes the increment of change in traffic by reach and by major commodity groups. The major strategic commodities affected by defense mobilization are petroleum, metals and ores, and chemicals. The scenario assumes that foreign sources of strategic commodities are less available. Therefore shifts to western hemisphere sources are required. The results show major impacts, in terms of problem development, on:

1. Great Lakes System
2. Ohio River System
3. Illinois Waterway
4. Gulf Coast-West

The Sault Ste. Marie Lock site on the Great Lakes System would be most severely affected by the mobilization. These locks would be unable to move an estimated 70 million tons of traffic, mostly iron ore. The Sault Ste. Marie Locks will be able to physically accommodate projected peacetime traffic through 2003.

Petroleum will experience the greatest increases under the Defense scenario and affect several coastal areas—West, Middle Atlantic, and Gulf coasts—most dramatically. The potential bottlenecks exacerbated by this surge in traffic will be Harvey, Algiers and Inner Harbor Locks on the Gulf Intracoastal Waterway. All three locks are forecast to experience congestion under all peacetime forecast levels. These locks will each have exceeded the design life of 50 years by 2003, thereby posing a potential reliability problem as well.

Table V–8

TRAFFIC SYSTEM PERFORMANCE UNDER DEFENSE EMERGENCY CONDITIONS

	Millions of Tons					
		Net Change In Traffic Flows[1]				
Reach or Commodity	High Use Traffic in 1990	Domestic	Foreign	Total	Defense Traffic Not Handled[2] 1990	Number of Locks Adversely Affected[2]
Upper Miss.	49.7	0	0	0	0	0
Lower Upper Miss.	115 1	1	0	1	0	1
L. Miss: Cairo to B.R.	160 2	4	0	4	1	0
L. Miss: B.R. to Gulf	427.8	21	–27	–6	1	0
Illinois Waterway	79.6	21	–2	19	5	6
Missouri River	7 4	0	0	0	0	0
Ohio River System	248.5	29	0	29	2	4
Tennessee River	44.3	3	0	3	0	0
Arkansas River	11.5	1	0	1	0	0
Gulf Coast-West	355.1	50	–24	26	0	2
Gulf Coast-East	139.7	8	–1	7	0	1
Mobile River & Trib.	86.9	7	–8	–1	0	1
South Atlantic Coast	68.0	13	–4	9	0	0
Middle Atlantic Coast	431.2	63	–31	32	0	0
North Atlantic Coast	78.3	16	–7	9	0	0
Great Lakes System	307.0	137	–18	119	72	9
Washington/Oregon Coast	116.0	19	–6	13	0	0
Columbia-Snake Waterway	52 9	1	–2	–1	0	0
California Coast	138.1	40	–4	36	0	0
Alaska	94.3	52	0	52	0	0
Hawaii	17.7	1	–1	1	0	0
Caribbean	84.1	12	–9	3	0	0
Total	2296.7[3]	346	–143	203	69	24
Agriculture Products	318 3	14.6	–39.0	–24.4	3	
Chemicals/Fertilizer	107 7	20.4	1.5	21.9	0	
Metals and Ores	224.0	143.7	–30.7	113.0	59	
Coal	413 8	11.6	–16 0	–4.4	6	
Petroleum	845.3	206.4	–53 0	153.4	0	
Forest Products	68 7	–2 7	–1 1	–3.8	0	
Other	318.7	–5 7	–4.4	–10.1	1	

1 Defense less peacetime High Use forecast rounded to nearest whole number
2 Table V–2 identifies each lock
3 Total does not sum from the reaches because many individual shipments pass through more than one reach

After the Gulf Intracoastal, the inland waterways which will experience the greatest impact from the 1990 defense mobilization are the Ohio River System, which grows by 29 million tons, and the Illinois Waterway, which increases by 19 million tons. Gallipolis Lock on the Ohio cannot pass all projected traffic during 1990 and three other locks become highly congested. Also, Marseilles Lock on the Illinois Waterway cannot pass all projected traffic, and six other Illinois Waterway locks, assuming low water conditions, become highly congested. Both the Illinois Waterway and the Ohio River Systems are linked to the steel production centers of the United States—Chicago and Pittsburgh, respectively.

Equally important in an analysis of capability under a defense mobilization is identification of those waterways which do not show net increases in traffic levels. The Mississippi River falls into this category. Under this scenario the greatest net loss in traffic is foreign trade of agricultural products (39 million ton loss). The waterways serving this commodity group, principally the entire Mississippi River, are most affected. However, the offsetting flows of petroleum, chemicals and metals and ores generally negate the loss of grain. Consequently, between Minneapolis, Minnesota, and Baton Rouge, Louisiana, little net change in total traffic is reported despite the change in commodity mix under peace and wartime scenarios.

The waterways most affected by the hypothetical mobilization are those with traffic flows heavily weighted by forecast tonnage in metals and ores, petroleum and chemicals. The Ohio River System, followed by the Great Lakes System and the Illinois Waterway, are the three inland reaches leading in shipments of primary metal products. The Great Lakes System overwhelmingly dominates domestic ore shipments with nearly 90 percent of this traffic. These three systems along with the Gulf Coast-West, which originates 25 percent of the domestic petroleum product movements, would experience capability problems in serving the nation's defense needs during this hypothetical conflict.

SUMMARY OF CAPABILITY EVALUATION

The evaluation of the capability of the existing water transportation system assessed problems—safety, reliability, efficiency and capacity—which impair the capability of that system through the year 2003. This capability was assessed across six peacetime forecasts and under a defense mobilization. Water transportation problems for shallow draft and Great Lakes reaches through 2003 are summarized in Table V–9. The analysis of the existing system showed that, assuming a safe and reliably maintained channel, locks generally limit the capability of the shallow draft and Great Lakes reaches. Capability of coastal reaches was linked to the ability to accommodate deep draft vessels moving coal, petroleum and farm products. Table V–5 displayed the characteristics of coastal reaches in terms of these commodities.

NATIONAL ASSESSMENT

The shallow draft and Great Lakes problems and needs displayed in Table V–9 have national as well as regional impacts. The consequences of not acting to remedy problems on a timely basis include:

1. Reliability: The 56 highly used locks which will have been in service in excess of their 50 year engineering design lives by 2003 will, collectively, seriously impair the dependability of waterways after that date. (See Table V–6 and Figure V–4 for lists.) Similarly, 1970 decade dredging practices resulting from environmental issues and funding limitations will contribute to undependable channels if continued.
2. Safety: An estimated 210 sites pose safety problems, risking personal injury and property damage.
3. Efficiency—Inland and Great Lakes: The unit operating cost (carrier linehaul costs) is forecast to increase by a maximum of 37 percent from 1977 to 2003 for all domestic commerce. For the inland system, total carrier linehaul costs would increase between $900 million and $1.2 billion by year 2003. On the Great Lakes these costs would grow by about $500 million for the same period. The major contributors to these increases are lock congestion and the increasing real cost of fuel.
Although 44 locks experiencing in excess of 80 percent utilization are identified in Figure V–4 under maximum forecast conditions, other locks will also experience heavier use, with corresponding increases in delay. Two commodities most affected by these increases are agricultural products and coal.
4. Efficiency—Coastal: The U.S. competitive posture in steam coal export trade is limited because the predominate coal export reaches lack depths capable of servicing the world fleet's deep draft vessels.
5. Capacity: Because physical capacity affects 20 U.S. and 8 Canadian locks under one or more peacetime forecasts, over 100 million tons of traffic—7 percent of the projected domestic waterway traffic—may not be served by year 2003. (See Figure V–4.) Half of this traffic loss in estimated to be coal and one-quarter is agricultural products. Metal and ores diversion makes up over 10 percent of the total unhandled

Table V-9
SUMMARY OF CAPABILITY ASSESSMENT

Reach	Number of Locks in Reach (Table V-6)	Number of Locks with Capability Problems: Reliability — Old and/or Obsolescent by 2003 (Table V-6)	Capacity — Constraining by 2003 (Table V-2)	Efficiency — Significant Congestion by 2003[1] (Table V-2)	Constraining or Congested by 1990 — Defense Mobilization (Table V-2)	Number of Safety Problems (Table V-7)
Upper Miss.	27	24	1	5	0	9
Lower Upper Miss	3	0	1	1	1	5
L Miss· Cairo to B.R	0	—	—	—	—	9
L Miss B.R to Gulf	8	0	0	0	0	11
Illinois Waterway	8	7	3	4	6	19
Missouri River	0	—	—	—	—	—
Ohio River System	61	11	7	2	4	27
Tennessee River	10	1	1	0	0	6
Arkansas River	17	0	0	0	0	—
Gulf Coast-West	10	2	0	2	2	31
Gulf Coast-East	9	1	1	0	1	9
Mobile River and Trib	19	1	5	1	1	13
South Atlantic Coast	6	0	0	0	0	5
Middle Atlantic Coast	2	0	0	0	0	9
North Atlantic Coast	—	—	—	—	—	5
Great Lakes System	17	8	8	1	9	37
Washington/Oregon Coast	1	0	0	0	0	7
Columbia-Snake Waterway	13	1	1	0	0	3
California Coast	—	—	—	—	—	4
Alaska	—	—	—	—	—	1
Hawaii	—	—	—	—	—	—
Caribbean	—	—	—	—	—	—
Total	209	56	28	16	24	210
U S	(196)	(48)	(20)	(16)	(16)	(210)
Canadian	(13)	(8)	(8)	—	(8)	—

1 Constraining locks in column 3 are not repeated in this column.

traffic. It is recognized that, in most cases, severe economic losses begin at lower traffic levels.

6. Defense: Under the assumed defense mobilization scenario, major problems were related to lock congestion and capacity at 16 U.S. lock sites and on the Welland Canal. The most critical lock related problem is forecast to be the Sault Ste. Marie Locks. Nationwide, the system would fail to serve about 70 million tons of traffic. Fifty-nine million tons of this loss are metals and ores, with coal losing six million. The entire Pacific Coast, Gulf Coast-West and the Middle Atlantic Coast would be stressed by very large increases in domestic petroleum movements.

REACH ASSESSMENT

A reach by reach capability analyses of the existing system, reflecting a much more limited geographical dispersion of problems and needs, more accurately points up those problems and needs than does a national analysis. The national level smooths the extremes in the forecasts, the same holds true for the indicators of problems and needs.

1. Reliability: Of the 56 aging locks expected to be highly used under the maximum traffic forecast conditions, 50 are located on four reaches:

Upper Mississippi—24 locks
Ohio River System—11 locks
Illinois Waterway—7 locks
Great Lakes—8 (Welland) locks

The very oldest ones are on the Ohio System's Monongahela River. These are also technologically obsolete and have known structural problems. Adverse ice conditions affecting reliability of locks and channels were identified for all four of the reaches listed above. Since ice accelerates structural deterioration, lock reliability in these reaches may be considered even more serious.

2. Safety: Forty-three of the 69 major channel safety problems (other than minor bridge problems) are clustered in a few reaches:

Ohio River System—17 sites
Gulf Coast-West—8 sites
Illinois Waterway—7 sites
Lower Mississippi: Baton Rouge to the Gulf—6 sites
Upper Mississippi—4 sites

3. Efficiency—Inland and Great Lakes: The reaches displaying the greatest potential number of congested and constraining locks by year 2003 under maximum peacetime traffic forecasts and low water conditions are:

Ohio River System—9 locks total, 7 constrain
Great Lakes—9 locks total, the 8 Canadian locks constrain
Illinois Waterway—7 locks total, 3 constrain

Figure V-4
SUMMARY OF LOCK PROBLEMS BY TIME PERIOD[1]

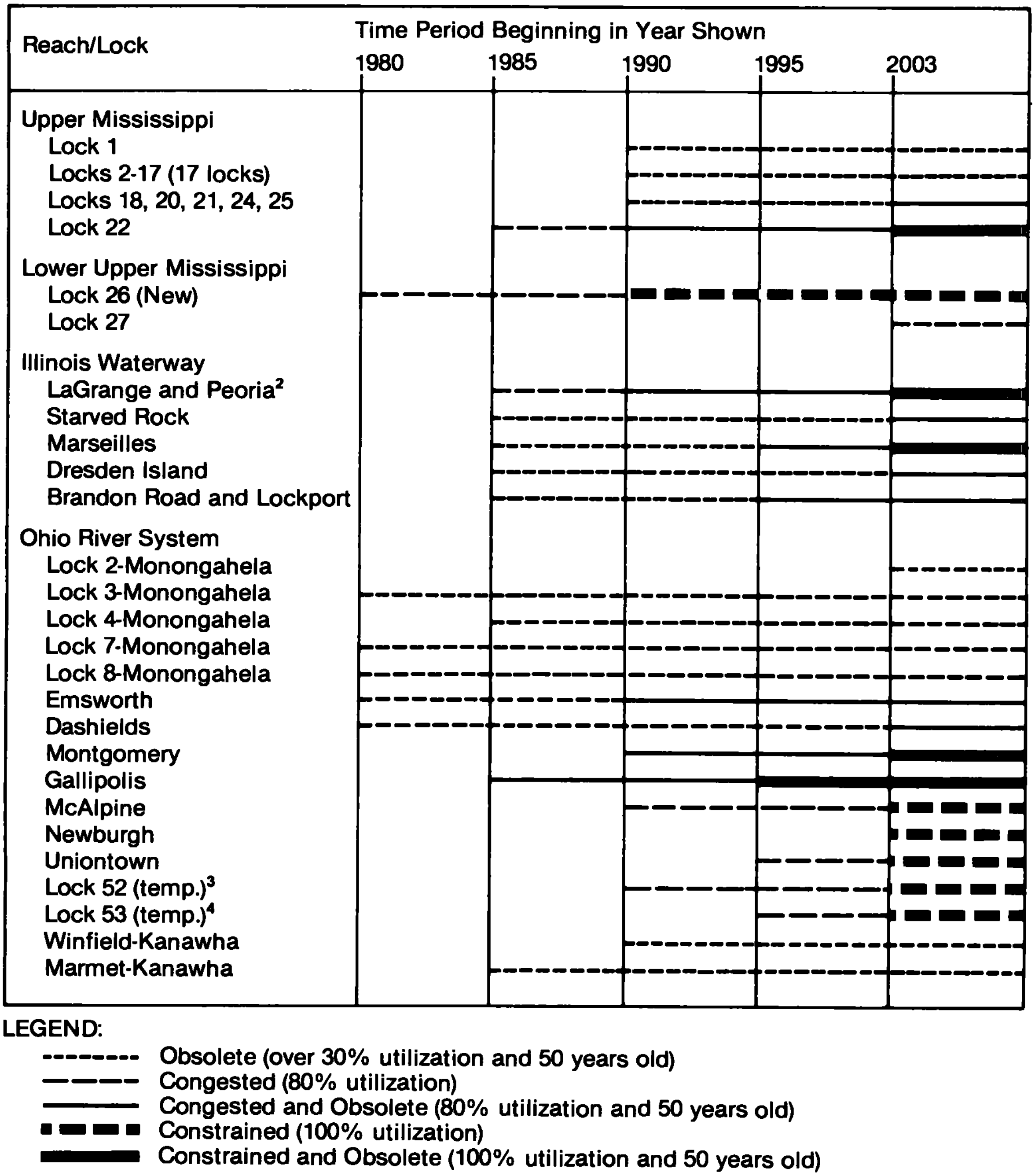
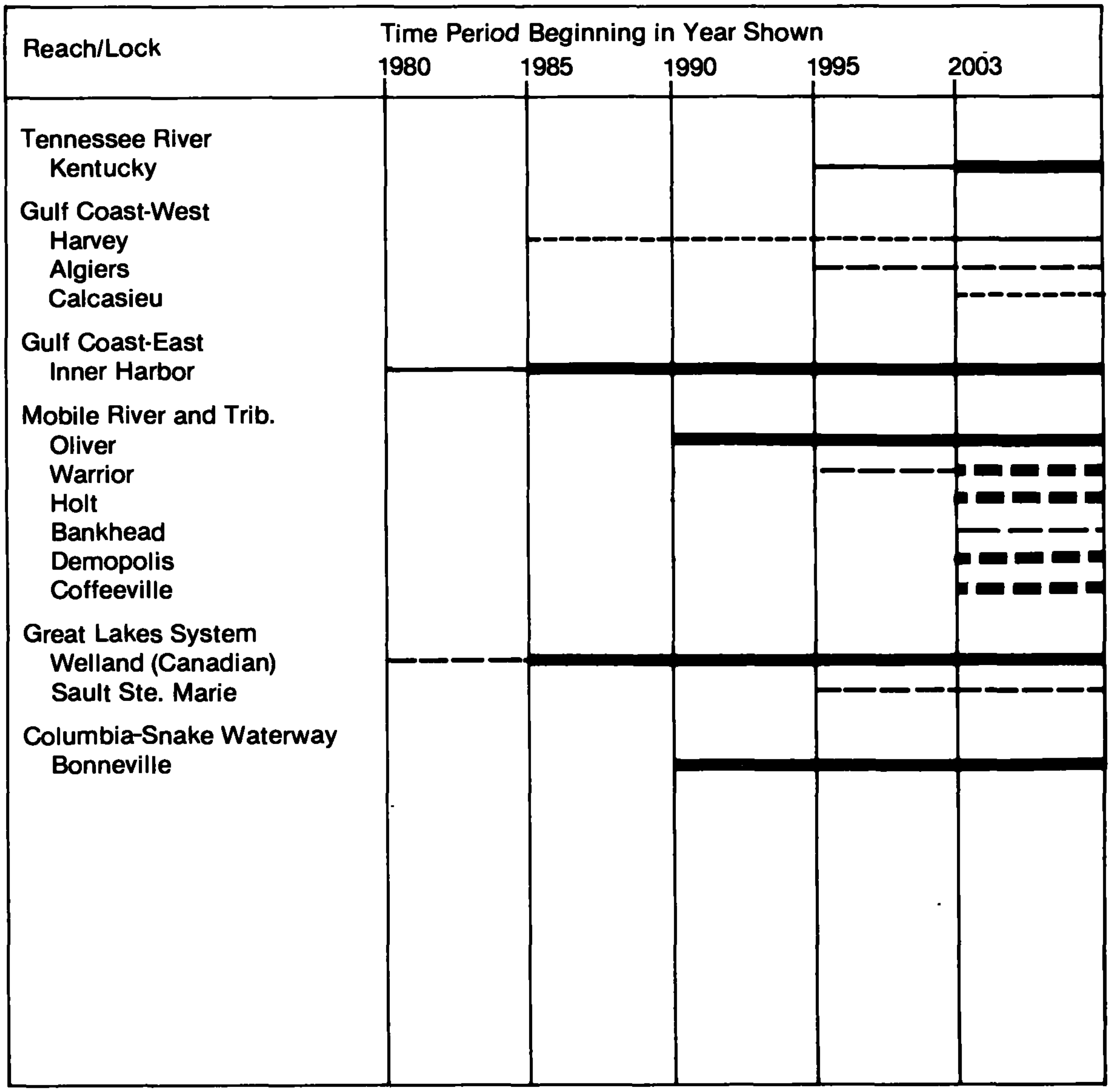


Figure V-4 (Continued)
SUMMARY OF LOCK PROBLEMS BY TIME PERIOD[1]



1. See Tables V-2 and V-6 for details of evaluation. New Pickwick, Vermilion and 26 locks are evaluated, not the existing structures. The time period for congestion or constraint shown is the earliest occurring under peacetime conditions.
2. Assumed locks in use full time. Average is about 60 percent of time.
3 Lock used 40 percent of year. Evaluation based on full use.
4 Lock used less than 10 percent of year. Evaluation based on full use.

Upper Mississippi River—6 locks total, 1 constrains

Mobile River and Tributaries—6 locks total, 5 constrain

4. Capacity: Twenty-three of the 28 lock constraints are centered in four reaches:

Great Lakes System—8 Welland Locks (Canadian)

Ohio River System—7 locks

Mobile River and Tributaries—5 locks

Illinois Waterway—3 locks

Under peacetime conditions, the greatest impact on any one system due to constraints is on the Ohio River System—65 million tons not handled by 2003 (mainly coal). Only the Lower Upper Mississippi approaches this maximum with 31 million tons not served. That reach, with its primary constraining lock, the new Lock 26, controls traffic growth on both the Illinois Waterway and Upper Mississippi reaches, each of which account for over one-quarter of the nation's waterborne agricultural shipments.

5. Defense: During the mobilization in 1990, traffic surges heavily on several reaches, which exacerbates an existing problem or creates either a congestion or constraint problem. Thirteen of the 16 U.S. lock problems are on four reaches:

Great Lakes System—1 U.S. and 8 Canadian locks

Illinois Waterway—6 locks

Ohio River System—4 locks

Gulf Coast-West—2 locks

The significance of this reach perspective is not only the obvious clustering of each type of problem in three or four reaches, but the finding that several of these same reaches have significant problems or needs in more than one need category. Those reaches falling in two or more of the preceding four lists, and the number of lists they are on, are:

Ohio River System—4

Illinois Waterway—4

Upper Mississippi—3

Great Lakes—3

Gulf Coast-West—2

Mobile River and Tributaries—2

Although the greatest number of problems and needs by the year 2003 are related to these reaches, severe isolated problem sites do exist elsewhere. The above list highlights those reaches which have a wide mixture of problems and, thus, are likely to have more acute impacts if these problems surface simultaneously.

SECTION VI

NATIONAL FRAMEWORK FOR WATERWAY DEVELOPMENT

DEFINITIONS

Existing System: The commercially navigable waterways in operation in 1978 plus commercial navigation projects presently funded for construction.

Maintain: Actions which sustain the reliability and safety of the existing system.

Improve: Actions taken solely for the purpose of increasing capacity and efficiency.

Framework: A set of studies of potential actions designed to maintain and/or improve the waterway system. Reaches are first organized by their contribution to one set of national goals. Then an action's timing within a reach becomes a function of traffic projections and the related system capability.

Planning-Construction Process: The steps and associated time between initiation of civil works project level studies and the end of construction.

Section VI

NATIONAL FRAMEWORK FOR WATERWAY DEVELOPMENT

Nationwide studies have found that the infrastructure required for economic and social development is rapidly decaying. This conclusion applies to such public works as roads, railroads, public buildings, and utilities, as well as the waterways. With this fact in mind, the Council of State Planning Agencies (Choate, 1981) concluded that a basis was needed on which decision makers could design expenditures to meet long-term public works needs of national economic renewal in concert with the short-term requirements associated with the rise and fall of the economy. The implication of this general review is that selected projects deserve consistent, long-term support in order to maintain viability of a system, whereas other projects, classified as less critical to achieving economic renewal, may be postponed or accelerated to reflect short-term goals.

Waterway maintenance and improvements display patterns similar to much of the basic public infrastructure, such as: growing age of structures, repeated funding shortages, and delays. The evaluation of needs (Section V) for example, identified 97 U.S. plus another 8 Canadian locks, which along with many other navigation structures are approaching the end of their normal design lives (50 years). Increased traffic and aging projects magnify the investment which will be required to maintain a safe and capable navigation system. Recent declines in waterway investment levels, increasing unit costs for construction, operation and maintenance, and longer schedules from initial planning to completion of construction combine to indicate potentially severe constraints in maintaining the current waterway capability. Between 1970 and 1980 a trend of falling construction expenditures (decreased 30 percent during the period) and increasing maintenance costs (increased 40 percent during the period) developed. A major contributory factor to the falling construction expenditures is implied in the results of a survey of 36 Corps of Engineers civil works projects completed in fiscal years 1973, 1974 and 1975 (see Figure VI–1). This survey showed an average duration from study authorization through completion of construction of 24.4 years and a median time of 15.2 years. If the median times were obtained, the technical steps shown in Figure VI–1 — survey, review, advanced engineering and design and construction — would take 11.8 years (78 percent of total elapsed time) with an average of 13.3 years (55 percent of total elapsed time). The remainder of the elapsed time is consumed waiting for authorization and funding. This ranges from 3.4 years, median time, to an average 11.1 years for the 36 projects surveyed.

The difficulty with the increasing number of waterway capability problems is less one of identification or design of solutions, than one involving the length of the total process. It is this process which must be reduced if problems identified in Section V are to be solved and a capable system maintained.

A framework for a long run, nationally focused program is essential for effective transportation into the twenty-first century, given the reality of limited funds for public works and few short-term solutions for interagency conflicts. Such a framework would provide a guide to studies addressing anticipated problems and time-phased solutions to achieve a set of goals, yet be flexible enough to respond to new and changing needs.

A decision framework focusing on four nationally important issues for maintaining a safe, reliable and efficient waterway system and increasing its capacity is developed in this section. After mention of the NWS methodology, the need for modifying the present decision making approach is discussed. The conclusions are drawn from the capability analysis, from the results of applying the existing planning-construction process and from analysis of four management-investment strategies.

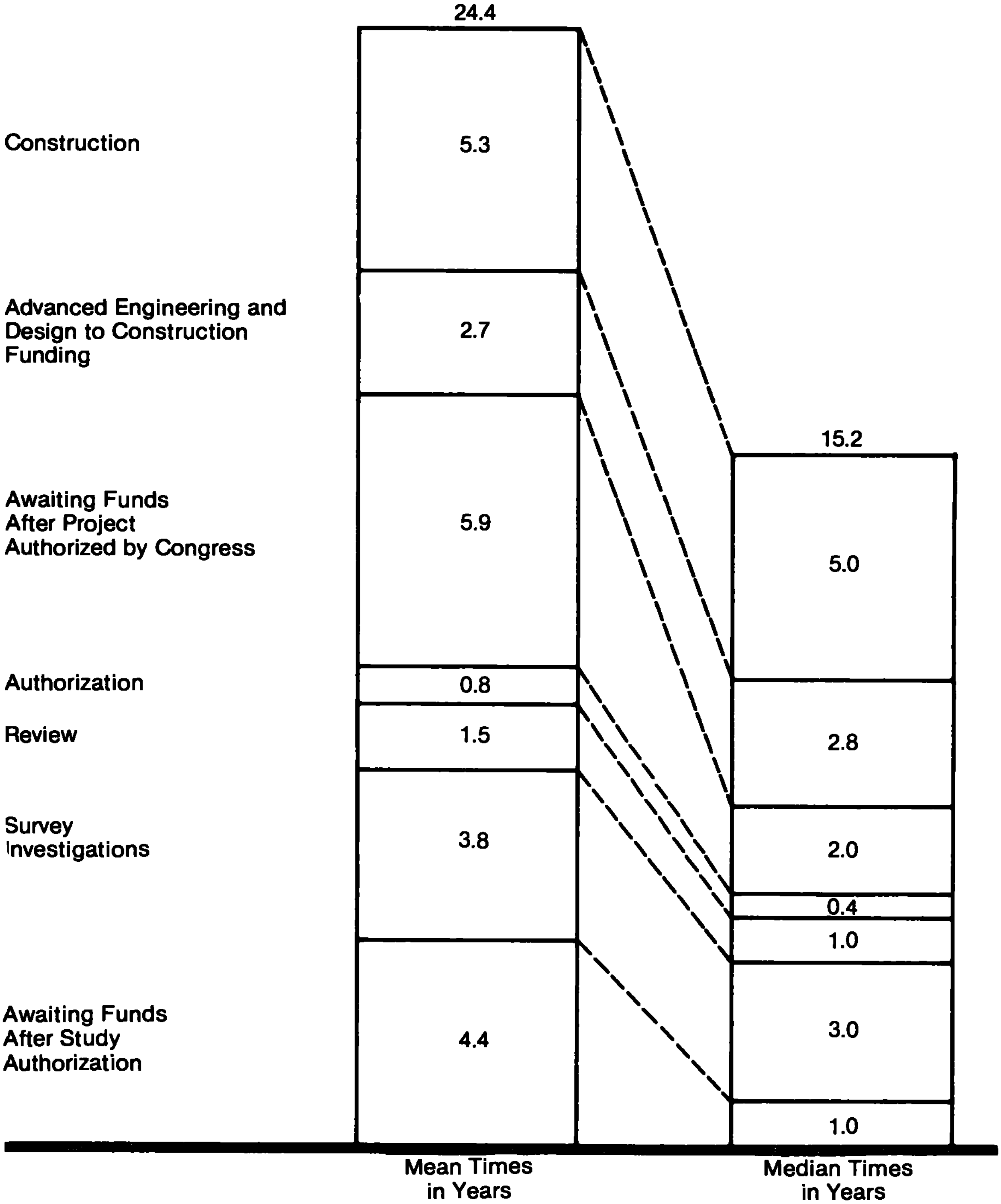
METHODOLOGY

The following paragraphs describe the methodology used in developing the framework. It was based on (1) an identification and scheduling of solutions to the problems identified in Section V; (2) performance evaluations of alternative management-investment strategies designed to meet the capability problems; and (3) development of framework options which emphasize one or more national goals. Each stage of the methodology is discussed below

1. Potential solutions to the safety, reliability, efficiency and capacity problems, collectively referenced as capability problems, were identified. Applying the historical planning-construction

Figure VI-1

MEAN AND COMPOSITE MEDIAN COMPLETION TIMES FOR MAJOR COMPONENTS IN THE PLANNING, DESIGN AND CONSTRUCTION OF CIVIL WORKS PROJECTS (YEARS)[1]



1. Times are based on 36 projects completed in Fiscal Years 1973, 1974 and 1975.

process, potential solutions were then scheduled in response to the earliest date a problem arose across all scenarios. The impact of the Low Use scenario on scheduling was also assessed to determine the range of timing (or the window) during which investment decisions should be made.

2. Strategies were designed to test options for aggregate funding levels, priorities for allocating resources, nonstructural policies and structural replacement policies. The findings and conclusions drawn from the strategy evaluation were inputs to the framework formulation.

3. Based on conclusions drawn from the two preceding steps, a framework approach was developed. It involved a comparison of reaches based on traffic and then an evaluation of projects within each reach (or group of reaches).

First, the shallow draft and Great Lakes System reaches were organized by total traffic, then in terms of agricultural shipments, and finally by coal shipments moving in each reach. These three traffic categories were selected to reflect a reach's contribution to national economic development, agricultural exports, and energy self-sufficiency. These became the basis for developing three frameworks. A fourth framework for the shallow draft and Great Lakes System was tied to a reach's support of industrial mobilization during a defense emergency. The coastal channel reaches were arrayed primarily by their coal export potential. Specific coastal harbors were not listed. Thus, the nature of traffic within a reach dictated the relative position of a reach.

Second, each potential project action previously identified within a single or a group of reaches was then classified according to the type and severity of problem(s) which it addressed. Those projects which would maintain the physical reliability and those needed to improve the efficiency and carrying capacity of a reach were determined. Projects within each reach were separated into two categories, those which maintained safety and reliability and those which singly improved the system by enhancing efficiency and adding capacity. All actions relating to physical reliability were generally placed ahead of actions needed only to enhance capacity or efficiency. Within each of these two subdivisions, proposed actions were then further classified according to the problem(s) they addressed, in the following order:

(1) Primary Constraint
(2) Secondary Constraint
(3) Congested
(4) Obsolete

If the average time shown in Figure VI–I (24.4 years) for the planning-construction process is built into the scheduling of project actions, many cannot possibly be in place by the time this analysis predicts potential severe efficiency, capacity or reliability problems. Therefore, attention is directed to means of accelerating the process.

Special consideration in the framework process was given to actions which uniquely contributed to national goals. This relied heavily on conclusions drawn from both the capability and strategy assessments. It involved only nationally strategic projects which would, if not improved, impose severe limitations on attainment of national goals.

Once the three peacetime and one defense frameworks were completed and nationally strategic projects incorporated, a single overall framework summary was prepared.

CAPABILITY PROBLEMS AND SOLUTIONS

The capability problems, potential solutions, and the ability of the present planning-construction process to provide them, as needed, are discussed in the following paragraphs.

CAPABILITY PROBLEMS

The capability problems discussed in Section V, and summarized below, focus on waterway system reliability, efficiency, capacity, safety and defense.

1. Reliability: This is the dependability of waterway structures, channels and ports in the future. The evaluation is based (1) on the age, use, condition and degree of technological obsolescence of structures, and (2) on the stability of channel dimensions and the presence of adequate depths during periods of low flow. By the year 2003, 97 U.S. locks will have exceeded the 50-year life for which they were designed. Of these 97, only 48 are forecast to be used intensively enough by year 2003 to warrant further study.
2. Capacity: This is the ability of the waterway system to physically handle the projected traffic. Twenty U.S. (and 8 Canadian) locks are likely to be unable to physically handle projected 2003 traffic. These locks constrain about 100 million tons of projected traffic (7 percent of total projected domestic waterway traffic). Coal and agricultural products are most affected.
3. Efficiency: The waterway users are forecast to experience severe congestion costs by the year 2003 unless capacity is added to the waterways. NWS assumed all feasible nonstructural measures would be implemented, which could add 10 to 20 percent capacity to the system. However, added capacity is still required to reduce congestion and improve operating efficiency. Sixteen locks, in addition to the 20 constraining structures, for a total of 36 U.S. locks, are forecast to be congested by the year 2003. Reducing congestion at locks can save waterway users approximately $500 million per year. Energy products and agricultural products are most severely

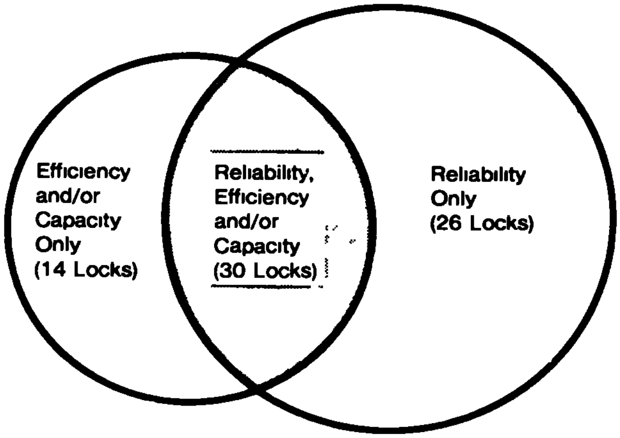
affected by congestion. Steam coal export competition from Australia and South Africa is heightened by the absence of any deepwater U.S. port on the Gulf and Atlantic coasts.

4. Safety: The NWS developed a list of potential safety hazards along the waterway system. High priority problem areas include 18 major bridge problem areas, 12 lock sites, 27 major congested stretches of waterway and 13 areas with restrictive channels.

5. Defense: A long-term mobilization for national defense would increase transport demand for U.S waterways. Several projects would be unable to serve these needs. Actions to enhance the national defense capability of water transportation would center on the Great Lakes System, the Ohio River System and the Illinois Waterway.

The greatest number of problems identified involved lock sites. Figure VI–2 summarizes these problems for all forecasts. The general conclusion is that as many as 70 locks may require action for reliability, efficiency and/or capacity problems by 2003. The problem is magnified for 30 lock sites which are forecast to be both inefficient and unreliable by 2003. Thus the existing system is unable to safely and effectively serve all projected traffic (over 100 million tons may go unserved by 2003). Consequently, it cannot fully support many of our important national goals — expanded foreign sales of coal and agricultural products, moving coal to domestic consumers, and/or providing timely and reliable service during a long term national defense mobilization.

Figure VI-2
LOCK PROBLEMS BY 2003[1]
(Number of Lock Sites)



Category	Number of Locks
Capacity Only	10
Efficiency Only	4
Reliability Only	26
Reliability and Capacity[2]	18
Reliability and Efficiency	12
TOTAL	70

1 Lock Problems as identified under one or more of seven forecasts, exclusive of safety problems Twelve locks, of which seven are included in the 70 shown, display safety problems by 2003

2 Includes eight Canadian Locks on the Welland Canal

POTENTIAL SOLUTIONS

Solutions were associated with each problem identified in the capability analysis — reliability, safety, efficiency and capacity. The discussion of solutions focuses first on maintaining a reliable, safe existing system, and second, on efficiency and capacity improvements.

Maintaining a Safe and Reliable Existing System

Maintenance, major rehabilitation and replacement are vital to the reliable functioning of a transportation system. The NWS found that the costs of maintaining the navigation system (excluding rehabilitation and replacement) in the decade of the 1970s increased by over 40 percent in real dollars. In part because of the revised interpretation of the 1909 Act replacement authority, little new replacement construction was initiated during the 1970s. And with an increasing number of older locks in the system, lock replacement or rehabilitation because of obsolescence should occur at a higher rate than that experienced in the 1970s decade.

Completion of the Existing System

The existing system as defined for the NWS included several projects under construction in FY 1981. The major projects are described in Section II. The cost of completing these projects is estimated at $2.0 billion in 1977 dollars ($2.9 billion in 1982 dollars). Added operations and maintenance (O&M) costs are estimated at $10.4 million annually for the two major waterway projects, Tennessee-Tombigbee and Red River.

Operation, Maintenance and Rehabilitation

Table VI–1 displays the necessary operations, maintenance and rehabilitation (OM&R) expenditure levels for the existing system, including the projects under construction. The annual costs to maintain the existing system are estimated at $403 million in 1977 dollars.

Investment in Replacement

Closely allied to maintenance and rehabilitation are major structural replacement actions. As discussed, the system is aging at an increasing rate and replacement is not keeping pace. Table V–6 displays the 97 U.S. and 8 Canadian commercial lock sites which will have exceeded their 50-year engineering design lives by year 2003. Forty-nine U.S. lock sites (out of the 97) are projected to have less than 30 percent of their available capacity used by 2003. These locks were not considered further in the NWS needs analysis. This reduced the lock reliability problems identified for further study to 48 U.S. and 8 Canadian locks. Table VI–2 shows a summary of lock sites which may require major rehabilitation or replacement to maintain reliability. The table reveals that many of these locks also are projected to become highly congested or physically unable to accommodate projected traffic. By 2003, nearly half, 22, of the 48 U.S. obsolete locks could be under serious pressure due to heavy use. Therefore these 22 probably should be evaluated early in any replacement or rehabilitation scheme. The cost for these 22 is estimated at $2.2 billion (1977 dollars). Some of the remaining 26 U.S. locks, probably the oldest and the technologically obsolete, will also require replacement or rehabilitation. The Monongahela River Locks 7 and 8 are examples of this. If a technologically modern lock structure were necessary at each of the 48 U.S. sites, the sum of first costs in 1977 dollars would be in the order of $4.2 billion. Replacement needs which were not assessed for other navigation structures — wiers, jetties, dams, among others — and cost estimates were not developed.

Safety

Provision of safe operating conditions is intrinsic to any maintenance program. The potential safety problems displayed in Figure V–3, Table V–7 and Appendix E are in addition to those which have been included in Fiscal Year 1978 U.S. Army Corps of Engineers (USACE) and U.S. Coast Guard (USCG) programs. Nearly all responses to safety hazards identified fall within the areas of USCG responsibility. The exceptions generally

Table VI–1
ANNUAL COSTS OF MAINTAINING EXISTING SYSTEM
(Millions of 1977 Dollars)

	Deep Draft	Shallow Draft	Total
Dredging			
Historical (1973–1977)	144	66	210
Deferred Dredging	12	9	21
System Under Construction	—	2	2
Subtotal	156	77	233
Non Dredging			
Historical (1973–1977)	26	98	124
System Under Construction	—	9	9
Subtotal	26	107	133
Rehabilitation[1]	—	—	37
Total	182	184	403

1. Rehabilitation is based on historical aggregate of all navigation structures No separate deep or shallow draft evaluation was performed.

Table VI–2
SUMMARY OF POTENTIAL LOCK PROBLEMS BY TIME PERIOD[1]

Problem	1980–84	1985–89	1990–94	1995–02	2003
Obsolete					
Obsolete Only-U.S	5	13	36	33	26
Obsolete and Congested-U.S.	1	1	6	9	12
Obsolete and Constrained	0	9	11	12	18
U.S	(0)	(1)	(3)	(4)	(10)
Canadian	(0)	(8)	(8)	(8)	(8)
Obsolete Total	6	23	53	54	56
U.S.	(6)	(15)	(45)	(46)	(48)
Canadian	(0)	(8)	(8)	(8)	(8)
Congested Only	8	4	1	8	4
U.S.	(0)	(4)	(1)	(8)	(4)
Canadian	(8)	(0)	(0)	(0)	(0)
Constrained Only	0	0	1	1	10
Total Needs	14	27	55	63	70
U.S.	(6)	(19)	(47)	(55)	(62)
Canadian	(8)	(8)	(8)	(8)	(8)

1. Timing of needs is based on the maximum traffic forecast for each reach and low water conditions for the Illinois Waterway and Ohio River System.

Table VI–3
SUMMARY OF COSTS TO MAINTAIN THE EXISTING SYSTEM, 1982–2003
(Millions of 1977 Dollars — No Real Cost Escalation)

	U.S. Coast Guard[1]	Corps of Engineers
Annual Costs	17	403
Investment-First Costs		
Complete Projects Under Construction[2]	—	1,980
System Replacement	—	4,200
Safety	500	50
Total Investment	500	6,230

1. Increment above 1978 U.S. Coast Guard Safety Program
2. Funds to complete from FY 1982

involved locks. Although each problem site identified merits detailed evaluation, sites with a history of serious accidents, with high traffic flows and/or hazardous commodity traffic, warrant priority treatment. Actions considered under each strategy are discussed and displayed in the report *Evaluation of Alternative Future Strategies for Action*, Exhibits IV–2 and IV–3. First costs (1977 dollars) estimated across the four strategies ranged from $300 to $550 million, with an added increment of USCG operation costs estimated at $17 million. The estimate for meeting all problems presented in Section V involves first costs of $500 million for USCG and $50 million for USACE, with a $17 million increase in annual USCG costs. Approximately 70 percent of the first costs would be for shallow draft actions, whereas the annual costs would be split evenly between deep and shallow draft.

Costs to Maintain the Existing System

The costs to maintain the existing system include investment and OM&R (including safety related) costs (all costs are in 1977 dollars). The annual USACE costs displayed in Table VI–3 are estimated at $403 million. The first cost estimate for the Corps of Engineers to maintain today's intensively used commercial waterway system between 1982 and 2003, in 1977 dollars, is estimated at $6,230 million. Approximately $500 million in first costs and $17 million in incremental annual charges are estimated as necessary to overcome those safety hazards identified in Section V which fall under the traditional responsibility of USCG.

Improvements to the Existing System for Efficiency and Capacity

A program to continue the existing system through the year 2003 was discussed in the preceding paragraphs. It would provide for maintenance of a safe, reliable water transportation system, but not one necessarily efficient or capable of moving forecast traffic flows. Adding improvements for efficiency and capacity would involve modification of several locks, channels and ports. The following paragraphs review the problems and discuss potential solutions.

Efficiency and Capacity Problems

The potential loss of over 100 million tons of traffic (50 percent coal and 25 percent grain) by 2003 is due to physical constraints at 28 (20 U.S.) lock sites by 2003. Congestion at these sites and 16 other congested sites could add $1.9 billion to annual linehaul costs by 2003. These costs would most likely accrue directly to barge and ship operators increasing transportation costs to shippers and their ultimate consumers. Table V–2 summarized the lock needs, the earliest date a constraint may arise (analysis assumes low water conditions for Locks 52, 53, LaGrange and Peoria), and the placement of a lock into primary or secondary constraint status based on a lock's impact on the level of traffic flow both within a reach and between reaches. In addition to problems directly related to locks, the physically restrictive channel from the Mobile River up to the Black Warrior River generally limits tows to six barges, preventing efficient use of the locks as well as of a carrier's equipment.

Deep draft coastal channels which have the greatest potential for service in terms of volume moved to the international coal trade are located in three reaches: (1) Middle Atlantic Coast, (2) Lower Mississippi: Baton Rouge to the Gulf, and (3) Mobile River and Tributaries. All have a potential to improve U.S. competitive status in coal exports. Several West Coast ports are handling increasing exports of western coal to Asian markets.

Actions for Efficiency and Capacity Problems

A congested or constraining lock which is not physically or technologically obsolete may either be supplemented with another structure or replaced with a larger structure. Final decisions on detailed actions will be made by individual project studies. Options considered to increase capacity and efficiency of reaches included both lock and channel modifications. Generally, choices of actions involved lock supplementation; however, in several reaches the problems and associated options were broader, as discussed below:

1. *Upper and Lower Upper Mississippi River and Illinois Waterway*
Because of a mix of highly influential regional factors, including environmental constraints and potential low flow problems, deepening of the Upper Mississippi River, Lower Upper Mississippi River and the Illinois Waterway as a means to enhance efficiency in these reaches, as proposed under Strategy IV, was not incorporated into the framework. Consequently, only lock actions remained to improve efficiency. All constraining and congested locks were named for supplementation or replacement. The evaluation was based on low water conditions for projects with open passes.
2. *Ohio River System*
The Ohio River System, which leads all other waterways in coal shipments, is projected to be increasingly congested. Many of the newer locks such as Smithland, Cannelton, Markland and Greenup will reach 75 percent utilization by 2003, if demand for coal is high. A channel deepening option was placed into the program for the Ohio because of the substantial cost reduction potential and the ability to increase the capacities of the newer generation of locks, thereby avoiding further addition of locks early in the 21st century. This deepening, in conjunction with lock actions for those locks shown in Section V, has the impact of reducing linehaul costs in 2003 by 1.2 mills per ton-mile. The 100 billion-plus ton-miles estimated for 2003 for the Ohio River System could move, with deepening, at a savings approaching 100 million dollars annually (1977 dollars).
3. *Mobile River and Tributaries*
The efficiency of the Mobile River and Tributaries reach could be increased by cutoffs and bend widening on the Tombigbee River below Demopolis, Alabama and on the Black Warrior River. Channel modifications could also increase lock efficiency. The potential for future coal exports from this reach place it among the leading reaches in coal exports by 2003 and thus Mobile Harbor becomes a serious candidate for deepening to 50–55 feet.
4. *Middle Atlantic Coast*
Deepening one or more coal ports to 50–55 feet in the established coal export center of the Middle Atlantic Coast reach could yield immediate returns by enhancing U.S. competitive position in international coal trade. This reach is expected to handle about 60 percent of the nation's overseas coal exports by 2003, while ranking third in both petroleum imports and grain exports.
5. *Lower Mississippi: Baton Rouge to Gulf*
The Lower Mississippi River will continue to move more traffic than any other waterway segment. It is the nation's leading export reach and third highest import reach. It is forecast to export 38 percent of the nation's farm products, import 23 percent of the crude petroleum and export up to 17 percent of the coal. Savings due to a deeper channel are significant.
6. *Gulf Coast-West*
The Gulf Coast-West, fourth ranked in terms of total traffic, has some potential for coal export. The total traffic volume, particularly the petroleum, supports further consideration for deepening.

Costs to Improve the Existing System

The costs in 1977 dollars to improve the existing system include investment in improvements not already associated with maintaining a safe, reliable system, plus additional O&M to cover these improvements. Table VI–4 displays these costs. The added O&M costs ($55 million) are almost entirely associated with deep draft actions. The first costs for improvements show an almost 40/60 split for deep versus shallow draft actions. Out of the total $2,919 million investment, $1,744 million is for shallow draft and $1,175 million is associated with deep draft actions which may be needed on or before 2003.

SCHEDULING

Each action (except those for potential safety problems) identified was scheduled according to the steps of the civil works planning-construction process. Each project schedule was based on the following information:

1. The phase an action is currently in, such as survey investigation, authorization, or awaiting funds after project has been authorized by Congress.
2. The year each problem category (obsolescence, congestion, constraint) would occur under the maximum traffic forecast.
3. Schedule requirements of closely interrelated system actions. Projects within a reach or several reaches which have a high level of interaction would show initiation of a system or subsystem study based on the earliest date any one project is needed in the interrelated system.

The average and median civil works planning-construction process times displayed in Figure VI–1 were applied to each identified action to determine the range for the expected completion dates. Since most actions were already underway, the stage of the process became the base for estimating the time to completion. The results are displayed in Appendix F, Figure F–1.

Table VI–4
SUMMARY OF COSTS TO IMPROVE THE EXISTING SYSTEM 1982–2003[1]
(Millions of 1977 Dollars)

Item	Deep Draft[2]	Shallow Draft/Great Lakes[3]	Total
Annual O&M Costs by 2003[4]			
Locks	—	2	2
Channels	52	1	53
Total	52	3	55
Investment			
Locks	—	1554	1554
Channels	1175	190	1365
Total	1175	1744	2919

1 Improvements for this table are those solutions to efficiency or capacity problems not already associated with maintaining a safe and reliable existing system
2 Improvements are for four coastal reaches
3 Improvements are only those classed as "Improve " The costs for others are included in Table VI–5.
4. Annual operations and maintenance costs associated with improvements, not with existing projects.

Scheduling Reliability Actions

The locks displayed in Section V, even with studies underway, may exceed their 50-year design lives by 10 to 15 years before replacement or rehabilitation is completed. If funds were available, replacements for these locks could conceivably be in place in the middle to late 1990s. However, if the mean time were to prevail for these as it has for the 1200-foot Lock 26, nearly all would be pushed beyond year 2003 — and result in increasing rates of periodic downtime for repairs and increased potential of major failure with systemwide ramifications.

Scheduling Efficiency and Capacity Actions

Project delays are expected with the continuation of the existing planning-construction process. The consequence will be increased congestion and physical constraints to traffic. Table VI–5 displays the impact on the identified lock problems of applying the range of process times (15.2–24.4 years) under the range of traffic forecasts. The Low Use forecast resulted in 27 congested locks by 2003, 17 less than under the maximum traffic forecast. These 17 however, would exceed the 80 percent use level within another 5 to 10 years. Lower forecasts, according to this analysis, do not eliminate problems, they only postpone them. Assuming the median process time (15.2 years) 17–20 congested locks could be replaced as needed; however, if the mean (24.4 years) would be realized, only one congested lock (given Low Use forecast) could be replaced. Whatever the forecast of traffic under the 15.2 year assumed process time from one-third to two-thirds of the congested locks would not be able to have added capacity as needed. The situation under the mean process time of 24.4 years shows for the 27–44 congested locks from one to six replacements could be in place as needed. Substantial delays are expected with continuation of the existing planning-construction process under all forecasts. There is a clear need to move expeditiously to relieve delays.

Scheduling Deep Draft Reaches

Appendix F, Figure F–1, displays the schedule for deep draft reaches as they relate to the entire navigation system. Deep draft improvements considered in the NWS were limited to deepening of Atlantic and Gulf ports to accommodate the 50–55 foot draft vessels which currently cannot call at any port along the U.S. Atlantic or Gulf coasts. Applying the median time line, the earliest such port depths would be available within these reaches would be about 1990. The United States could not, therefore, be able to attain the competitive edge associated with deeper draft vessels until after that date. This would reduce the ability of the United States to maintain leadership as a world coal supplier.

STRATEGY DEVELOPMENT AND EVALUATION

As a major step toward formulating the framework, strategies were developed to illustrate the degree of success of various management philosophies in meeting water transportation needs. The aim was not to select one in its entirety, as one would project level alternatives, but to use the evaluation to test the assumptions regarding funding and allocation. A strategy consists of a statement of management philosophy and a set of management policies by which individual investment actions and other expenditures are chosen and prioritized for implementation.

DESCRIPTION AND EVALUATION OF STRATEGIES

Four strategies were defined, each with a discrete variance, to facilitate comparative analysis of such policy differences as allocation priorities and funding levels. These strategies did not, nor could they, replicate complexities and interrelationships of the real world. What they provided to the NWS analysis was a systematic assessment of a few key policy and programming assumptions. The following paragraphs discuss the assessment of the four strategies:

Strategy I — Continue present policies and programs with historical funding levels.
Strategy II — Reprioritize resources on existing system with historical funding levels.
Strategy III — Fund minimum system needs — no funding limit.
Strategy IV — Enhance the navigation system — no funding limit.

The two basic types of controlling assumptions common to all strategies were: funding availability and the hierarchical ranking of needs — by category, by segments and by use (see Table VI–6). *Evaluation of Alternative Future Strategies for Action* reports on the details of each strategy and on the evaluation of its results. The evaluation of the four strategies is discussed below and summarized in Table VI–7.

Strategy I: Continue present policies and programs with historical level of funding. The objective of this strategy was to simulate the possible result of following historical policies for authorization, funding and construction of projects and O&M. Its assumed investment allocation gives priority to operations and maintenance over construction and safety actions. It maintains a 1970s-level of funding and continues present funding allocation policies. Costs average about $656 million annually. Major actions and findings indicated:

1. Improve one constraining lock — the second Lock 26.
2. No deepening of ports and channels.
3. Fails to maintain safe, reliable system.
4. System cannot handle 74 million tons of forecast 2003 traffic, coal traffic is most affected.
5. Some improvement to system efficiency.
6. Fails to accommodate defense scenario traffic surge.

Strategy II: Reprioritize present resources on existing system. This strategy was intended to serve the greatest level of traffic at the least total cost. High cost, low traffic volume waterways would not be maintained as funds would be freed for construction of needed improvements on high volume waterways. This strategy would maintain 1970s-level funding and alter allocation policies. Costs average about $656 million annually. Major actions and findings indicated:

1. Adds capacity at six constraining locks.
2. Terminates maintenance of seven inland waterways and hundreds of small coastal ports and side channels.
3. No port or channel deepening.
4. Fails to maintain reliable system.
5. Safety improvements through minor nonstructural actions.
6. Unable to handle 77 million tons of forecast 2003 traffic.
7. Improve efficiency — linehaul costs compared to Strategy I decrease by $40 million annually.
8. Defense mobilization capability inadequate, but better than Strategy I.

Strategy III: Fund minimum system. Funding does not correct deferred rehabilitation and maintenance. It would add funding to increase lock capacity at 18 lock sites and increase the

Table VI–5
LOCK SITE IMPROVEMENTS IN PLACE AS NEEDED — EXISTING PROCESS

	Congested Locks — Improved[1]						Constraining Locks — Improved					
	Total		Locks Over 50[2]		Locks Under 50[2]		Total		Locks Over 50[2]		Locks Under 50[2]	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Number of Sites with Needs	44	27	30[3]	22	14	5	28	14	18[3]	12	10	2
Sites Improved Upon Under Median Time[4]	20	17	10	15	10	2	14	14	5	12	9	2
Sites Improved Upon Under Mean Time[4]	6	1	1	0	5	1	8	3	1	2	7	1

1. This is the sum of all constraining and congested locks—improved Congestion is defined as 80 percent utilization or greater, whereas constraining is 100 percent utilization
2. Locks in excess of 50 years old are shown to emphasize the dual problem of reliability and congestion.
3 Includes 8 Canadian locks at the Welland Canal.
4 Median and mean planning times are based on Figure VI–1.

Table VI-6
COMPARISON OF STRATEGY DECISION CRITERIA[1]

Needs Categories	Strategy I	Strategy II	Strategy III	Strategy IV
Reliability (OM&R)	Meet all O&M needs for Class "A" segments and major ports[2]. If funds are available: 1. Meet O&M needs for Class "B" segments. 2. Meet O&M needs for Class "C" segments, secondary ports, and side channels.	Same as I, except actions for adding lock capacity in Class "A" segments have priority over the needs for operations and maintenance of Class "B" and "C" segments as well as secondary ports.	Funding of channel maintenance needs to maintain 1973–1977 reliability and complete funding of operations and rehabilitation needs	Same as III, but fund annual deferred maintenance dredging as well.
Lock Capacity	If funds are available: Add lock capacity at 95% utilization of practical capacity Minor structural and nonstructural actions taken at congested locks.	Same as I, but lock capacity actions for Class "A" segments are made before meeting the O&M needs of Class "B" and "C" segments Minor structural and nonstructural actions taken at congested locks	Add lock capacity at 95% utilization wherever it occurs. Minor structural and nonstructural actions are taken at congested locks.	Add lock capacity at 85% utilization wherever it occurs Replace selected obsolete locks. Minor structural and nonstructural actions are taken at congested locks.
Safety	If funds are available. Take minor and non-structural actions in reaches with traffic growth of no less than 10,000,000 tons by year 2003.	Same as I, but safety actions for reaches with traffic growth of no less than 10,000,000 tons are given priority over the need for operation and maintenance of Class "C" segments.	Take minor and nonstructural actions in reaches with traffic growth of no less than 10,000,000 tons by the year 2003	Similar to III, but take some major structural actions to alter or replace bridges and widen reaches.
Efficiency: Inland	No actions	No actions	No actions	Deepen heavily used waterways to achieve reduction in linehaul costs.
Efficiency: Coastal	No actions	No actions	No actions	Deepen reaches to 50 feet or more which are forecast to move large amounts of export coal by 2003.

1 It is assumed that the Red River and Tennessee-Tombigbee projects, the single 1200-foot lock replacement project at Lock and Dam 26, the 12-foot channel from Baton Rouge to Cairo, the additional lock at Pickwick Lock and Dam on the Tennessee River, Vermilion Lock on the Gulf Intracoastal Waterway, and replacement of Locks 6 and 8 on the Ouachita River, are completed as part of the "present system" Expenditures for these projects will prevent any new major actions for lock construction and safety from being taken under Strategies I and II until after 1990 due to assumed funding limits of $585 million (1977 dollars)

2 Class A, B, and C inland waterway segments have been grouped in an analysis prepared by A T Keamey, Inc according to projected operations and maintenance costs per ton-mile of projected traffic in 2003 Class "C" inland segments have an O&M cost per ton-mile of 5 mills or more Class "B" segments have a ratio of 1 5 to 5 mills and Class "A" inland segments have a ratio of 1 5 mills or less Side channels are short spurs that do not carry through traffic Minor ports are all those on the Great Lakes or coasts that handled less than 1,000,000 tons in 1977

maintenance budget. Annual costs would be in excess of $700 million. Major actions and findings indicated:

1. Adds capacity at 18 locks.
2. No port or channel deepening included.
3. Serves all forecast traffic.
4. Improves efficiency — reduces linehaul costs over Strategy I by as much as $130 million annually.
5. Some improvement in reliability.
6. Safety unchanged from Strategy II.
7. Defense mobilization prospects improved, except in Great Lakes.

Strategy IV: Enhance the navigation system. There would be no funding limits. Rehabilitation and deferred maintenance were added as was replacement for projects judged to be obsolete in 1977. Deepening and widening of channels and ports were added. Policies for improvement actions were liberalized — locks were replaced when traffic levels reach 85 percent of maximum physical capacity rather than 95 percent, as used in all other strategies. It would add funding to maximize potential savings in linehaul costs and consider coastal needs. Annual costs would be as much as $988 million. Major actions and findings indicated:

1. Construct 35 locks.
2. Modify inland channels in five reaches.
3. Deepen five coastal ports.
4. Major safety improvements added.
5. Serves all forecast traffic.
6. Reduces linehaul costs by $400 to $600 million annually over Strategy I.
7. Improves existing system reliability.
8. Serves most of the defense mobilization needs.

Table VI-7
SUMMARY OF STRATEGY EVALUATION

Need Category	Strategy Performance I	II	III	IV
Reliability				
Adequate O&M thru 2000	No	No	Yes	Yes
Channel Dimensions Deferred Dredging	No	No	No	Yes, 30 million cubic yards
Structural Obsolescence	No	No	No	11 locks obsolete in 1977
Lock Capacity				
Add Minor Structural and Nonstructural Actions	Yes	Yes	Yes	Yes
Add Capacity at U S Locks (No of Locks)	1	6	18	35
Maximum Traffic Not Accommodated (Millions of Tons)	74	77	0	0
Agricultural Products	11	3	0	0
Chemicals/Fertilizers	7	7	0	0
Metals & Ores	4	9	0	0
Coal	44	36	0	0
Petroleum	6	6	0	0
Forest Products	1	1	0	0
Other	6	9	0	0
Efficiency				
Lock Capacity at Congested Sites	No	No	No	17 locks
Deepen or Widen Inland Channels	No	No	No	5 channels
Ports and Waterway Closures	No	7 Waterways 100's of ports	No	No
Port Deepening	No	No	No	5
Domestic Inland Linehaul Cost Reduction Range (Millions of 1977 $) in 2003[1]	105–134	140–179	140–268	491–759
Agricultural Products	34	46	46	148
Chemicals/Fertilizers	11	22	11	72
Metals & Ores	0	5	3	10
Coal	16	16	49	178
Petroleum	0	5	0	26
Other	3	8	5	34
Safety[2]				
Minor Actions	0	223	223	188
Major Actions	0	0	0	22
Defense Needs In Emergency	No	No	Yes	Yes
Estimated Costs for Construction and O&M for Period 1978–2003 (Billions of 1977 $)				
Total	16	16	18–19	22–25
Inland	11	10	11–12	13–15
Annual Average Expenditures for 1978–2003 (Millions 1977$)	656	656	700–748	892–988
Inland Fuel Tax Receipts-Year 2003 under PL95–502 (Millions in 1977 $)	82–86	68–82	71–94	69–88

1 Commodity display shows for Strategy I and II the High Use evaluation and for Strategy III and IV the Miscellaneous Forecast evaluation Miscellaneous forecast was not evaluated by commodity for I and II Commodity reductions were not chosen to display the limits but to display a distribution across commodities for a single forecast

2 Safety actions were applied only to waterways with over 10 million tons growth between 1977 and 2003 Numbers displayed are the maximum actions under anyone forecast

FINDINGS AND CONCLUSIONS FROM STRATEGY EVALUATION

The strategy evaluation findings of interest to framework formulation and policy making were:

1. Continued funding at present levels will result in a waterway system which cannot physically serve all traffic, will be increasingly costly to use, will suffer from reduced dependability, and will be less safe. The ability to compete effectively in world agricultural and coal markets will be impaired due to these conditions.

2. Fund allocation policies should respond to changes in use and national goals.

3. Variations in NWS waterway traffic forecasts would delay the time when lock replacement or supplementation should take place by 5 to 10 years. Under the minimum traffic forecast, five of the lock actions considered in Strategy IV would be delayed past 2003.

4. The analysis assumed implementation of all feasible nonstructural and minor structural improvements which reduce delays. They reduce congestion levels at lock sites and may postpone major investment in capacity improvement measures.

5. None of the strategies considered improvements other than locks and channel modification. Other structures, such as those for river training, must also receive program consideration.

6. Strategies assumed that the solution to a problem would usually be in place as

needed — when 85 or 95 percent of lock capacity was reached or at the attainment of the 50-year design life for heavily used locks. Only the construction period was incorporated into the strategies, not the entire planning-construction process. Therefore, the annual distribution of funding needs, as portrayed for each strategy, would be early.

7. Strategies assumed the replacement at 85 to 95 percent physical lock capacity. Detailed economic and engineering analyses are required to determine optimal timing. Project level studies have indicated that economic capacity can vary quite significantly from lock to lock.

FRAMEWORK FORMULATION

A review of both the capability and the strategy evaluation results pointed out a major gap as well as major findings important to the formulation of a decision making framework. That gap, the major findings and the NWS response are as follows:

First, the 25-year study time frame, 1978–2003, and the strategy responses concealed a large number of rapidly developing lock congestion problems. Therefore, in order to identify and address these, the NWS framework reported lock congestion levels at 80 percent use by 2003 instead of the 85–95 percent assumed by the strategies and provided estimates of needs occurring 10 years beyond 2003.

Second, the capability assessment identified 97 U.S. plus 8 Canadian locks which will have exceeded their estimated engineering design lives by 2003 and therefore may warrent major rehabilitation or replacement. The framework response was to include 48 U.S. and the 8 Canadian locks which exhibited both age and significant levels of use. This response supports the contention that a safe, reliable system contributes just as significantly to the U.S. water transportation capability as adding capacity, although somewhat less directly.

Third, evaluation of waterways capability during a hypothesized defense mobilization showed the importance of the waterways and individual locks to this mobilization. The framework response was to add these capability requirements to those occurring during peacetime conditions.

Fourth, some of the inland segments can be deepened or widened to achieve significant linehaul cost reductions and possibly preclude the addition of a third generation of locks early in the 21st century. The response was to incorporate two channel modification actions.

Other major findings influencing framework development involved organization:

Since time and funding will be limited, a means to organize actions according to their contribution to various national goals — national economy, energy self sufficiency, coal and agricultural exports and defense — was adopted. The methodology and criteria applied to measure the relative contribution of each reach, and in a few

Table VI–8
TRAFFIC AND COMMODITY DATA FOR ORGANIZING REACHES

Reach and 2003 Traffic[1] (Millions of Tons)	Percentage Distribution of 2003 Traffic: Farm Products[2] Total Flow	Farm Products Domestic Shipments	Farm Products Domestic Receipts	Farm Products Exports	Coal[3] Total Flow	Coal Domestic Shipments	Coal Domestic Receipts	Coal Exports[4]
L Miss B R to Gulf (591) (2)	50	—	82	38	13	1	10	14
Middle Atlantic Coast (515) (NC)	3	—	—	12	21	11	10	37
Great Lakes System (411) (3)	6	1	1	11	13	7	9	20
Gulf Coast-West (404) (5)	12	—	—	19	3	0	1	7
Ohio River System* (383) (1)	3	9	—	—	35	54	35	—
L Miss Cairo to B R.* (248) (4)	22	9	—	—	8	0	2	—
Gulf Coast-East (178) (7)	3	—	—	2	6	3	9	—
Mobile River and Trib (178) (8)	3	—	3	2	14	6	8	15
Lower Upper Miss * (171) (6)	17	6	—	—	6	6	4	—
Illinois Waterway* (108) (9)	8	28	—	—	3	3	3	—
Tennessee River* (86) (10)	1	—	2	—	8	5	4	—
Upper Miss * (69) (11)	7	28	—	—	3	3	4	—
Columbia-Snake Waterway (64) (NC)	5	5	7	5	0	—	—	4[5]
Arkansas* (26) (12)	1	3	—	—	1	1	—	—
Missouri* (8) (13)	1	2	—	—	0	—	—	—

1 Asterisk denotes inland waterway with only domestic traffic Tonnage indicated in the first parenthesis is maximum peacetime level forecast for reach, foreign and domestic Second number indicates rank of reach in serving total domestic traffic flows only NC means not calculated
2 Farm products group distributed according to Miscellaneous forecast Total flow is for all agricultural products, not just farm products Total flows sum to over 100 because each ton may travel on several reaches Not all reaches are shown, therefore shipments and receipts may not total to 100
3 Coal distributed according to High Coal Export forecast Total flow does not sum to 100 because of interregional movements Not all reaches are shown, therefore shipments and receipts may not total to 100
4 Includes Great Lakes System exports which are primarily destined for Canada
5 Oregon/Washington Coast shows four percent share of exports This may be distributed to Columbia-Snake Waterway as well

cases individual projects, were discussed earlier under "METHODOLOGY."

Shallow draft and Great Lakes reaches with identified problems were organized according to their volumes of total traffic, then by coal shipments, agricultural shipments, and finally by defense mobilization traffic levels. The coastal reaches were evaluated primarily by their potential for coal exports. Table VI-8 displays the traffic and commodity data used for all but defense framework development.

Once the reaches were organized according to their relative contribution to national goals, projects within each reach were separated into those which maintained safety and reliability and those which simply improved the system by enhancing efficiency and adding capacity. Within these two subdivisions, proposed actions were further classified according to the problem(s) they addressed, in the following order: (1) Primary Constraint, (2) Secondary Constraint, (3) Congested, and (4) Obsolete.

FRAMEWORK OPTIONS FOR PEACETIME CONDITIONS

Shallow Draft and Great Lakes Studies

Organizing reaches with respect to their contributions to various national goals provides a guide for project implementation. Table VI–9 displays three options based on the following criteria:

Table VI–9

PEACETIME FRAMEWORK OPTIONS FOR SHALLOW DRAFT AND GREAT LAKES SYSTEM ACTIONS[1]

Economic-Total Domestic Traffic Flows

Maintain	Improve
	Lock 26—new*[3]
Ohio River System and Tenn R	
Gallipolis[1]	McAlpine[1]
Emsworth[2]	Newburgh[1]
Montgomery[2]	Uniontown[1]
Dashields[2]	Lock 52[1]
Kentucky[2]-Tenn	Lock 53[1]
Lock 7-Mon	Deepen Channel[2]
Lock 8-Mon	
Lock 3-Mon	
Lock 4-Mon.	
Winfield-Kan.	
Marmet-Kan	
Great Lakes System	
Welland Locks[3] (Canadian)	Sault Ste Marie[2]
Gulf Coast-West	
Harvey[2]	Algiers[2]
Calcasieu	
Lower Upper Miss· See Ag.	
Gulf Coast-East	
Inner Harbor[3]	
Mobile River and Trib. See Energy	
Illinois Waterway: See Ag	
Columbia-Snake Waterway. See Ag	

Energy Self Sufficiency and Export-Coal Shipments

Maintain	Improve
	Lock 26—new*[1]
Ohio River System and Tenn. R	
See Economic	
Great Lakes System: See Economic	
Mobile River and Trib	
Oliver[3]	Demopolis[1]
	Coffeeville[1]
	Warrior[3]
	Holt[1]
	Bankhead[4]
	Modify Channel[2]
Lower Upper Miss See Ag.	
Illinois Waterway See Ag.	
Upper Miss: See Ag	
Gulf Coast-East: See Economic	

Agricultural Exports-Farm Product Shipments

Maintain	Improve
	Lock 26—new*[1]
Upper Miss.	
Lock 22[1]	
Lock 21[2]	
Lock 24[2]	
Lock 25[2]	
Lock 18[1]	
Lock 20[5]	
Locks 2-17	
Illinois Waterway	
Marseilles[1]	
Peoria[1]	
La Grange[1]	
Lockport[2]	
Brandon Road[2]	
Dresden Island[2]	
Starved Rock[2]	
Ohio River System and Tenn R	
See Economic	
Lower Upper Miss [6]	
	Lock 27[2]
Columbia-Snake Waterway	
Bonneville[5]	

1 Maintain column includes locks evaluated in Section V which are old with a high level of utilization in year 2003 Improvements to these lock sites are designated by footnotes which identify problems being addressed—congestion or constraining Improvements to locks not exceeding their 50 year life by 2003 are shown under the improve column *Lock 26-new is the only lock identified which significantly and singly has an impact upon national goal achievement and therefore warrants treatment outside its reach
2 Congested—Locks in use over 80 percent of time during their operating season under two or more forecasts
3 Constraining—Locks in use over 100 percent of time during their operating season under two or more forecasts
4 Congested under one forecast out of six peacetime forecasts
5 Constraining under one forecast out of six peacetime forecasts Since traffic analysis was completed for forecasts using 1977 base data, tonnage doubled in 1981 to a level equal to five of the 2003 forecasts
6 If Domestic Farm Product flows were used instead of shipments, the resulting sequence for the agricultural export goal would be the Lower Upper Mississippi reach first, followed by the Upper Mississippi, Illinois Waterway, Ohio River System and Columbia-Snake Waterway

1. Economic growth — measured by domestic traffic flows
2. Energy self sufficiency and exports — measured by coal shipments
3. Agricultural exports — measured by farm product shipments

The following paragraphs discuss the contribution of selected congested reaches to the three goals. Only one project was identified and treated separately, the second new Lock 26 on the Lower Upper Mississippi River. It is forecast to restrict traffic as early as 1990. The greatest impact would be on agricultural and energy products.

Ohio River System

The Ohio carries more domestic flows than any other reach. It also ranks first in coal originations and third in grain shipments. Eleven actions were identified to maintain a reliable existing system. Paramount among these is Gallipolis Lock. The returns from improvements, whether for capacity or congestion, would be greater than for all other reaches.

Great Lakes System

The Great Lakes is second to the Ohio River System both in total domestic flows and coal shipments. Early consideration of Sault Ste. Marie Lock studies are important because of the magnitude of traffic involved. The highly congested Welland Locks, however, are Canadian; therefore, schedule acceleration is at that government's discretion.

Gulf Coast-West

The primary problem associated with the third-ranked domestic traffic reach, Gulf Coast-West, involves Harvey Lock. It exceeds its 50-year engineering design life by 1985, but no solution is possible under the existing schedule until 1995.

Lower Upper Mississippi

This reach ranks fourth in domestic traffic flows as well as coal and agricultural shipments. It serves the leading agricultural reaches of the Upper Mississippi and the Illinois Waterway and carries the second highest level of domestic agricultural flows in the United States. Only the downstream reach of the Mississippi from Cairo to Baton Rouge carries more. The primary constraint, Lock 26, becomes a national problem from not only from the agricultural perspective, but also from energy and total economics perspectives as well.

Gulf Coast-East

The Gulf Coast-East follows the Lower Upper Mississippi in total domestic traffic flows. Potentially, it could produce the earliest, 1985, primary constraint in the U.S. system; scheduled study plans fall far short of meeting the need on a timely basis.

Mobile River and Tributaries

The Mobile River and Tributaries reach ranks sixth in domestic flows and third in coal shipments. The technologically obsolete Oliver Lock requires prompt schedule acceleration. The potential for several other locks to reach constraining levels by 2003 and the use of larger tows which exacerbate the problem created by numerous bends suggest that all solutions be considered in a systems context.

Illinois Waterway and Upper Mississippi River

The Illinois Waterway, together with the Upper Mississippi System, collectively, are forecast to ship up to 60 percent of the U.S. waterborne farm products by 2003. Each would move half of the 68 million tons forecast for these reaches. This is up considerably from 1977 when the Illinois Waterway originated 15 million tons and the Upper Mississippi 11.5 million tons. Next to Lock 26 on the Lower Upper Mississippi, there is an urgent need, if agriculture is going to receive a high priority, to accelerate schedules on these reaches. The Upper Mississippi has the largest number of old lock sites of any reach. All but one lock on the Illinois Waterway, the T. J. O'Brien, is old and congested or constraining.

Columbia-Snake Waterway

The Columbia-Snake Waterway is fifth in farm products shipments. The major problems at Bonneville Lock of technological obsolescence and age are magnified by a current safety hazard. It is also forecast to be constraining under one or more scenarios.

NWS ranked the reaches in terms of their contributions to economic development, energy self sufficiency and export, and agricultural exports. As discussed above, the Ohio River System ranked first in both economics and energy, while the Upper Mississippi and Illinois Waterway reaches tied for first in agricultural shipments.

Project level studies should proceed in groups of projects closely interrelated by traffic flows (see Table VI–9). The main stem Ohio River, for example, would consist of the following groups: Gallipolis; Upper Ohio — Emsworth, Dashields, and Montgomery; the Lower Ohio — Locks 52 and 53, McAlpine, Uniontown, Newburgh, channel deepening plus Kentucky Lock on the Tennessee River; the Monongahela River — Locks 2, 4, 7 and 8; and the Kanawha River — Winfield and Marmet Locks.

Deep Draft Studies

Coal export was the primary criterion for organizing the coastal reaches. Other potentially benefiting traffic is represented by total exports and imports. The list displayed in Table VI–10 ranks the reaches: Middle Atlantic Coast; Lower Mississippi: Baton Rouge to the Gulf; Mobile River and Tributaries; and Gulf Coast-West. The great total volume moving through the Mississippi reach

Table VI–10
DEEP DRAFT PROGRAM

Reach[1]	Reach Share of Foreign Trade (Percent)			Study Status of Projects	Range of Projection Completion Dates[2]
	Coal Exports	All Exports	All Imports		
Middle Atlantic Coast	37	21	22	Underway	1989–1993
L Miss: B.R. to Gulf	14	24	16	Underway	1992–1997
Mobile River & Trib.	15	3	4	Underway	1993–1998
Gulf Coast-West	7	13	21	Underway	1995–2004
All Other Reaches	27	39	37	—	— —
Total	100	100	100		

1 Objectives served in the short run are coal exports In the longer term a mix of other imports and exports will ultimately contribute benefits to varying degrees These reaches are ordered by this long term potential See Section V discussion
2 Reach dates are based on status of most advanced project which was under study in 1982 The range reflects application of the median and mean times of 15 2 and 24 4 years

influenced its placement ahead of Mobile River and Tributaries.

FRAMEWORK OPTION FOR DEFENSE MOBILIZATION

Waterways are critical assets in effective defense industry mobilization. The success of a nation in military conflict depends on materiel production, transportation of materials for that production, as well as final delivery. The following paragraphs assess the Defense scenario and its affects on the peacetime framework options.

Impact of the Defense Scenario

Traffic demand in the Defense scenario included a 130 percent increase in the domestic movement of metals and ores, 46 percent increase in domestic petroleum flows, and 20 percent increase in domestic chemical flows over the High Use forecast for 1990. These commodities were concentrated in several coastal reaches, the Great Lakes, and in several inland reaches. Nationwide, nearly 70 million tons of traffic would not be served during the hypothesized mobilization.

Coastal reaches would be particularly affected by the increase of over 200 million tons of domestic petroleum and the decline of 53 million tons of imported petroleum. The net tonnage changes shown in Table V–8 for Alaska and the Washington, Oregon and California coasts are primarily petroleum flows from Alaska to the west coast. The entire Atlantic Coast, with its defense installations, experiences increases; the Middle Atlantic Coast alone has flows increasing by 32 million tons. Similarly, the Gulf Coast-West, with its petroleum refining and petrochemical complexes, shows increases in domestic traffic of 50 million tons while losing 24 million tons of foreign trade — primarly petroleum imports and agricultural exports. The Great Lakes System is exposed to the greatest single surge — 119 million tons — with most of traffic increase attributable to the steel industry inputs and outputs. Inland, two reaches show sizeable net increases — the Ohio River System and the Illinois Waterway. Both serve the iron and steel centers of the nation, Pittsburgh, Pennsylvania and Chicago, Illinois.

Defense Framework

System capability under circumstances where intensive use is imperative for defense industry mobilization, focuses attention on four reaches — the Great Lakes System, the Gulf Coast-West, the Ohio River System, and the Illinois Waterway. The options developed for peacetime conditions placed three of the four reaches into either the number 1 or 2 position. Therefore, they prominently serve one or more of the three peacetime goals — national economic growth, energy self sufficiency and exports, or agricultural exports. Each of these reaches (except the Gulf Coast-West) contain one or more sites which would physically constrain traffic under the assumptions of this mobilization scenario. Table VI–11 organizes the solutions to lock problems under the hypothesized mobilization according to net increases in domestic traffic. Conclusions regarding reach capability problems during the mobilization are summarized below:

1. Six locks on the Illinois Waterway would be congested during this emergency with Marseilles Lock constraining the traffic flow. The Illinois Waterway traffic mix serving the Chicago industrial complex includes not only the metals and ores but energy and chemical products.
2. The Ohio River System locks of McAlpine, Gallipolis, Montgomery and Emsworth would be congested, with Gallipolis Lock constraining. The Ohio River System defense contribution would be greater in the upper segments where locally mined metallurgical coal moves from mines to steel mills by water.
3. The Great Lakes System, according to the analysis, would be unable to move 72 million tons of the needed traffic during this mobilization. This failure is primarily due to capacity limitations at Sault Ste. Marie Locks which, under the peacetime forecasts, would be congested by the year 2003. Most

of this traffic would be iron ore destined for the steel mills. Over 59 million tons of metals and ores could not be served nationally.

4. Petroleum and chemicals on the Gulf coast contribute to congestion at Harvey, Algiers and Inner Harbor Locks.

5. Conditions on the Mobile River and Tributaries inhibit effective mobilization. Traffic in metallic ores for the regional steel industry would double. Oliver Lock is the most severe constraint.

If the emergency had been hypothesized under the High Coal Export or Miscellaneous forecasts rather than High Use, or later in the planning time frame, the number of constraints would increase.

The single project which is forecast to impact on successful defense mobilization more than any other single site or reach is the Sault Ste. Marie Locks site. Thus, if the peacetime framework options are adjusted for such a mobilization contingency, this site along with the second Lock 26 would be considered for rapid schedule acceleration.

An effective water transportation system is critical to U.S. defense. The mobilization evaluated by NWS indicated that generally shallow draft and Great Lakes problems during peacetime and defense mobilization were the same, only that timing differed. Water transportation's contribution to national defense cannot be measured by one structure or by total traffic, but must consider the entire system and the commodity substitution possibilities during an emergency.

SUMMARY FRAMEWORK

A summary framework for studies associated with shallow draft and Great Lakes reaches is presented in Table VI–12. Column 1 of the table merges the three peacetime and the defense mobilization frameworks. Column 2, after a revised organization of reaches, identifies the groups of projects which should be studied together. Column 3 gives the year the first problem within a study group was forecast to require a remedial action. Based on this earliest problem and on the status of ongoing studies, a fourth column was added to suggest the necessity of schedule acceleration at a rate greater than that afforded by the current planning-construction process.

Beginning with a summary such as this, a continuous modification process could and should be initiated. As detailed studies are completed, or as new problems surface, the framework and related scheduling could then be adequately adjusted.

FRAMEWORK RELATED WATER TRANSPORTATION EXPENDITURES, 1982–2003

Estimated expenditures (all costs in this section are expressed first in 1977 dollars with 1982 price level displayed in parentheses) to complete and support a reliable, safe and efficient U.S. navigation system through 2003 involve Federal first cost of about $9.2 billion ($13.6 billion) for USACE and $0.5 billion ($0.8 billion) for USCG. Annual USACE operations and maintenance costs associated with water transportation are estimated at about $458 million ($687 million) by 2003. Private and non-Federal landside investment in port facilities and investment in the vessel fleet are estimated to require as much as $63 billion ($95 billion) through 2003.

Table VI–11
LOCK CAPACITY ACTIONS FOR DEFENSE MOBILIZATION[1]

Reach (Millions of Tons Increase in Domestic Traffic)	Actions
Great Lakes System (137)	Welland (8 locks)[2] Sault Ste. Marie[3]
Gulf Coast-West (50)	Harvey[2] Algiers[2]
Ohio River System (29)	Gallipolis[3] Montgomery[2] Emsworth[2] McAlpine[2]
Illinois Waterway (21)	Lockport[2] Brandon Road[2] Marseilles[3] Starved Rock[2] Peoria[2] LaGrange[2]
Gulf Coast-East (8)	Inner Harbor[2]
Mobile River and Trib. (7)	Oliver[2]

1 Inland and Great Lake System reaches are organized by their contribution to domestic traffic increases under the hypothesized emergency in 1990
2. Congested under emergency
3 Constraining under emergency

Table VI–12

SUMMARY FRAMEWORK FOR U.S. SHALLOW DRAFT-GREAT LAKES[1]

Potential Investment Needs[2]		System Study[3]	Earliest Date Project Required[4]		Need for Process Acceleration[5]
Maintain	Improve		Aged	Congested	
L. Up. Miss	Second Lock 26	Lock 26	—	1981	Yes
Great Lakes (3)	Sault Ste Marie	Sault Ste. Marie	—	1990	Yes
Ohio River System and Tenn R (4)					
Gallipolis		Gallipolis	1985	1985	Yes
Emsworth Montgomery Dashields		Upper Ohio	1980	1990	Yes
Kentucky-Tenn.	McAlpine Newburgh Uniontown Lock 52 Lock 53 Deepen Channel	Lower Ohio and Tennessee	1995	1990	Yes
Monongahela-3, 4, 7 & 8		Monongahela	1980	—	Yes
Winfield-Kanawha Marmet-Kanawha		Kanawha	1985	—	No
Illinois Waterway (2) (4) and Lower Upper Miss. (3)					
Marseilles Peoria LaGrange Lockport Brandon Road Dresden Island Starved Rock	Lock 27	Illinois	1983	1985	Yes
Gulf Coast-West (2)					
Harvey Calcasieu	Algiers	Gulf Coast-West	1985	1995	No
Mobile River and Tributaries (1) (3)					
Oliver	Demopolis Coffeeville Warrior Holt Bankhead Channel Mod.	Mobile River and Trib	1989	1990	Yes
Upper Mississippi (1) (3)					
Locks 2–17 Locks 18, 20–25		Upper Mississippi	1986	1990	Yes
Gulf Coast-East (0) (3)					
Inner Harbor		Inner Harbor	1980	1980	Yes
Columbia-Snake Waterway (0) (2)					
Bonneville		Bonneville	1987	1990	No

1 Composite of four objectives — economics, energy, exports and defense
2 Reach is listed (first numeral) according to number of times it is listed among the leading four contributors to the four national goals in Tables VI–9 and 10 A second number, only if different from the first, reflects the number of goals it contributes significantly to, but need not be among the leading four
3 Studies are identified by the approximate geographical coverage, given the interrelationships between and within reaches
4 Earliest date any one need in a closely interrelated group of projects is exceeded Need is expressed when a lock exceeds its 50 year engineering life (aged) or 80 percent utilization (congested)
5. The existing civil works process (median time of 15 years) as applied to Table F–1, Appendix F requires process acceleration (Yes) or not (No) to meet earliest forecast

Federal Investments

The Federal investment requirements shown in Table VI–13 are categorized as those identified with completion of the existing system, those associated with maintaining a safe and reliable system and those associated only with improvements to the system's capacity and efficiency.

The first category involves those navigation projects under construction but not yet completed. These were considered as part of the existing system. Only funds budgeted to complete the projects after 1981 are included in this category. The first costs are estimated at $1,980 million ($2,866 million).

The second category includes project actions essential for maintaining a reliable system. Many of the sites are also projected to become congested and/or constraining before 2003. These conditions merely compound the reliability problem. All safety actions are considered in this category. Investment required to maintain a safe, dependable system is estimated at about $4,250 million ($6,375 million) for USACE and $500 million ($750 million) for USCG.

The third classification is limited to sites which are forecast to be highly reliable, but have the potential for becoming severely congested or constraining by year 2003. All deep draft actions are included in this category. The increment associated with this category is $2,919 million ($4,379 million).

For the entire period 1982–2003 the $9,149 million ($13,620 million) for USACE, which includes funding to complete the existing system, averages $435 million annually ($650 million), a figure nearly twice the 1970s decade level of $250 million ($375 million). The need to maintain a safe and reliable existing system will dominate USACE investment requirements through the end of the century — $4,250 million ($6,375 million) — compared to the improvement category level of $2,919 million ($4,379 million). Spread evenly over 21 years, $200 million ($300 million) or about 45 percent of all Corps of Engineers navigation investment would be associated with maintaining a dependable system, and $139 million ($209 million) or about 30 percent is linked solely with capacity and efficiency improvements. Completing the projects under construction would make up the remaining $94 million ($136 million), somewhat less than 25 percent.

Federal Average Annual Operations and Maintenance

The average annual Federal operations and maintenance costs, like investment, include costs associated the system currently under construction, costs associated with maintaining safety and reliability of the system in place, and those identified solely with expanding capacity and efficiency of the system. Since a breakdown of USCG costs allocated to commercial navigation was not available, only the incremental $17 million ($26 million) associated with problems displayed in Section V is presented. The Corps of Engineers costs are estimated at $458 million ($687 million). The added costs associated with completing the system are $11 million ($17 million). Maintaining the portion currently in place costs $392 million ($588 million). Nearly all the improvement costs estimated at $55 million ($83 million), are for new deep draft maintenance dredging. Compared to the 1970s level of Corps of Engineers funding, the framework program plus the system under construction shows O&M costs increasing by more than $100 million ($150 million), to $458 million ($687 million) compared with the 1970 level of $334 million ($501 million).

SUMMARY OF FINDINGS

The key findings from this section cover a breadth of areas, however they all contribute to one generalized conclusion: That is, changes to the status quo are essential if a safe, reliable and efficient waterway system is to be available to the users of the 21st century. These findings are:

— The 1970 decade level of funding, if extended into the future, would be inadequate to maintain system capability. The Corps of Engineers 1982–2003 budgets would fall short by nearly $200 million ($275 million in 1982 dollars) annually for construction and by more than $100 million ($150 million in 1982 dollars) for O&M.

— The median time required between initiation of a study until project completion is 15.2 years and the average time is 24.4 years. Reduction in this time is necessary if the majority of solutions are to be implemented in a timely manner.

— A program capable of solving most peacetime needs in a timely fashion, in most instances will serve the defense industrial mobilization requirements. However, solutions to some forecast defense problems would have to be placed on an accelerated schedule.

— Problems — Safety, reliability, efficiency, and capacity — within closely

Table VI–13
SUMMARY OF CORPS OF ENGINEERS COSTS TO COMPLETE, MAINTAIN AND IMPROVE THE EXISTING NATIONAL WATERWAYS SYSTEM
(Millions of Dollars)

Annual Operations and Maintenance[1]	1977 Dollars	1982 Dollars
Complete	11	17
Maintain	392	588
Improve	55	82
Total	458	687
Investment 1982–2003[2]		
Complete System	1980	2866
Maintain System	4250	6375
Improve System	2919	4379
Total	9149	13620

1. USCG incremental operation and maintenance costs above the current program are estimated to be $17 million ($26 million in 1982 dollars).
2. USCG investment for meeting safety problems discussed in Section V is estimated to be $500 million ($750 million in 1982 dollars).

interrelated sections of the waterway system (related by traffic flows and/or hydrology) should be studied together if system effectiveness is to be achieved

— Future reliability of channel dimensions and management of the costs of dredging and dredged material disposal will require continued improvement in interagency coordination relating to regulatory and environmental policies and fuel prices.

— Programs which monitor structural integrity of aging structures and detailed engineering and economic analyses may necessitate increased funding over time to cover the added effort associated with the aging system.

SECTION VII

NWS FINDINGS, CONCLUSIONS AND THEIR IMPLICATIONS

NWS FINDINGS, CONCLUSIONS AND THEIR IMPLICATIONS

FINDINGS AND CONCLUSIONS

The selected findings and conclusions discussed below are covered in detail in the preceding sections of this report and the eight technical volumes identified in Appendix H. These findings and conclusions are grouped into those associated with problems—capability analysis, framework formulation, and technical studies.

PROBLEMS

The capability of the national waterways to meet traffic forecasts was evaluated in terms of reliability, efficiency, capacity and safety. Efficiency for shallow draft and deep draft reaches was assessed separately. The findings and conclusions under the assumed defense mobilization involved all capability analysis categories and are discussed in contrast to the findings under peacetime assumptions.

Reliability

One hundred and five locks—97 U.S. and 8 Canadian—will have exceeded their 50-year engineering design lives by 2003. It is estimated that over half—56 locks—may require major rehabilitation or replacement in order to maintain the reliability of the navigation system. Forty-two of the aging U.S. locks are clustered on three reaches: Two of these reaches are responsible for half of the U.S. grain shipments, the Illinois Waterway and the Upper Mississippi; the third, the leading coal shipping reach, is the Ohio River System. About 30 of these aging locks are also forecast to have significant congestion (over 80 percent utilization) by 2003. Therefore,

SITE SPECIFIC ENGINEERING AND ECONOMIC STUDIES OF THESE AGING LOCKS SHOULD BE PURSUED—WITH EMPHASIS ON STRUCTURES IN REACHES WITH HEAVY TRAFFIC.

Efficiency

Forty-four locks (36 U.S. and 8 Canadian) will be significantly congested under one or more scenarios by 2003. Under the lowest forecast—which assumed limited improvements in agricultural productivity and coal exports less than experienced in 1981—27 locks are forecast to be congested. The remaining 17 locks become congested in another 5 to 10 years. Under all forecasts, congestion increases the costs of transportation. It is estimated that these inefficiencies could increase linehaul costs nationally by more than $1 billion a year over the 1977 level by the year 2003. The three reaches dominating reliability problems are the same for efficiency problems—the Ohio, the Illinois and Upper Mississippi. Again, coal and agricultural product movements are most affected. Therefore,

SOME LOCK CAPACITY EXPANSION WILL BE NECESSARY TO MAINTAIN OPERATING EFFICIENCY.

Capacity

Twenty-eight (20 U.S. and 8 Canadian) of the 44 congested locks would constrain traffic growth by 2003—that is, forecast traffic potential would exceed 100 percent of lock capacity (see Table V–2). The greatest potential adverse impact on traffic is on the Ohio River System where as much as 65 million tons could not physically be passed through locks. Assuming a single 1200-foot lock for Lock 26 on the Mississippi, traffic is forecast to exceed that structure's physical capacity by over 30 million tons. The major commodities affected by constraints are coal and grain. Therefore,

IF THE MINIMUM FORECAST TRAFFIC LEVEL IS TO BE SERVED BY 2003, ADDITIONAL CAPACITY WOULD BE NEEDED AT 14 LOCKS (28 LOCKS UNDER THE MAXIMUM FORECAST TRAFFIC LEVEL).

Safety

Two hundred and ten sites were identified as potential threats to personal well-being and property due to bridge clearance, alignment and other safety problems. These were predominately in reaches carrying high traffic levels and/or significant proportions of hazardous commodities. Sixty-nine sites were considered as problems requiring actions other than routine navigational aids. About one-quarter of these are on the Ohio River System. Most solutions are under the traditional jurisdiction of the U.S. Coast Guard, except for problems at 12 locks and one butterfly dam under the jurisdiction of the Corps of Engineers. Therefore,

EFFORTS TO MAINTAIN THE EXCELLENT SAFETY RECORD OF THE NATION'S WATERWAYS SHOULD CONTINUE.

Coastal Ports

The U.S. competitive position in the steam coal export trade from the Gulf and East coasts may be reduced because of the limited depths at ports potentially capable of servicing the world's fleet of deep draft vessels. Therefore,

PROMPT AUTHORIZATION AND FUNDING FOR SEVERAL PORTS CAN EXPEDITE COAL EXPORTS.

Defense

A major defense mobilization requirement would induce sharp increases in waterborne traffic of strategic materials such as primary metal products, ores, energy commodities and chemicals. The major sources of supply and production of these materials are accessible by the national waterways. The capability analysis under the defense scenario (evaluated for the year 1990) revealed that major congestion could develop at 24 locks—at 16 U.S. lock sites and at the 8 Canadian locks on the Welland Canal. Nationwide, the system may not be able to annually serve an estimated 70 million tons of the increased traffic—85 percent of it being metals and ores. The Great Lakes, because of capacity limitations at the Sault Ste. Marie Locks, are the most adversely affected, followed by the waterways serving the steel industry, which include the Ohio River System and the Illinois Waterway. Domestic petroleum shipments would substantially increase traffic affecting the entire Pacific Coast, the Gulf Coast-West and the Middle Atlantic Coast. Defense mobilization requirements may influence the timing of various waterway improvements. Therefore,

DEFENSE MOBILIZATION SHOULD BE INTEGRATED INTO ALL WATER TRANSPORTATION PLANNING AND INVESTMENT DECISIONS. ONE OR MORE DEFENSE MOBILIZATION SCENARIOS SHOULD BE EVALUATED TO DETERMINE WHETHER LOCK AND/OR CHANNEL DESIGNS ARE ADEQUATE TO ACCOMMODATE PRIORITY TRAFFIC. THE ADEQUACY OF LOCK AND CHANNEL CAPACITY AND RELIABILITY UNDER DEFENSE AND NON-DEFENSE CONDITIONS SHOULD JOINTLY INFLUENCE PROJECT FUNDING DECISIONS.

FORMULATION

Formulation of an approach to meet capability needs in a timely manner while supporting key national goals involved an assessment of the current planning-construction process, funding, and alternative management-investment strategies.

Timing

The time required from initiation of planning through the design and construction of waterway projects can average from 15 to 24 years. If the High Coal Export scenario would be realized, serious timing problems would occur—from 4 to 17 locks out of the 44 congested locks, and 54 of the 56 obsolete locks could not be completed on time. Defense mobilization problems would not be remedied. The existing process could also lead to a clustering of funding requirements within a 10-year period. Therefore,

MODIFICATION OF THE PLANNING-CONSTRUCTION PROCESS MAY BE NEEDED TO PROVIDE FOR ADVANCED PLANNING AND AUTHORIZATION; AND/OR ELIMINATE SOME OF THE STEPS IN THE CIVIL WORKS PLANNING-CONSTRUCTION PROCESS.

Funding

Continued funding at the rate experienced during the decade of the 1970s will lead to increasing transportation costs from congestion induced delays and to a reduction in the reliability of the national waterway system. Aging structures will require funds for rehabilitation or replacement if the system is to be maintained. Discontinuing or reducing service on low volume navigation projects is not likely to release adequate funds. Costs for construction of all projects within the Corps of Engineers program in the NWS framework are estimated at $7 billion in 1977 dollars ($11 billion in 1982 dollars). Together with the $2.0 billion in 1977 dollars ($2.9 billion in 1982 dollars) estimated to complete the projects currently under construction, the annual Corps of Engineers expenditure rate for construction (which includes major rehabilitation) from 1982 to 2003 could be as much as $435 million in 1977 dollars ($650 million in 1982 dollars). This compares to the level realized during the decade of the 1970s of about $250 million in 1977 dollars ($375 million in 1982 dollars). Some deferral would occur if lower traffic levels are realized. Therefore,

FUNDING ABOVE THE LEVEL REALIZED DURING THE 1970s DECADE WILL BE REQUIRED TO MEET PROBLEMS IDENTIFIED BY NWS.

Dredging and Dredged Material Disposal

The rapidly increasing costs of dredging and dredge material disposal experienced during the 1970s decade were closely linked to environmental and other regulatory policies and increasing fuel prices. Therefore,

CONTINUED ATTENTION TO COST MANAGEMENT AT THE AGENCY LEVEL AND TO REDUCTION, CLARIFICATION AND

COORDINATION OF ALL REGULATORY AND ENVIRONMENTAL POLICIES IS NECESSARY. MAINTENANCE FOR A RELIABLE SYSTEM AT A REASONABLE COST REQUIRES CAREFUL BALANCING OF ENVIRONMENTAL AND REGULATORY POLICIES.

TECHNICAL STUDIES

Shippers, Carriers, Ports and Terminals

Most transportation decisions relating to bulk commodities which could be shipped by waterways are an integral part of long-run shipper logistics decision-making processes. Modal choice is a stable part of a shipper's long term investment strategy. Capability of navigation and predictability of cost levels contribute to sound long range business planning. Therefore,

DECISION MAKERS AT THE FEDERAL AND OTHER GOVERNMENTAL LEVELS NEED TO COMMUNICATE THEIR INTENTIONS CLEARLY AND IN A TIMELY FASHION (SUFFICIENT FOR INDUSTRY'S LONG RANGE PLANNING).

Shippers will continue the practice of seeking the best combination of cost and service, and use each mode of transportation for the role that each plays best. The NWS traffic forecasts reflect the increasing role of pipelines for petroleum and an increasing railroad share of coal shipments as western coal fields increase output. Of the three modes—rail, pipeline and water—rail is the only mode forecast to increase its overall share from 1977 to 2003. The rail share which grows from 39 to 48 percent of total traffic under the NWS Baseline forecast, is primarily due to the increasing shipments of western coal. Therefore,

PLANNING, DESIGN, CONSTRUCTION AND MAINTENANCE PLANNING ASSOCIATED WITH TRANSPORTATION PROGRAMS SHOULD EMPHASIZE LOGISTICS NEEDS FOR EMERGENCY AND DEFENSE MOBILIZATION SINCE THE PRIVATE SECTOR WILL NORMALLY EMPHASIZE PEACETIME CONDITIONS IN ITS INVESTMENT PLANNING.

International competitiveness of U.S. exports in world trade requires maintenance of reliable, modern, and efficient deep draft system. The current inability of Gulf and East coast ports to handle 120,000 deadweight ton carriers may limit U.S. competitiveness. Therefore,

IF THE U.S. IS TO BE A SECURE SOURCE OF COAL FOR WORLD MARKETS, ITS COASTAL CHANNELS MUST BE MAINTAINED AND IMPROVED. THE ABILITY TO MAINTAIN AND INCREASE THE U.S. SHARE OF THE WORLD MARKET INCLUDES THE ABILITY TO OFFER SELECTIVE PORTS WITH DEPTHS CAPABLE OF SERVING THE EFFICIENT DEEP DRAFT COLLIERS.

Waterborne Commodity Traffic

Projected waterborne traffic shows continued growth under the six peacetime scenarios and one defense scenario. Overall projected growth for the 25-year period ending in 2003 ranges from 24 percent to 51 percent. The higher growth rate is directly related to growth in steam coal exports. Coal is the most rapidly growing commodity in waterborne commerce—NWS coal forecasts range between 125 and 280 percent growth from 1977 to 2003. Agricultural products were second in growth for the period ranging from 107 to 127 percent. Metals and ores were third in growth, increasing from 76 to 112 percent. Petroleum may, however, drop by as much as 37 percent by 2003 under 1977 levels due to greater reliance on pipelines and reduced imports. Therefore,

OVERALL, THE ENERGY, AGRICULTURE AND STEELMAKING SECTORS OF THE U.S. ECONOMY WILL CONTINUE TO RELY HEAVILY ON WATER TRANSPORTATION. THE ALASKA REACH, MOVING DOMESTIC PETROLEUM, AND MOBILE RIVER AND TRIBUTARIES, SHIPPING COAL, ARE PROJECTED TO INCREASE BY THE GREATEST PERCENTAGES. IN TOTAL TONNAGE, THE OHIO RIVER SYSTEM AND THE MISSISSIPPI RIVER BELOW CAIRO ARE THE LEADERS.

Over half of the U.S. agricultural exports (these exports contributed $43 billion to U.S. balance of payments in 1980) move by barge to export ports. Consequently,

THE INLAND SYSTEM LINKING TO EXPORT PORTS PLAYS A CRITICAL ROLE IN THE U.S. ECONOMY.

Commodities most influenced by an industrial mobilization for a defense emergency (a five-year, two front conflict assumed to end in 1990) were domestic petroleum shipments which increased by 206 million tons compared to non-defense traffic conditions in 1990. Declines in traffic were predominantly related to foreign trade. Petroleum imports fell by 53 million tons, followed by agricultural products exports with a 39 million ton loss.

THE BASIC COMMODITIES FOR DEFENSE MOBILIZATION—ENERGY, AND METALS AND ORES—ARE HEAVILY DEPENDENT ON WATER TRANSPORTATION—INLAND, COASTAL AND GREAT LAKES.

Environmental Issues

Environmental effects of lock rehabilitation or replacement are related to the construction itself and are relatively short term. However, larger locks and channel modifications which add capacity may increase environmental impacts because of the increased dredging involved and the subsequent increase in size and number of tows. Dredging and dredged material disposal were identified as a major environmental constraint not only to sustaining an efficiently operated navigation system, but also to improving it.

CONTINUED EFFORTS TO MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS FROM NAVIGATION-RELATED IMPROVEMENTS AND MAINTENANCE ARE NECESSARY; MODIFIED DESIGN, OPERATION AND MANAGEMENT PRACTICES ACT TO CONTROL ADVERSE IMPACTS.

Multiple Purpose Water Use Issues

Navigation is one of many uses of the nation's waterways. Some tension between navigation and other water uses will continue during periods of high and low streamflow. However, improvements for navigation and other purposes also complement each other. Therefore, the Federal role in multiple purpose river basin development and management is the most effective means to balance competing water uses affecting interstate commerce. A potential conflict may result from increases in upstream irrigation on the Missouri River. This would affect both the Missouri River and the Mississippi River below the mouth of the Missouri. Increasing upstream uses are likely to compete with navigation on the Appalachicola-Chatahoochee-Flint system.

IMPLICATIONS OF FINDINGS AND CONCLUSIONS

The NWS findings and conclusions have serious implications for future navigation planning, policy and programs. The funding and timing implications are discussed in substantial detail, and are followed by coverage of a mix of issues ranging from defense mobilization analysis through intensified engineering studies programs.

APPROACH TO PLANNING AND PROGRAMMING

The NWS found that increased navigation funding will be necessary to maintain physical waterway capability under a variety of projected peacetime and defense mobilization conditions. Waterways also support several important national goals. With adequate capacity, the nation's waterways will continue to be a low cost and low energy using mode. The proposed framework was designed to provide a viable waterway system to meet the needs of the 21st century and allows for varying investment emphases. The summary framework for shallow draft and Great Lakes solutions with study and timing implications is displayed as Table VI–12. The funding requirements which follow are summarized first in 1977 dollars, the base year for analysis, and then the 1982 dollar level is shown in parentheses. The estimated USACE funding requirements for projects for the 1982–2003 period are $7.2 billion ($10.8 billion) for investment in those projects in the framework and selected port deepening, plus $2.0 billion ($2.9 billion) to complete projects under construction, for a total of $9.2 billion ($13.6 billion). If this $9.2 billion ($13.6 billion) were distributed evenly over the 21 years, $435 million ($650 million) would be required annually, about $200 million ($300 million) higher than that expended in the 1970s decade. Total O&M is estimated to increase to about $458 million ($687 million)—about $100 million ($150 million) above the level experienced during the 1970s decade. This is due primarily to new projects now under construction and channel modification projects suggested in the framework. Figure VII–1 displays the estimated navigation funding for the Corps of Engineers for the period 1982–2003.

Any practical approach to planning and programming must incorporate sufficient flexibility to respond to changing policies and priorities and to changing traffic patterns. As displayed in Tables VI–9 and 11, the prominence of specific investment emphases can have an impact upon the urgency of various potential projects. Emphasis on agricultural exports would accelerate improvements in the Upper Mississippi, the Illinois Waterway and the Lower Upper Mississippi. A focus on coal would shift emphasis to the Ohio River System and Mobile River and Tributaries along with improvements of coastal ports. The NWS framework can support the existing budget formulation process since the long range budgeting process used by the Corps of Engineers was designed to operate to highlight projects which are responsive to Federal policies. The NWS framework addresses only the physical requirements of the system, as projected.

POLICY AND PROGRAM CHANGES

Implementation of a national framework concept to guide decision making will require several policy and program changes. These are discussed below.

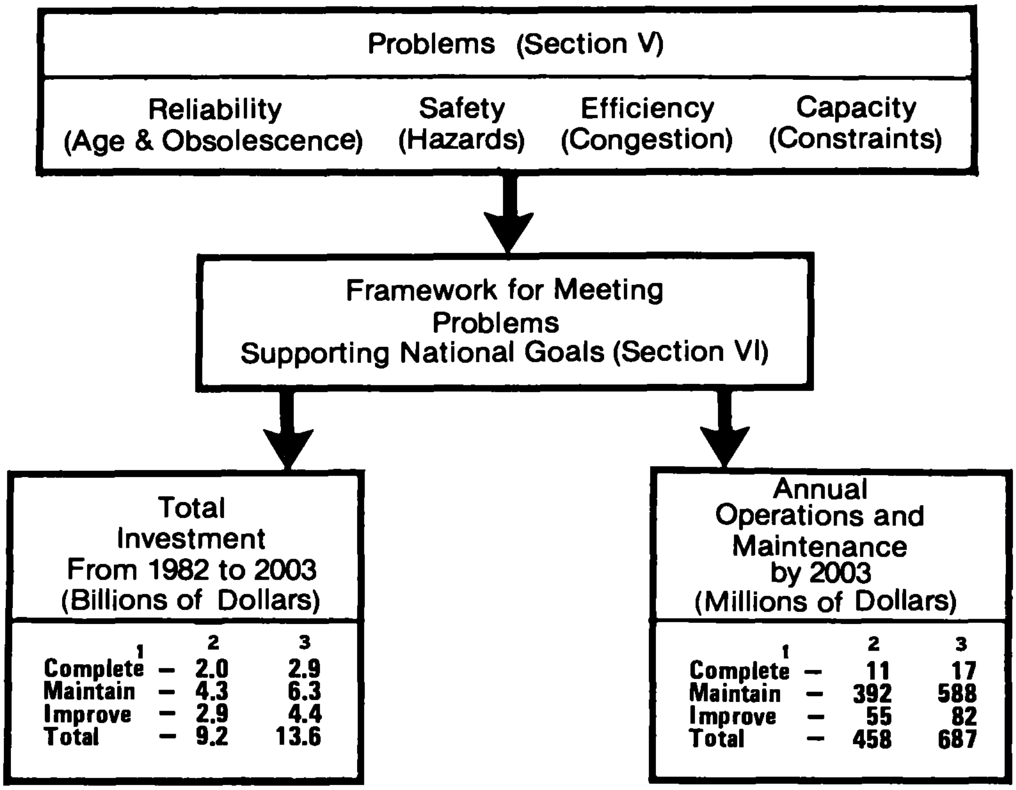
Goal Selection

The national goals supported by the nation's waterways include:

1. Economic growth
2. Energy self-sufficiency
3. Export promotion of agricultural products and coal
4. National defense

Criteria used by the NWS were responsive to these four goals and are important to total program development. Navigation projects, however, recommended for construction by the Corps of Engineers are formulated and evaluated according to criteria contained in the *Principles and Guidelines*. The basic criterion there is to contribute to national economic development. Any plan would be subject to environmental statutes, however.

Figure VII-1
NATIONAL WATERWAYS STUDY: ESTIMATED NAVIGATION FUNDING FOR CORPS OF ENGINEERS -- 1982-2003



1. **Projects under construction in 1981.**
2. **1977 dollars**
3. **1982 dollars**

Civil Works Project Processing

Civil works projects take an average of 24 years, or 15 years median (see Figure VI–1), from initial study resolution through the completion of construction. Large projects may take longer for construction. A substantial portion of the lapsed time for all projects, however, is spent awaiting funds (from 3 to 10 years). If projected traffic levels materialize, it does not appear possible that the construction would be in place in time to alleviate serious congestion and maintain the reliability of the waterway system. The process can be accelerated by:

1. Reducing the time-lapse within each step. Some potential changes which should be considered include:

   a. Federal interagency coordination: Agreements of understanding between the Army, the Department of Interior's Fish and Wildlife Service, and the Environmental Protection Agency could be modified to expedite report processing.

   b. State-Federal interagency coordination: Federal authority over maintaining and improving navigable waterways serving interstate commerce should be retained. The coordination procedures necessary to comply with state and local regulations should be changed to allow realistic, but fair time limits.

   c. Higher levels and more timely funding for high priority projects will be required to maintain a viable waterways system.

   d. Authorize the Secretary of the Army, acting through the Chief of Engineers, to undertake modifications of existing structures which are necessary to provide adequate facilities for projected navigation needs.

2. Fund high priority projects for Advanced Engineering and Design (AE&D) while the feasibility (survey) report is undergoing administration or congressional review. This readies the project for construction start in the shortest possible time by maintaining momentum associated with the survey. This technique, begun in Fiscal Year 1982, should reduce the project completion time by several years.

3. Adopt briefer, modified procedures for satisfying National Environmental Policy Act (NEPA) requirements.

STUDIES FOR FRAMEWORK DEVELOPMENT

In order to complete a national framework and update the NWS framework, several major study efforts are needed:

Deep Draft

Continue the port and channel actions to deepen U.S. ports which are now underway. Some coastal reaches may have potential to provide internationally competitive deep draft (50–55 feet) coal ports. Port studies should be integrated into a national framework for future port development.

Defense Mobilization

Industrial mobilization to support defense emergencies should be an integral part of all water transportation planning and budgeting. The limited analyses performed in the NWS were sufficient to indicate the importance of the nation's waterways to defense mobilization and the potential problems which could result from mobilization. Several defense scenarios should be assessed systematically and every navigation project evaluated for its response to mobilization requirements.

Operations and Maintenance

Marginal Projects

Further work on determining criteria for allocating O&M funding is desirable. Over time some navigation projects experience increased use, while others remain relatively constant and some lose traffic. The result is that the unit O&M costs of some projects increase. The Corps of Engineers maintains an ongoing surveillance program which identifies the marginal projects. Decisions to reduce operation and maintenance should continue to evaluate savings to shippers, alternatives for shipping, other water resource uses and other public interest issues including defense mobilization.

Dredging and Dredge Material Disposal Coordination

Dredging and dredge material disposal have become increasingly complex because of the restrictions associated with environmental and other regulatory policies—Federal and non-Federal. The Federal responsibility under the Interstate Commerce clause of the U.S. Constitution requires that the Federal Government maintain waterways for free flow of interstate commerce. To provide for this, further work on streamlining coordination procedures among Federal, state and local regulatory bodies regarding Federal dredging is necessary. The jurisdictional limits of Federal and non-Federal agencies should be clearly established to protect the integrity of the waterways for interstate commerce and to protect the environment.

Engineering

Over 100 lock structures will be older than their engineering design lives by 2003. Many of these locks will also be heavily used as traffic increases. As a result of both factors, the engineering review program of these locks will become more important. The Corps of Engineer's program of engineering technological development for rehabilitation and replacement, should be similarly expanded to accompany the growing number of project reviews.

Periodic Framework Reassessment

A flexible approach to decision making requires not only periodic input from project studies as they are completed, but a conscious effort to periodically incorporate new traffic trends, projections, needs, and policies. In order to attain this flexibility several discrete review programs should be formalized:

- —Continuous monitoring and analysis of traffic trends
- —Periodic update of traffic projections
- —Periodic review of emerging and declining national objectives
- —Periodic reassessment of industrial mobilization scenarios for defense emergencies
- —Integration of findings from the above into an updated framework and, in turn, into the Corps of Engineers projected planning, construction and operations budget.

SUMMARY

The framework approach presented in this study may be used to identify an early action phase for waterway improvements or indeed to organize a complete program, but its value over the long run is in the process used in shaping the choices coming before decision makers. This emphasis on how choices are made gives the approach a resiliency which justifies the intent that it serve as a general guide to waterway initiatives that will extend through the year 2003.

ENVIRONMENTAL ASSESSMENT

NEED FOR NWS

Since the development of modern water transportation technology and infrastructure in the early part of the 20th century, water transportation has experienced tremendous growth. Much of the current navigation system was designed and constructed for smaller tows than are now commercially feasible. Physical deterioration of navigation support structures has reduced reliability and has contributed to delays. Increasing operations and maintenance costs for water transportation facilities have reduced funds which might otherwise be available for major repairs, rehabilitation, and new construction. Likewise, increasing costs for dredging actions, coupled with increased concern over the effects of dredging and dredge material disposal, have resulted in less dredging and reduced the ability to maintain channels at their authorized depths.

Recent legislation and regulations have increased intervention by opposing economic interests. The resulting litigation over compliance of navigation projects (i.e. Lock and Dam 26, Tennessee-Tombigbee Waterway) has further delayed modernization and improvements to the navigation system. A recurring issue in litigation centers around the incremental nature of navigation project evaluation. The existing planning process is often unable to cope with rapidly changing technology and market shifts. Incorporation of state and local government as well as public concerns and aims, in many cases not the same as national needs, may delay projects needed to attain national goals.

To improve waterways technology and better understand environmental effects of construction and operation of waterways actions, the Corps of Engineers initiated such programs as the Dredged Material Research Program (DMRP) and Environmental and Water Quality Operational Studies (EWQOS), and actively supported the Upper Mississippi River Basin Commission (UMRBC) studies and the Great River Environmental Action Team (GREAT). Along with these efforts, the NWS was initiated to develop an overall national analysis of the projected traffic which might use U.S. waterways, analyze the capability of the existing system to handle projected traffic, and evaluate various strategies for ensuring an effective water transport system.

The National Waterways Study was mandated in Section 158 of the Water Resources Development Act of 1976 (Public Law 94–587). It was the result of a growing awareness on the part of Congress, shippers, water carriers, the Corps of Engineers, and others that the nation's waterway system has developed without an overall plan. Each part of the overall system has been evaluated on the basis of basin, or in most cases, individual project analysis. This process does not allow for an overall assessment of system problems, needs, and opportunities. Variance among national, state, and local goals has delayed or halted projects important to national economic objectives. The NWS provides information about the nation's overall navigation system and projects needs through 2003, to supplement studies of individual projects.

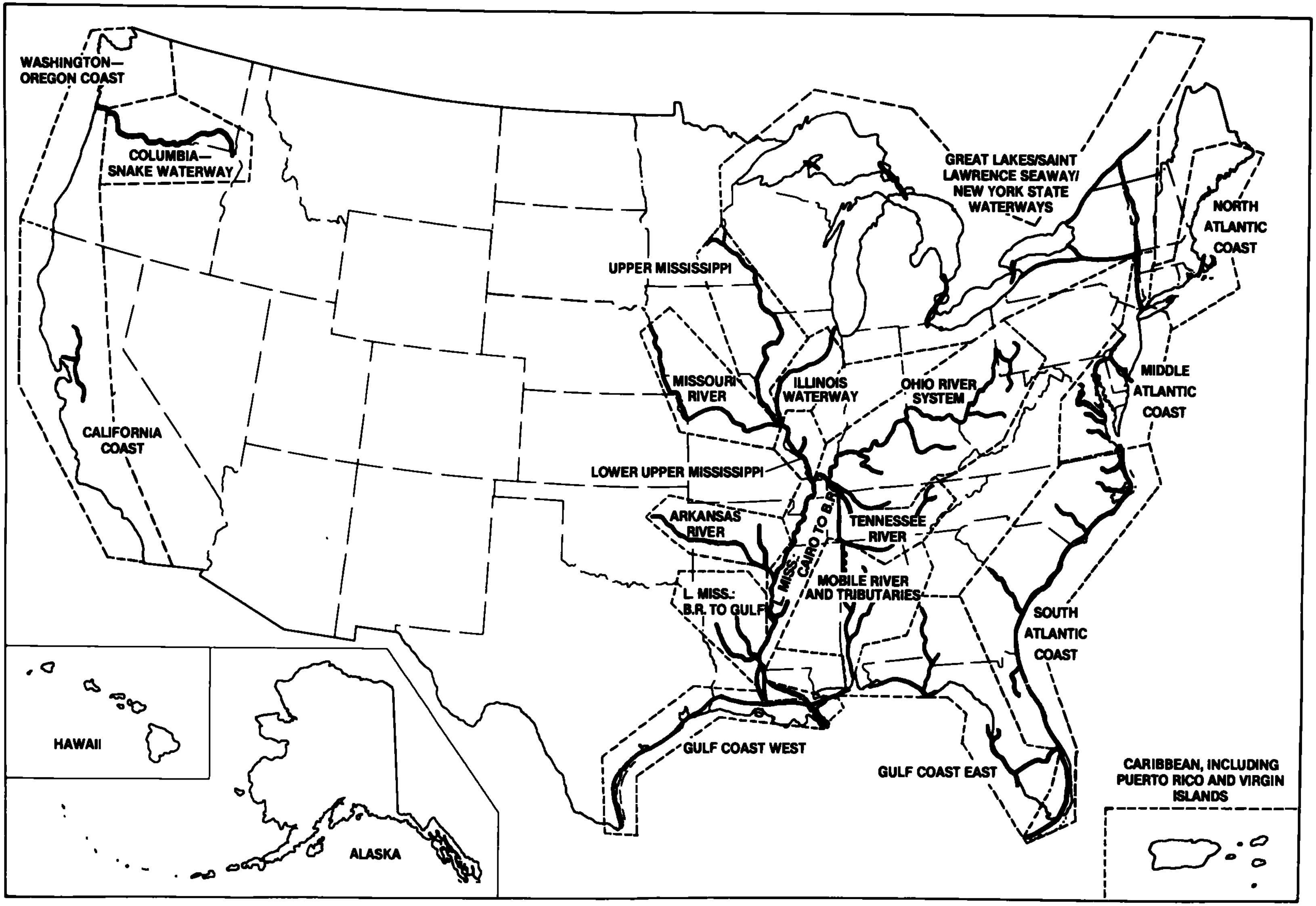
NWS BACKGROUND

The NWS was designed solely as a water transportation study, and considered other water uses and alternative transport modes only as they related to commercial water transportation. The study included extensive technical research and a series of reports. Traffic projections were based on seven future scenarios. Alternative strategies were formulated and evaluated to reflect various funding levels and management philosophies. Further information is in Sections I–VII of the NWS Final Report and supporting appendices and reports. Appendix H of the report contains a list of NWS publications.

WATERWAYS SYSTEM DEFINED

The basic waterways system for this study included the navigation system in use as of December 1978 plus commercial navigation projects then under construction in 1981. Projects under construction included the Tennessee-Tombigbee Waterway; the Red River to Shreveport, Louisiana; a new dam and a single 1,200-foot by 110-foot lock chamber to replace Locks and Dam 26 at Alton, Illinois; replacement of the Vermilion Lock on the Gulf Intracoastal Waterway in Louisiana; two replacement locks on the Ouachita River in Arkansas, another chamber at the Pickwick Lock on the Tennessee River; and completion of the regulatory works from Cairo, Illinois to Baton Rouge, Louisiana on the Mississippi River. For analytical purposes, the nation's commercially navigable waterways (including ports) were grouped into 61 segments. The 61 segments were aggregated into 22 "reaches" for reporting purposes (Figure EA–1).

Figure EA-1
NWS REPORTING REACHES



FORECAST DEVELOPMENT

Seven waterborne traffic forecasts were developed to reflect a range of future water transportation demands. Four reflect a combination of economic and policy assumptions to bracket normal peacetime conditions. A fifth forecast was developed in response to recent sharp increases in coal exports. A sixth forecast integrated recent individual project projections and corrections to base year tonnage. The final forecast reflected a substantial defense mobilization to support a two-front, conventional overseas war.

PROBLEM IDENTIFICATION

The NWS coupled an evaluation of the present system with a series of seven traffic forecasts. Problems were identified on a "worst case" basis to accommodate the uncertainty inherent in predicting future needs and technology (Figure EA-2). The NWS developed several categories to illustrate possible future conditions at lock sites during the study period. These categories included primary constraint sites, where lock capacity is insufficient to pass the projected tonnage for the reach; and secondary constraint sites, which would limit traffic only after primary constraints were removed, whereupon they would be constraining. Congested sites would allow traffic to pass, but are projected to be in use 80 percent of their theoretical capacity, causing significant delays and potential traffic limitations if problems occur at the site. Age, together with utilization levels and system compatability, was used as a predictor of potential reliability problems. Sites with problems which would be exacerbated by the hypothetical defense scenario were also identified.

STRATEGY AND FRAMEWORK DEVELOPMENT

The NWS was structured around potential future scenarios which reflect various assumptions and logical conclusions concerning policy environments in the future. The ability of the current system to handle traffic projected in the scenarios was evaluated. If existing lock capacity would not be able to serve projected traffic, if substantial congestion would develop, or if individual projects would be aged and obsolete, measures to address the problems were formulated. Four alternative strategies to reflect a range of possible management and funding philosophies were initially developed and evaluated. The Framework was developed by the Corps of Engineers after examination and evaluation of four initial strategies — policy or program approaches to projected water transportation problems. General categories of actions, and locations where major structural actions may be expected to occur under the philosophies and funding levels of each strategy are identified.

The four alternative management strategies developed during the contractor portion of the study to identify actions likely under the various management and funding philosophies were:

I Continue Present Trends with Fixed Real Budget;

II Refocus Present Resources on Present System;

III Refocus Expanded Resources on Present System;

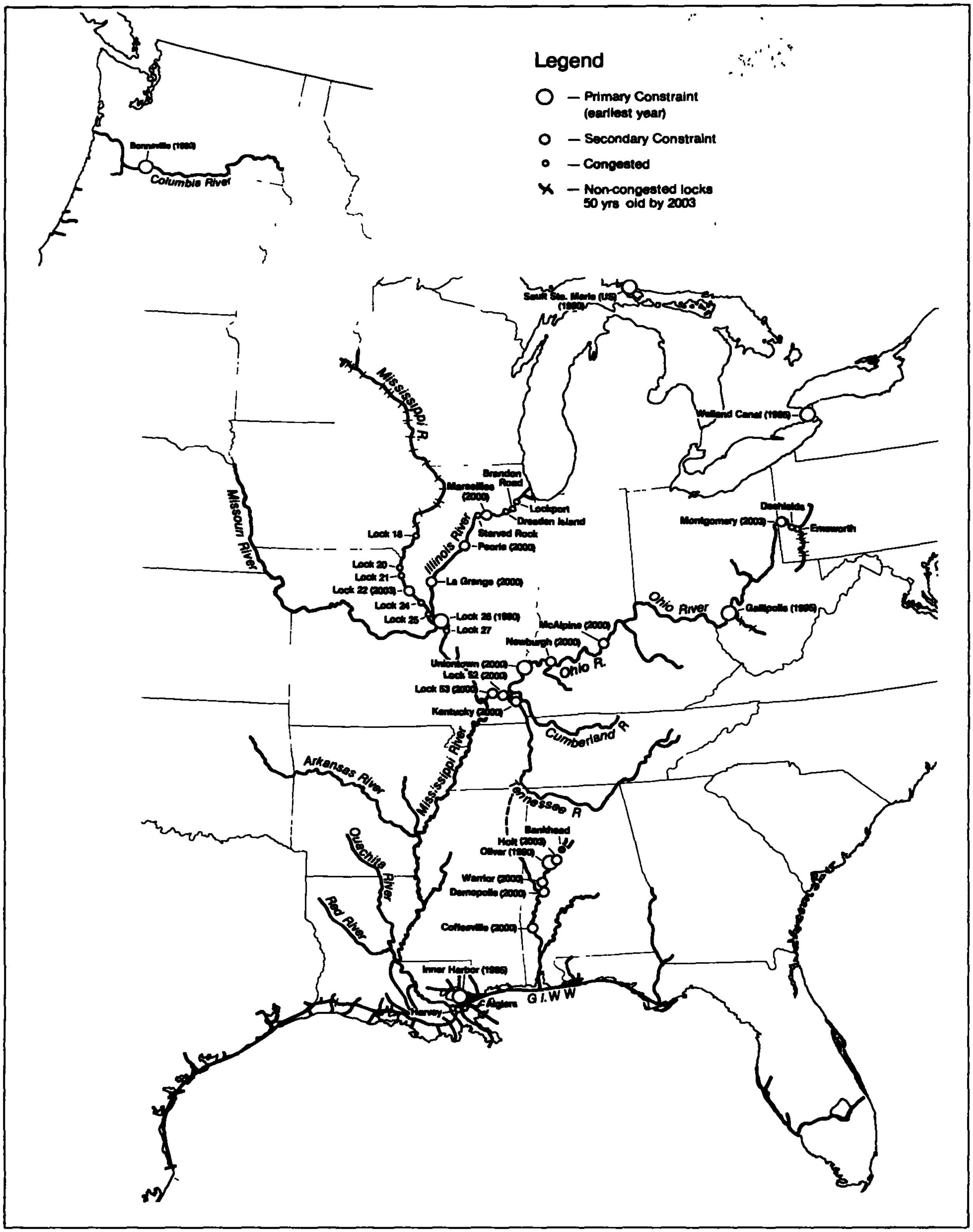
IV Improve the Waterways System.

A description of actions which might be necessary as a result of decision criteria illustrated by each of Strategies I–IV is presented in NWS technical reports, *Evaluation of Alternative Future Strategies for Action* and *Findings and Conclusions* described in Appendix H. The framework and actions which may be needed are discussed in the NWS Final Report.

The strategies were formulated with certain philosophies in mind. Among the considerations was the concept of funds availability. Two major funding philosophies were used: a continuation of recent trends, and a liberal funding program to accommodate water transportation. Strategies I and II follow recent trends of limited funds, while Strategies III and IV, as well as the Framework, presume a willingness to invest more money than in the 1970s decade. Nonstructural and minor structural measures to increase effective lock capacity are assumed to occur under all strategies. These actions would increase capacity 10 to 20 percent. Incorporation of defense considerations into the strategies accelerates congestion rates and needs for capacity increases, particularly at Great Lakes, Illinois Waterway, and Ohio River System sites, and to a lesser degree at Mobile River and Tributaries and intracoastal waterways sites.

Strategy I focuses existing funding levels on operation, maintenance, and rehabilitation of the present navigation network. No deep draft actions were considered. If recent trends on shallow draft waterways continue, an increasing share of funds would be required for channel maintenance. The fiscal limits of Strategy I generally do not allow for major actions to increase capacity, relieve congestion, or improve safety. Major structural actions which might be expected under the decision rules of Strategy I include a second lock at Lock 26 on the Mississippi, and actions by Canada to increase capacity of the Welland Canal Operations, maintenance, and rehabilitation would continue, but funds would be insufficient to continue full operation of the water transportation network by the end of the NWS study period. Given the restrictive funding and allocation assumptions of Strategy I, neither major structural nor efficiency-capacity needs could be adequately met. Therefore, it failed to meet water transportation needs as directed in the enabling legislation Strategy I most closely corresponds to a "No Action" alternative on the basis that present waterways activities would not be significantly changed during the NWS planning period.

Figure EA-2
PREDICTED LOCK CONDITIONS BY 2003



Strategy II is subject to similar funding limits as Strategy I, but provides funds for necessary major structural actions by Federal abandonment of shallow draft navigation segments with high ratios of costs per ton-mile of commercial traffic. Cost per ton-mile ratios were developed for each analytical segment with shallow draft projects, and those segments were prioritized according to their ratios and placed into three categories, with funding for continuing operations and major construction going only to those projects in the upper category, i.e., those segments with low cost/ton-mile ratios. All ports and side channels with less than one million tons of annual traffic were also dropped. The strategy presumed that moneys saved by abandonment of Federal support for high cost and low volume waterways would be devoted to meeting needs of the major waterways and ports. No actions for safety or efficiency were considered. Major structural actions to increase lock capacity are projected for Lock 26, Welland Canal, Gallipolis, Uniontown, Demopolis, LaGrange, Peoria, Marseilles, and Lock 22. In addition, funds are expected to be available for operation, maintenance, and rehabilitation on waterways not abandoned. Deep draft improvements were not considered.

In general, Strategies I and II are alternative means of meeting water transportation needs subject to annual limits for waterway transportation expenditures. Under both strategies, the annual budget limit expressed in 1977 dollars is equivalent to the Corps' average annual navigation budget during the decade of the 1970s of approximately $585 million, consisting of $332 million operations and maintenance, and an average $253 million construction costs.

In constrast to Strategies I and II, Strategy III assumes that adequate funds would be available to meet selected water transportation problems. Major requirements known in 1977 for operations, maintenance and rehabilitation would be met as well as adequate physical lock capacity and a higher degree of navigation safety. Strategy III envisions major structural actions to increase capacity at up to 24 lock sites. As in Strategies I and II, congestion and safety needs were not considered. But for funding differences, Strategy III resembles Strategy I in that no drastic changes are proposed for water transportation. Replacement of structures obsolete in 1977 would be funded, as would the continued management of the existing system.

Strategy IV reflects a policy to reduce costs and improve the level of service for water transportation users. The strategy envisions a campaign to increase waterways capacity through channel enlargements and lock actions. Locks would be programmed for replacement when they reach 85 percent of capacity, rather than the 95 percent level assumed under Strategies I–III, and the Framework. Replacement of locks which were obsolete in 1977 would occur on reaches with extensive traffic. In all, some 54 locks would be replaced under this strategy. Four inland reaches, the main stem Ohio of the Ohio River System, the Upper Mississippi to Dubuque, Iowa, the Lower Upper Mississippi, and the Illinois Waterway would undergo deepening actions. All would be deepened to 12 feet except the 365 mile stretch of the Upper Mississippi, which would be deepened to 10 feet. The strategy envisions enlargement of channels in the Mobile River and Tributaries reach. In addition to meeting water transportation needs of additional lock capacity and safety, the strategy proposes actions to deepen several existing deep draft ports. Four ports are proposed for deepening actions along the Gulf and Atlantic coasts.

The Framework reflects findings from the evaluation of the existing system, the four initial strategies, and additional decision criteria developed during the technical studies. The Framework focuses on maintenance of the integrity of the existing water transportation system. The mainstem Ohio and the Mobile River and Tributaries reaches have been identified for studies of channel enlargement. The projected increase in coal exports may increase the likelihood of port deepening along the Atlantic and Gulf coasts. Following the logic of the Framework, 62 U.S. and 8 Canadian locks may undergo further studies for major structural actions. The Framework, using age, use, and technological compatability to indicate obsolescence, identifies 48 U.S. and 8 Canadian locks out of the 70 which will meet these criteria by 2003. Site specific studies to determine the actual condition of individual structures are anticipated prior to the actual 50 year age.

ENVIRONMENTAL EFFECTS OF WATER TRANSPORTATION

Alterations of natural watercourses to accommodate commercial navigation generally reduce the variety of natural habitats. Natural stream depths are seldom adequate for modern commercial navigation. Engineering efforts to provide dependable navigable depths have included dredging, river training, upstream reservoir releases, and canalization. Depths in coastal ports are maintained through engineering works such as jetties and breakwaters, as well as dredging. Effects of construction and use of waterways are varied, and depend on site-specific conditions.

DREDGING AND DISPOSAL

Construction and operation of any waterway will often entail dredging and the subsequent disposal of the dredged material. At the national scale of the NWS, only general statements can be made regarding environmental effects of such actions. The actions and their effects vary according to conditions at the site. Dredging itself generally induces only minor changes to the geomorphology of a stream. Conditions which result in shoals will continue to deposit materials, regardless of dredging efforts. Dredging is thus a short term means to remove or reduce an immediate problem. Long term cures must apply to the causes of shoal occurrence rather than reliance on symptomatic actions such as dredging. Only in very stable environments can dredging be viewed as an economically or environmentally feasible long term means to maintain navigable depths.

While dredging has little effect on the long term geomorphological situation, it can significantly affect the local biological community. The impact area of dredging itself depends on the nature of the dredging site. Considerations may include the nature of the waterway itself, the material to be removed, and water quality at the site. Dredging disrupts and removes benthos at the site, increases turbidity, and may resuspend sediments which will settle downplume, with the possibility of burying benthos there.

In a similar vein, the magnitude of disposal impact varies according to the type of disposal, and the nature of the disposal site. Several methods of disposal are practiced, including open water, island and shoal creation, open channel, nearshore, wetland replenishment, and terrestrial. Open water disposal is generally used if an appropriate disposal area is within economic distance, and if the material contains only minimal amounts of toxic materials, and low biological-chemical oxygen demand. Federal regulations identify parameters for open water disposal. In some areas of relatively shallow open water the material may be deposited so that shoals or islands are created. Research conducted in part by the Dredged Material Research Program (DMRP) has documented the ability of dredged material disposal sites to provide desirable habitat diversity (Smith, 1978). The significance of open channel disposal varies according to the the conditions of the receiving waters. In the Lower Mississippi, the suspended load of the river is such that there is very little difference between receiving waters and the disposal plume (US Army Engineer District, New Orleans, 1981). In receiving environments such as those found several hundred miles upstream in the Upper Mississippi, however, the sediment plume from open channel disposal would be discernable from the surrounding waters for several miles downstream (UMRBC, 1982, GREAT, 1980). Nearshore disposal creates a different category of effects; in areas with nearshore emergent vegetation, disposal of dredged material can disrupt, and may eliminate that vegetation and shallow water aquatic habitat. Along many waterways, shallower areas are very productive, and are vulnerable to short term disruptions such as disposal of dredged material. Disposal of dredged material may provide a means to mitigate other damages to the environment caused by past problems. In the Mississippi Delta of Louisiana, an agglomeration of factors — including natural rise of sea level, consolidation of sediments, and the absence of overbank deposits as a result of construction of flood control levees — are causing terrestrial and wetland habitats to submerge at the rate of approximately 40 square miles per year. Disposal of material in those disappearing wetlands may help to slow that trend. Terrestrial disposal has the least effect on the aquatic environment of current disposal options. In certain areas, terrestrial disposal offers only minimal long term impacts, and can provide successional stages of terrestrial habitat seres. This habitat variety can be particularly beneficial in areas where the natural river migrated across the floodplain, resulting in a series of successional stages. River training has served to limit the meandering of such rivers, and the enforced stability of the stream limits future natural initiation of successional stages. Dredge material disposal can provide, in a limited way, some semblance of the succession no longer possible along the regulated river. However, along waterways with very limited natural vegetation, where a narrow river corridor is the only source of natural terrestrial habitat, elimination of that habitat can extract a high price in habitat values. As such, dredge material disposal planning has many considerations in addition to consideration of general Federal regulations.

CONSTRUCTION

Alteration of a natural watercourse to provide depths sufficient to accommodate commercial navigation may follow several methods. The two most prevalent are channelization (lowering bed elevations through river training works and upstream reservoir releases) and canalization (raising water surface elevations through the development of a series of pools in a stair-step sequence). Alteration of a waterway may permit the colonization of the area by exotic organisms not originally found in the project area, as well as the expansion of indigenous residents whose requirements are better met by the altered conditions. Such increases are generally paralleled by a decrease or elimination of native species not adaptable to the changes. The relative value of the action may depend, in part, on the perceived value of those species whose populations are changed.

River training, used primarily in alluvial streams, tends to constrict channels, reducing the surface area (width) of a stream, and uses the energy of the flowing water to excavate a deeper channel. River training attempts to stabilize the river into a channel configuration which will minimize areas of deposition. Releases from upstream reservoirs may aid in maintenance of sufficient flows to maintain navigable depths, reducing flow extremes by storing runoff to be released during low flow periods. Channelization actions generally cut off biologically productive side channels and sloughs, directing the maximum flow and energy into the main channel. Although side channels would naturally be abandoned under natural conditions, additional channels would be created; this does not occur in a "trained" river. As such, river training tends to reduce both terrestrial and aquatic habitat diversity. River training actions tend to remove shallower shoal areas which would obstruct commercial traffic, but may serve as important feeding grounds. Removal may reduce aquatic habitat variety, resulting in reduction or elimination of species specialized for that habitat.

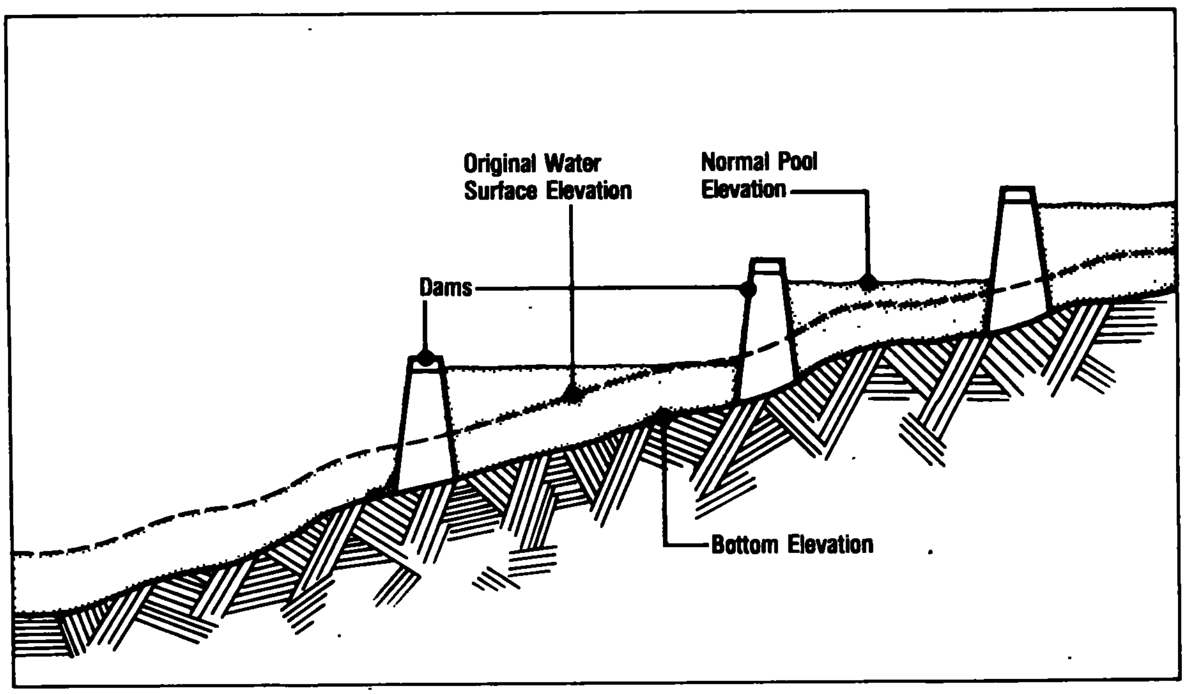
Canalization is generally used in streams where flows are not sufficient to maintain dependable depths, or in streams where the gradient is too steep for river training works to be effective. Dams are constructed to provide a series of pools (Figure EA–3) such that adequate navigation depths are ensured. Construction of the dams results in inundation of many low areas of the floodplain. While terrestrial habitat is lost, the raise in water surface elevations provides additional aquatic habitat, frequently in the productive photic zone. The raise in water levels may restore abandoned sloughs and side channels. Implementation of a 9-foot channel on the Upper Mississippi involved the construction of a series of dams, and aided in the restoration of the Mississippi Flyway's importance to migrating waterfowl. The dams themselves, however, may interrupt migration by aquatic species, and passage through alternative structures such as fish ladders may induce stress. On the Columbia and Snake rivers, the change from the natural flowing environment to a series of slackwater environments has hampered anadromous fisheries migrations. For juveniles migrating to the sea, the trip through the pools takes much longer than through undammed streams. Nitrogenation of waters downstream of the dams has resulted in injury and death to individual fish. Increasing awareness and cooperation between the operating agencies and conservation agencies is reducing the adverse effects of dams on anadromous fisheries. Construction of slackwater navigation facilities may allow installation of hydroelectric generation capacity, and the impoundments may provide recreational, water supply, and flood control uses.

Land cuts, such as used on the Panama Canal, the Erie Canal, and currently being used on the Tennessee-Tombigbee Waterway, have minimal effect on the existing aquatic environment, as none exists until the waterway is constructed. Such actions remove terrestrial habitat, replacing it with aquatic habitat. In addition, connection of two drainage systems may allow colonization by species existing in one watershed but not the other.

OPERATION

Operation of navigable waterways, while generally not responsible for the same magnitude of impact as construction, may cumulatively affect the natural inhabitants to a greater degree than the single perturbation of construction. In order to maintain navigable depths, flow extremes are generally moderated, with storage by upstream dams or the navigation dams themselves retaining seasonal high flows for release during periods when natural flows are at their lowest. Use of the waterway by commercial vessels may cause turbulence and subsequent resuspension of sediments. Wave wash from passage of vessels is

Figure EA-3
EFFECTS OF NAVIGATION POOLS



generally not as significant in bank erosion as wind-generated waves, however, some impact may be attributed to vessel passage. Fleeting operations may cause some deterioration of the aquatic habitat in the immediate area, and may result in public ire if the areas are such that scenic views are disrupted. Landside requirements for waterways operations result in some loss of terrestrial habitat, and docking and berthing facilities in the channel may adversely affect nearshore aquatic conditions. During waterway operations, accidental discharges and spills may occur. Transport of toxic materials on waterways generally poses fewer hazards to human safety than land based transport. While containment of pollutants released in waterways may be difficult to impossible, the dilutive capacity of the receiving waters tends to reduce adverse affects of accidental releases. Air quality degradation by commercial navigation is minimal; the large volume of commodity moved per vessel is such that comparatively few vessels are required to transport large volumes of commodity. Water routes tend to pass through generally undeveloped areas, reducing the cumulative negative contribution to regional air quality experienced by all transportation modes in more densely developed areas.

ENVIRONMENTAL IMPLICATIONS OF NWS

The NWS, in that it does not recommend specific projects for authorization, will have no significant impact on the human environment. Given its national scale and general nature, the study was not structured as traditional project-specific studies might be, and site-specific alternatives were not developed. Instead strategies developed during the technical research phase of the study were used to predict potential results of various water transportation philosophies. Conclusions derived from NWS research have been assimilated into a flexible framework, designed to alert planners and decision makers to possible water transport problems Although neither the NWS strategies nor the Framework act as site-specific alternatives in the traditional planning sense, for purposes of this document, they provide a useful vehicle to develop a conceptual analogue to a project study. In that vein, the strategies and the Framework will be compared with respect to general environmental considerations. The NWS does not propose a revolutionary change in project planning, rather, it is intended to introduce a national perspective for decision makers as project planning, authorization, and construction follow the traditional Corps of Engineers planning process. The NWS identifies locations where problems may occur and actions which may be necessary.

STRATEGY AND FRAMEWORK EVALUATION

Strategy I, "Continue Present Trends with Fixed Real Budget," in that it most clearly continues recent trends, is most analogous to a "No Action" alternative. Under this strategy, waterways actions would continue to be evaluated, funded, and implemented under current guidelines. Construction of a second lock at Lock 26 on the Mississippi River is the sole major structural action envisioned under the decision criteria of Strategy I. The strategy implies that major construction and safety actions would generally have lower priority than operations and maintenance, and most would not be performed. As a result, impacts of construction actions would be minimal when viewed at the national scale. Under conditions presumed by Strategy I, current annual dredging requirements of approximately 300 million cubic yards (c.y.) may be expected to continue. Although nonstructural managerial actions are expected to increase lock capacity by 10–20 percent, the projected increase in traffic on the waterways, coupled with the projected lack of needed safety actions, would increase the probability of accidental spills and collisions. Increasing waterway congestion may induce some commerce to shift to other modes. Transport by other modes would entail economic, environmental, and social consequences. Environmental implications of most aspects of this strategy under Corps of Engineers domain have largely been addressed in NEPA documents prepared for existing projects. Strategy I would not likely accommodate projected traffic, would permit sharp increases in congestion costs, and would not fully fund operations and rehabilitations past the turn of the century.

Strategy II, "Refocus Present Resources on Present System," would fund structural improvements on higher traffic segments by closing high cost waterways, minor ports, and side channels. Such "saved" funds would be devoted to replacement construction to increase capacity at constrained locks on more cost effective rivers. Lock 26 on the Mississippi, Gallipolis on the Ohio, and the Welland Canal Locks (Canada) on the Great Lakes would have major structural actions to increase capacity. Dredging requirements anticipated under Strategy II would be reduced from current average requirements by about 10 percent, approximately 30 million c.y., to 265 million c.y. No reliable scale exists to compare environmental significance between lock replacement and elimination of navigation support activities. Addition of lock chambers at existing dams would generally produce moderate, essentially short term environmental effects. Long term negative effects may be expected from increased traffic on busier reaches. Net environmental values may be generally enhanced by elimination of navigation on those segments, if other water uses such as water supply, low flow augmentation, and flood control can continue. However, cessation of Federal navigation support would eliminate water access to areas now dependent on water transportation service. Recently constructed waterways which have not reached their full traffic potential are among those which would lose service, thus the sizeable Federal investment and environmental alterations which have already occurred would serve no purpose. As a result of the abandonments, less traffic may be available to utilize the major waterways since smaller waterways generating part of this traffic would no longer be operational. Abandonment of navigation support on projects which were authorized for, or evolved to support multiple use raises the issue of payment distribution for the facilities if navigation monies are no longer provided. In areas where the entire project was built and is maintained by navigation funds, the continued operation and use of the project, and the potential demise of associated land uses which have developed as a result of the waterway are in question. Wright (1980) observed that extensive study may be appropriate prior to retirement decisions. From a limited "environmental quality" perspective, actions envisioned under Strategy II would likely have the fewest significant negative environmental implications; but the strategy would fail to fulfill water transportation needs, an explicit directive of the NWS.

Strategy III, "Refocus Expanded Resources on Present System," would increase funding to permit addition of lock chambers as projects reach physical capacity. In many philosophical respects, Strategy III resembles Strategy I in that no major alterations of the existing system are envisioned, but sufficient funds for operating, maintenance, and capacity needs are presumed to be available under this strategy. The strategy presumes a willingness to accommodate the increase in traffic forecast in the projections. No coastal port or channel enlargements are included. Construction of a second lock is anticipated at Lock 26. Gallipolis Lock on the Ohio would be replaced, and actions to increase lock capacity would be undertaken at Welland Canal (Canada), La Grange, Peoria, Marseilles, Demopolis and Oliver Locks. Under two forecasts, construction of additional capacity at Lock 22 on the Upper Mississippi River would occur. A total of 24 major lock capacity increases would be required under the highest use forecast. High priority safety actions would be funded under this strategy. Operation of all existing waterways will be continued. Dredging requirements expected under this strategy would remain very close to the current average annual requirement of approximately 300 million c.y. Environmental effects of this strategy would be similar to Strategy I with respect to dredging, but with substantially greater impacts from construction. Longer term impacts might be expected from increased traffic levels as a result of capacity increases.

Actions likely under Strategy IV, "Improve the Waterways System," include the most significant environmental effects of the strategies. It proposes lock replacement at 85 percent of capacity rather than 95 percent, as in the previous strategies, and replacement of locks obsolete in 1977. Channel deepening on 365 miles of the Upper Mississippi River (10 feet), the Lower Upper Mississippi River, Illinois Waterway, and Ohio River (12 feet) would occur. Portions of the Mobile River and Tributaries reach would be widened upon completion of the Tennessee-Tombigbee Waterway. Dredging requirements under Strategy IV would include the present average annual 300 million c.y., and add 40 million c.y. as it revives a large schedule of presently deferred maintenance dredging projects throughout the system, and would add additional annual dredging to accommodate the proposed port and channel deepenings. The strategy would fund all major and minor safety actions to reduce accidents and spills. Many of the actions which might be expected under Strategy IV would have major negative environmental implications, and would need extensive studies to comply with the National Environmental Policy Act (NEPA) and other environmental legislation and regulations. Several coastal ports are candidates for deepening actions. Negative environmental effects which may be expected from Strategy IV are the most extensive of the strategies.

The Framework contains a smaller construction and deepening program than Strategy IV, and incorporates decision criteria not used in the previous four strategies. The Framework was developed from the review and evaluation of contractor findings and incorporated pertinent considerations not in the original strategies. Many actions suggested in Strategy IV underevaluated regional and national environmental sensitivities which would likely delay or prevent project completion. Strategy IV, for example, recommends channel enlargement on four inland reaches: Ohio River System, Lower Upper Mississippi, Upper Mississippi, and the Illinois Waterway. The two Mississippi reaches and the Illinois Waterway have been the subject of a preliminary evaluation of possible channel enlargements. At the time of the study, deepening was not recommended (Corps of Engineers, 1973). Controversy associated with dredging and disposal on the Illinois and the Mississippi above Cairo was reflected in the GREAT I (1980) and UMRBC Master Plan (1982) efforts, none of whose findings supported channel enlargement. The Lower Upper Mississippi is constrained by potentially inadequate water quantities, and some question exists as to whether a dependable 12 foot channel could be maintained without enlargement of existing river training works. As most traffic on the Illinois Waterway connects with the Lower Upper Mississippi reach, a channel depth of 12 feet on the Illinois would serve little purpose if that reach would not allow passsage of 12 foot draft vessels. Channel enlargement on the three reaches would need to be interrelated to be effective, and present conditions make that unlikely.

The main stem Ohio, part of the Ohio River System, is also proposed for consideration of potential deepening actions. The Ohio River is nearing completion of a modernization program which has increased capacity on the system. According to all NWS forecasts, traffic on the Ohio will continue to rise. As the nearly completed system nears capacity, actions to alleviate congestion and increase capacity can either increase lock chamber size or number, allowing more vessels through in less time, increase channel depth, allowing more commodity per vessel unit, or both. In lieu of adding a third system of lock chambers, channel enlargement on the mainstem Ohio merits further investigation. Extensive study will be necessary to document existing conditions, as well as predict environmental and economic effects of the actions. Concerns may include dredging and disposal effects, and impacts on water quality, benthos, and aquatic and terrestrial habitats. As a result of past degradation the Ohio River aquatic community is very tolerant of alterations

Port deepening proposals in the NWS are limited to identification of NWS reaches where sufficient increases in water traffic are projected. Unlike Strategy IV, which identified ports for deepening, careful reexamination of NWS methodology reveals insufficient data to predict individual ports for deepening, only reaches where traffic forecasts reflect a future potential for port deepening. Port development is projected along the Gulf and Atlantic coasts. Environmental responses which may result from deepening actions include saltwater intrusions and alteration of salinity gradients in estuarine habitats. Ongoing environmental research is being performed at several ports in the two reaches, analyzing the current situation prior to development. Such studies will continue if port deepenings are to occur.

Dredging requirements anticipated under the Framework would include the current 300 million c.y. average annual dredging volume, plus an additional 64.5 million c.y. annually as a result of the proposed Ohio, Middle Atlantic, Lower Mississippi below Baton Rouge and other deepenings projected for the Gulf coast, for an average annual dredging requirement of about 360 million c.y. The Framework identifies 70 locks which may have need for future major structural actions. In addition, nonstructural management, as well as minor structural safety actions will continue to be required.

POTENTIAL ACTIONS: CATEGORIES OF EFFECTS

The NWS identifies 70 lock sites where projections indicate a demand for structural action during the NWS study period. In addition, several channel enlargement options were considered. Construction actions which might result from needs forecast by NWS can be generically aggregated into three categories according to their potential effects on the existing natural environments.

Replacement of existing locks with structures of equal capacity would entail short run construction-related effects. Traffic levels, and the level of effects would not change. Twenty-six lock sites where such actions may be appropriate are identified in the Framework.

Replacement of existing locks with structures of greater capacity would entail construction impacts as mentioned above, and may cause additional environmental effects due to additional increases in traffic. The Framework identifies 44 lock sites which may experience such effects, should site specific investigations confirm NWS projections of demand.

Actions to increase channel dimensions comprise the third category of effects. Channel enlargement actions would involve benthic community habitat losses, and dredge material disposal problems. Excavation activities would disrupt biological community structure in both dredging and disposal areas. Maintenance of the deeper channel would increase any adverse effects related to dredging and disposal. Since capacity would be increased, adverse effects relating to traffic increase would occur. The Framework identifies two inland channels, the main stem Ohio River, and the Mobile River and Tributaries reach below Demopolis, Alabama, as potential reaches where efficiency could be improved with selective channel enlargements. It also identifies the efficiency potential of deep draft channel enlargements along the Gulf and Atlantic coasts.

NEPA documentation has been prepared for all existing navigation projects, in the form of operation and maintenance EIS's, as well as construction EIS's for those projects completed after 1970. NEPA documentation for the NWS in no way is intended to satisfy requirements for site specific NEPA evaluation and documentation. Site specific NEPA documentation will be prepared for projects at a far greater level of detail than possible at the national scale of NWS. All navigation projects which are identified as potential construction candidates by the NWS will comply with NEPA and other applicable legislation and regulations prior to initiation of construction.

COORDINATION AND PUBLIC INVOLVEMENT

Public involvement has been an important part of the NWS study. Through information bulletins, public meetings, agency briefings, and technical reports, the study has benefited from an active exchange of ideas with a wide variety of interested organizations and individuals. The NWS has spawned a number of professional papers and presentations, reviews of which have further added to the content of the study.

Agency coordination for the NWS has been accommodated by the existence of an interagency Steering Committee, headed by the NWS Study Director, the Deputy Director of Civil Works. Members from other Federal agencies have included representatives from U.S. Departments of the Interior, Transportation, Commerce (Maritime Administration), and the Council on Environmental

Quality. The Steering Committee has been an important part of NWS, providing policy guidance throughout the study.

Due to the general nature and the national scale of NWS, formal coordination with state and local governments and agencies normal in project planning has not been possible. They have, however, been informed of the study's progress and direction through regional meetings and mailings, and many pertinent issues have been raised as a result of their interest. Normal coordination with those agencies and publics will be a part of any future project planning. Thirteen public meetings were held at various locations throughout the United States, providing broad geographic input (Table II–1). In addition, the NWS has sponsored meetings for various interests groups, and its staff members have given numerous presentations throughout the country for different trade organizations, professional associations, and other Federal, state and local agencies. Further information on the NWS public involvement effort is found in the document *National Waterways Study Public Involvement Program.*

LIST OF PREPARERS

The following individuals were primarily responsible for preparation of this assessment Background material prepared during the contractor portion of the study was the province of Messrs Thomas Week and Brook Crossan of Louis Berger and Associates, and Mr Jim Levine of A T Kearney Management Consultants

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Dr. Lloyd G Antle	Economist	3 yrs, Louisville District, 3 yrs, Office of Appalachian Studies, 13 yrs, Institute for Water Resources, 4 yrs, Chief, Research and Development Division, 2 yrs, Chief, National Studies Division.	Study guidance and administration.
Mrs Arlene L Dietz	Economist, Water Resource Planner	9 yrs, Chief Economist, Chicago District Managed inland and Great Lakes navigation studies, 5 yrs, Institute for Water Resources	NWS Study Manager, study development
Mr. David V Grier	Transportation Geographer	1 yr, Florida State Department of Transportation, 3 yrs, Institute for Water Resources	Public involvement, Agency coordination
Mr. Dana B. Grover	Environmental Planner	3 yrs, Research Associate, Southern Illinois University, 2 yrs, Environmental Studies Section, St Louis District, 2 yrs, Environmental Planner, Institute for Water Resources.	Resource descriptions, effects on fish and wildlife habitat, geomorphology
Mr. Leonard Crook	Engineer	8 yrs, Chief, Planning Branch, Panama Canal, 19 yrs, Board of Engineers for Rivers and Harbors, 14 yrs, Planning Director, Great Lakes Basin Commission	Federal policy review
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NATIONAL WATERWAYS STUDY

U. S. Army Corps of Engineers

FINDING OF NO SIGNIFICANT IMPACT

I have reviewed the Environmental Assessment (EA) prepared for the National Waterways Study (NWS) and have determined that the nature and extent of the environmental consequences resulting from the study will have no significant effects on the human environment. The National Waterways Study, using an interdisciplinary approach, examined the existing commercial water transportation system on a national scale, identified sites where problems are likely to occur through 2003, and proposed further studies for specific sites to outline appropriate actions and policy changes. The EA generically examined the environmental implications of the study. An extensive public involvement and coordination effort has been performed as part of NWS. The study is not intended to replace traditional project planning, but to provide a national overview to supplement the existing planning and appropriation process pursuant to National Environmental Policy Act (NEPA) documentation requirements. Since individual actions identified by the NWS will be evaluated at the project-level, this EA will comply with those requirements as well as those of the Council on Environmental Quality regulations (40 CFR 1500–1508), and an Environmental Impact Statement will not be prepared.

Forrest T Gay III

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APPENDIX A

NATIONAL WATERWAYS STUDY REACH AND SEGMENT DEFINITIONS

APPENDIX A

NATIONAL WATERWAYS STUDY REACH AND SEGMENT DEFINITIONS

Table A-1

NATIONAL WATERWAYS STUDY REACH AND SEGMENT DEFINITIONS

Reach Name	Description	Segment Name
1 Upper Mississippi River	Minneapolis, MN, to mouth of Illinois River	1. Upper Mississippi River
2. Lower Upper Mississippi River	Mouth of Illinois River to mouth of Ohio River (Cairo, IL)	2 Lower Upper Mississippi River (Illinois River to Missouri River)
		3. Middle Mississippi River (Missouri River to Ohio River including Kaskaskia River)
3 Lower Mississippi River: Cairo to Baton Rouge	Mouth of Ohio River (Cairo, IL), to Baton Rouge, LA	4. Lower Middle Mississippi River (Ohio River to White River) including Yazoo River.
		5 Upper Lower Mississippi River (White River to Old River)
		6. Lower Mississippi River (Old River to Baton Rouge)
4. Lower Mississippi River: Baton Rouge to Gulf	Baton Rouge, LA (including port) to Gulf and other channels and rivers	7 Mississippi River (Baton Rouge to New Orleans)
		8 Mississippi River (New Orleans to Gulf)
		25. Ouachita—Black and Red rivers
		26. Old and Atchafalaya rivers, (from Mississippi River to Gulf)
		27 Baton Rouge to Morgan City, LA, Bypass
5. Illinois Waterway	Chicago, IL (Chicago River Lock) to mouth of Illinois River	9. Illinois Waterway
6. Missouri River	Sioux City, IA to mouth at Mississippi River	10. Missouri River
7. Ohio River System	Heads of navigation to mouth	11 Upper Ohio River (confluence of Monongahela and Allegheny at Pittsburgh to Kanawha River)
		12. Middle Ohio River (Kanawha River to Kentucky River)
		13. Lower Ohio River—Three (Kentucky River to Green River)
		14 Lower Ohio River—Two (Green River to Tennessee River)
		15. Lower Ohio River—One (Tennessee River to mouth)
		16 Monongahela River
		17 Allegheny River
		18 Kanawha River
		19 Kentucky River
		20. Green and Barren rivers
		21. Cumberland River
8 Tennessee River	Head of navigation above Knoxville, TN to mouth	22. Upper Tennessee River and Clinch River (head of navigation to junction with Tennessee-Tombigbee Waterway)
		23. Lower Tennessee River (from junction with Tennessee-Tombigbee Waterway to Ohio River)
9. Arkansas River	Catoosa, OK (near Tulsa) to mouth	24 Arkansas River (including Verdigris, White and Black rivers)

Table A-1

NATIONAL WATERWAYS STUDY REACH AND SEGMENT DEFINITIONS **(continued)**

10. Gulf Coast-West	New Orleans to Brownsville, TX	28. GIWW West—One (from New Orleans, LA to Calcasieu River) 29 GIWW West—Two (Calcasieu River to Corpus Christi, TX) 30. GIWW West—Three (Corpus Christi, TX to Brownsville, TX) 34. Houston Ship Channel
11. Gulf Coast-East	New Orleans to Key West, FL	31. GIWW East—One (from New Orleans, LA to Mobile Bay including Mississippi River Gulf Outlet and Pearl River) 32. GIWW East—Two (Mobile Bay to St. Marks, FL) 33 Florida Gulf Coast (St. Marks, FL, to Key West, FL) 38. Apalachicola, Chattahoochee, and Flint rivers
12 Mobile River and Tributaries	Head of navigation to mouth	35. Black Warrior-Mobile Harbor (Black Warrior River—head of navigation to mouth, Tombigbee River—mouth of Black Warrior River to confluence with Alabama River, Mobile River to Mobile Bay, Mobile Harbor) 36. Alabama-Coosa rivers 37. Tennessee-Tombigbee Waterway
13 South Atlantic Coast	Key West, FL, to North Carolina/Virginia border	39. Florida/Georgia coast 40 Carolinas coast
14. Middle Atlantic Coast	North Carolina/Virginia border to New York/Connecticut border (includes Hudson River from Waterford, NY to mouth)	41. Chesapeake and Delaware bays 42 New Jersey/New York coasts (includes Hudson River to Waterford, NY)
15. North Atlantic Coast	New York/Connecticut border to Canadian border	44 North Atlantic Coast
16. Great Lakes System	Great Lakes, St Lawrence Seaway, New York State waterways, and connecting channels	43 New York State waterways 45. Lake Ontario and St. Lawrence Seaway 46 Lake Erie 47 Lake Huron 48. Lake Michigan 49. Lake Superior
17. Washington/Oregon Coast	Puget Sound to California/Oregon border	50 Puget Sound 53. Oregon/Washington coast
18. Columbia-Snake Waterway/Willamette River	Lewiston, ID, to mouth	51. Upper Columbia-Snake Waterway (Lewiston, ID to Bonneville Lock and Dam) 52. Lower Columbia-Snake Waterway (from Bonneville lock to mouth)/Willamette River
19. California Coast	California/Oregon border to Mexican border	54 Northern California (Oregon/California border to San Francisco Bay) 55 San Francisco Bay area, Sacramento River, and San Joaquin River 56. Central/South California (from San Francisco Bay to Mexican border)

Table A-1

NATIONAL WATERWAYS STUDY REACH AND SEGMENT DEFINITIONS (continued)

20. Alaska		57. Southeast Alaska (panhandle) 58. South central Alaska coast 59. West and north coasts of Alaska (including Aleutians)
21. Hawaii and Pacific Territories		60. Hawaii and Pacific Territories (includes Hawaii, American Samoa, Guam, and Commonwealth of Northern Mariana Islands)
22 Caribbean	Puerto Rico and Virgin Islands	61 Caribbean (Puerto Rico and Virgin Islands) 62. Rest of World (not included as a Reach)

APPENDIX B

NAVIGATION ENGINEERING; VESSEL CHARACTERISTICS; OTHER WATERWAY USES

NAVIGATION ENGINEERING; VESSEL CHARACTERISTICS; OTHER WATERWAY USES

This appendix provides a more detailed discussion of several topics which were discussed only briefly in the main report. First, aspects of engineering to provide a navigable waterway are identified; various methods of improving rivers to meet modern commercial water transportation needs are highlighted and explained. This appendix then examines the characteristics of the waterborne carrier fleet. Differences between vessels of the inland, Great Lakes and coastal areas are presented as well as discussions of terminal facilities and capabilities. Changes in the number and types of vessels, as well as apparent trends in recent years, are further analyzed.

ELEMENTS OF ENGINEERING FOR NAVIGATION

Most problems in alluvial rivers are indirectly or directly created by the movement and storage of sediments. Any solution involves the proper control of slope and the energy to move or store residual sediments. Most all modifications for navigation on rivers, including locks and dams, cutoffs, bank stabilization, realignment, and training structures, change the river's natural slope and, consequently, the sediment movement.

This section focuses on the problems scientists and engineers face in improving and operating an effective and reliable commercial waterway and port system. Effective waterways for commercial navigation are a result of system designs created in concert with the natural environment, manmade modifications and vessel characteristics.

There are a variety of manmade engineering modifications which help promote an efficient, safe and reliable navigation system.

— Efficiency improvements to reduce vessel drag and speed are obtained by modifying channel dimensions (widening and deepening) and alignments (straightening and training). Lock efficiencies to reduce vessel service time involve structural and nonstructural options. Efficiency improvements allow increases in speed by eliminating dangerous, slow traffic sections.

— Reliability is enhanced by control of or improved information about water depths, currents, flow velocities, and weather associated conditions such as ice and fog. Reservoir management, river training, communication systems and special engineering solutions are applied to enhance channel and lock reliability.

— Safety is inversely proportional to traffic congestion, adverse currents, high flow velocities, inclement weather, restrictive channel alignments and dimensions.

PHYSICAL FACTORS AFFECTING RIVER NAVIGATION

The physical factors which affect the cost of waterborne transport for the commercial vessel operator include width, depth and alignment of channel, locking time, current velocity, and the terminal facilities. Commercial inland water transport is, for the most part, accomplished by barge tows consisting of 1 to 40 or more barges drawing 9 feet or less pushed by a shallow draft river towboat. The cost for a trip between any two terminals is the sum of the fuel cost, wages, fixed charges, and other operating expenses dependent on the time of transit. The cost per ton-mile is the cost divided by the product of the mileage and tons transported. Relatively low ton-mile costs result from short transit times or large tonnage per tow.

Vessel loading is limited by the depth of the channel at its shallowest point. When a vessel hugs the bottom, drag increases and additional power is required. This raises the cost of operations. For example, fuel costs are about 25 percent lower with 5 feet of water under the barge than with 2 feet.

The number of barges in a tow and the transit time depend on the alignment, width, and current velocity of a given waterway. Sharp bends set a definite limit on the length of a tow that can pass through them. A fairly wide channel with curves of long radius is necessary for efficient tow operation.

Transit time is a function of current velocity and lockage delays. There are also other factors involved which relate to vessel operating characteristics, as well as to weather and other physical delays (narrow channels, bridges, port congestion, etc.). The speed of most barge tows in slackwater (1 foot per second or less) is around 6 mph or 9 ft/sec. Current velocities on the order of 3 or 4 ft/sec represent a substantial reduction in speed for tows bound upstream, or more specifically in the ton-miles moved per horsepower-hour. The time required for a tow to pass through locks also directly affects transit time. In many cases it is necessary to break up a tow and take it through a lock in portions because the lock is not large enough to accept the entire tow. This increases the time consumed in locking.

Since charges for tows and barges continue while the tow is at a terminal, facilities which permit rapid cargo transfer reduce time lost and thus decrease cost. Terminal facilities, therefore, are an important factor in the economics of navigation projects.

ENGINEERING IMPROVEMENTS FOR RIVER NAVIGATION

Because few rivers in their natural state meet the requirements of commercial water transportation, engineering solutions have been required. There are three basic methods for improving a river for navigation—channelization (open rivers or channels), canalization (locks and dams), and land-cut canals. Open-channel methods seek to improve the existing channel to the point where navigation is feasible through a combination of dredging and training works. River training works help to direct natural currents in such a way as to aid in the maintenance of navigable depths. Dams create a series of slackwater pools through which the traffic can move, with locks to lift the vessels from one pool to the next. Land-cut canals provide a totally new channel cut by artificial means around an otherwise impassable obstruction or between two navigable bodies of water.

Channelization

Open-channel navigation may be improved by some combination of three methods: (a) regulating the flow by storage reservoirs, (b) river training, and (c) dredging.

River stages can be manipulated by releases from multipurpose reservoirs. Currently, this is most effectively done on the Missouri River, where upstream reservoir releases permit downstream open-channel navigation between Sioux City, Iowa and the mouth near St. Louis, Missouri.

Most rivers tend to migrate, gradually changing natural channels over time. In addition, seasonal variation in discharge often results in shoals which impede and create hazards to navigation. Dredging can be used to effectively overcome the latter problem. To combat both problems and achieve a relatively self-maintaining river with respect to navigation depths, river training is used.

To stabilize channel alignment, bank protection referred to as revetment is applied to the outside of river bends to arrest their movement. A revetment must be sufficiently long to protect the entire concave bend and should extend from the top of the bank to the thalweg (the deepest point of the navigation channel). A revetment is merely a form of pavement or bank lining, and a wide range of materials have been employed for the purpose. Woven willow mattresses were used extensively until about 1930. This type of revetment has been replaced by articulated concrete mattresses on the Lower Mississippi River, while riprap (stone) is used above Memphis, Tennessee.

Contraction works called dikes are stone structures (only on the Columbia River are timber piles still employed) of various dimensions and shapes used to contract and align the channel. They are generally used in the crossings (reaches of a river between bends) where the channel is most unstable and likely to shoal. They are also used to protect the inside of bends from being breached.

River training at one location affects reaches both upstream and downstream. Therefore, it should be incorporated as part of an overall system plan. Of course, restrictions of funds, labor and plant necessitate a phased implementation of the system plan.

The capacity of open-channel rivers is greatest in the Mississippi below St. Louis, which can accommodate tows with over 40 barges stretching a quarter of a mile and carrying up to 50,000 tons; below Baton Rouge, oceangoing ships drawing up to 40 feet can be accommodated.

Canalization

In the improvement of a river for navigation, lock and dam construction is indicated where conditions are unfavorable for open-channel methods. A series of locks and dams can be maintained if flow is sufficient to provide the minimum water for lockages, sanitary releases as may be required, and evaporation losses from the pools. This usually requires much less water to maintain a comparable depth than open-channel procedures would. Usually some dredging is required to maintain depths on a canalized river, although not as much as on an open-channel river. The general features of a stream suitable for lock and dam construction for navigation improvement are (1) conditions unsatisfactory for open-channel methods, (2) low sediment transport, and (3) suitable dam sites. Cost of locks and dams is usually high compared with open-channel methods, especially if much land is to be submerged or many streambank facilities are to be relocated.

A lock and dam slackwater system is used to reduce the gradient and increase depths, usually in the upper portions of river systems. Both fixed and movable dams have been employed. The latter are especially useful when satisfactory channel depths are available during much of the year such as at Locks and Dams 52 and 53 on the Ohio River. When this is not possible, fixed dams are used and passage from pool to pool or from free flowing portions to the upstream pool is provided by locks. A special case usage of the lock and dam system is found in certain coastal areas, most notably in Louisiana, where locks are sometimes used as part of a saltwater intrusion barrier.

In raising river levels to form a pool for navigation, the selection of the project height is determined by the desirable channel characteristics upstream rather than by a required storage capacity. In other words, the dam must be high enough so that adequate depths are provided as far upstream as desired. If the minimum flow of the stream is inadequate to provide water for locking, some storage capacity in the pool above navigable depth may be provided. Dredging of the channel may serve as a means of minimizing the height of the dam. Some dredging may be necessary in any case to provide sufficient channel width and access to terminal facilities.

Several dams will be required to open a long waterway to navigation. Unless there are channel reaches which are navigable in their natural state, the dams must be located so that their pools overlap, i.e., each dam backs water up to the dam upstream. Higher dams will reduce the total number required for canalization, but will be individually more expensive. The cost of a dam increases exponentially with its height.

The two major items in the planning of navigation locks are the determination of size and the design of the filling and emptying systems. The height of the lock is fixed by the selected upstream and downstream pool levels. The overall height of the lock chamber must equal the maximum expected difference in pool elevations plus the required navigable depth. Some of the highest locks are on the Columbia River—the John Day Lock near Wasco, Oregon, is the nation's highest at 113 feet. The elevation of the bottom of the lock chamber is influenced by the need for under-keel clearance. The dimensions of a proposed lock chamber depend on the traffic expected to pass through it. The Corps has standardized lock sizes as follows: (1) lock width of 84 feet with length of 400, 600, 720, 800, or 1200 feet; (2) lock width of 110 feet with length of 600, 800, or 1200 feet; and (3) locks on the Columbia-Snake Waterway of width 86 feet and length 675 feet.

Twenty-four standard 175-foot by 26-foot barges make up a tow four abreast and six long, less one barge out for the towboat, for passage through a lock chamber 110 feet wide by 1200 feet long; or four abreast and three long with one barge out for the towboat to pass through a lock chamber 110 feet by 600 feet. Barges of jumbo length of 195 feet by 35 feet wide can be made up three abreast and six long and three abreast and three long for passage respectively through a standard size lock chamber of 110 feet wide by 1200 feet long or 110 feet wide by 600 feet long.

Lock chambers of adequate size to accommodate the type of tows that operate on a waterway are important to the economics of barge transportation. The average lock is designed to accommodate the passage of vessels in a 20 to 30 minute operation. Tows which are too large to pass through a lock in a single operation require double lockage. This involves the breakup and reassembly of the tow, together with the two lockage operations, and takes about an hour and a half. Since operating costs of a towboat average from $50 to $100 per hour (1977 dollars), double lockages impose a cost penalty to operators and added costs to shippers. (All costs are in 1977 dollars unless otherwise stated.)

The design of the lock-filling-and-emptying system requires a compromise between two differing demands: (1) that the filling and emptying times be as short as engineering and economic aspects permit (15 minutes) in order to minimize the delay to traffic; and (2) that the disturbances in the lock chamber not cause stresses in mooring hawsers which might cause the tow to break loose and be damaged or damage the lock structure.

Because the tows must approach the lock at low speed to avoid damage from collision, and since they have little steering control at low speeds, it is important that the lock approaches be protected by guide walls so that eddies and turbulence in the navigation channel as a result of flow over the dam will be minimized. In many instances the guide walls may be several hundred feet long.

The tonnage which can be handled on a given canalized river reach varies considerably depending upon lock size. On sections of the Ohio River equipped with new 110 by 1200-foot locks, and with high lift dams backing up deep pools for as much as 100 miles, 20,000 tons is a typical optimum load. On the other systems with smaller locks and often as close together as 15 miles, considerably smaller tonnages are necessary.

COASTAL NAVIGATION

Commercial coastal water transportation ranges from shallow draft vessels such as fishing boats and barge tows to the deep draft vessels. The coastal waterways include bay and river entrance channels, channels within the various bays and estuaries and the intracoastal waterways.

Barrier islands, inlets to bays and estuaries, and river deltas all shift and shoal over time. Dredging and training works are the basic methods of improving coastal navigation.

Breakwaters and jetties are used at entrance channels to interrupt littoral drift, reduce wave height, and direct and confine currents to aid navigation, prevent shoaling, and stabilize the land-water interface. These structures must be high enough to accommodate the prevailing maximum spring tide range as well as endure tremendous wave forces.

Channel Depths

Entrance channels often have to be deeper than interior channels because of pitching, rolling, and heaving of ships due to waves and swells. This problem is probably worst at the mouth of the Columbia River where pitch motions have been observed in excess of 25 feet.

Naturally occurring tidal entrances often have insufficient depth for navigation. Small inlets may have controlling depths of less than 6 feet with continuously shifting channels. Such a channel is not satisfactory even for pleasure boats. These shallow bar crossings are also subject to heavy wave conditions, and it is often necessary to provide wave protection in the form of a breakwater (or jetty) in order to obtain safe navigating conditions even if the natural or dredged depth is sufficient.

Larger natural entrances are often connected to commercial waterways. Ports are located in bays, estuaries and rivers; thus, it is necessary to provide sufficient and dependable channel depths for commercial navigation. This type of traffic varies from small commercial fishing boats and barges to super tankers.

Even though intracoastal waterways and bay/estuary channels are more protected than entrance channels, they tend to shoal because of tidal circulation carrying local sediments as well as sediment brought in by rivers. Periodic dredging is required.

Channel widths should be designed to provide for the safe and efficient movement of the vessels expected to use the channel. The minimum channel width required depends on the size of the largest vessel expected to use the waterway, maneuverability of the vessel, channel shape and alignment, traffic congestion, wind, waves, currents, visibility and whether one-way or two-way traffic is to be accommodated.

Increases in channel dimensions, primarily depth, will generally result in increased shoaling unless specific control structures are provided, such as in the unique case of Savannah. Increased depths in estuaries may cause a significant increase in salinity intrusion, which in turn can cause an unexpected increase in upstream shoaling, perhaps endangering water supplies and altering the ecology of an area. It is also possible for a major project to affect the tidal characteristics of the estuary. Care must be taken that the project does not create hazardous cross currents and that the proposed channel avoids areas where such dangerous currents already exist.

Jetties

The primary elements of an entrance improvement project are a deeper channel and jetties. The dredged channel is required to provide for a depth greater than that naturally existing in the entrance. The jetties are multipurpose structures. In the first place, they protect the channel from the direct encroachment of littoral drift. Secondly, they confine the tidal currents which would normally spread out rapidly and weaken over the outer bar. If the dimensions are properly chosen, the resulting velocities may be competent to naturally scour material from the channel, thus reducing dredging requirements. Finally, the jetties can provide protection from waves approaching from some, but not all, directions for ships entering or leaving coastal channels. This wave protection is most important at the shallowest part of the bar crossing where the ship is most likely to hit the bottom in heavy seas.

FLOATING SUPPORT PLANT AND EQUIPMENT

Floating support equipment for the waterways is used for construction, maintenance and reconnaissance. Crewboats, towboats and barges perform a number of miscellaneous tasks. Construction and maintenance equipment such as draglines and piledrivers are often temporarily converted from land use simply by floating them on barges. Other equipment is designed and built specifically for waterway work. Reconnaissance work is performed by survey boats equipped with sophisticated instrumentation. Channel deepening is done by dredges. Articulated concrete mattresses used to line the banks of the lower Mississippi are laid by specially designed mat-laying units.

Hydrographic Survey Euqipment

Hydrographic surveys have been and still are necessary for the determination of channel depths, depths at dredged material disposal sites, and for the preparation and evaluation of dredging contracts. Recent advances in electronics have allowed the Corps districts to acquire a fleet of sophisticated automated hydrographic survey boats. These vessels are equipped with sensing devices, which, through an onboard computer provide real time hydrographic surveys, simultaneously recording water depths and boat position while compensating for river stage or tide level.

Hydrographic surveys are becoming more necessary. As an increasing amount of the dredge workload is undertaken by industry, a greater employment of hydrographic survey equipment will be necessary to monitor contracts. Model studies, both physical and numerical, are based upon complete and up-to-date surveys. Basic research and evaluation of training works depend on periodic repetitive surveys.

Dredges

Equipment unique to waterways engineering tasks include the vast floating plant required for dredging nearly 300 million cubic yards of material annually from the coastal and inland waterways. Over 95 percent of the dredging is accomplished by three types of dredges—the cutterhead, dustpan and seagoing hopper dredges. Gradually private industry has taken over an increasing share of non-hopper dredging, while hopper dredging continues to be carried out predominantly by the Federal dredge fleet. Recently, a number of modern new hopper dredges have been added to the Federal fleet to insure a minimum capability to meet national defense and emergency requirements. The role of the aging Federal fleet of 33 dredges, with an average age of over 35 years, is presently being changed through the application of the Industry Capability Program (P.L. 95–269). The private fleet, owned by over 240 firms, has 480 dredges, with an average age of 25 years. This law provides for growth of the private fleet by insuring a share of the total dredging program. Providing for national defense and national security, the law incorporated the establishment of a minimum sized, modern Federal fleet.

Hopper Dredges

The hopper dredge is somewhat akin to a floating vacuum cleaner. Generally, these dredges are self-propelled oceangoing vessels with up to three drag arms which suck up a slurry mixture into hoppers or holding tanks on board while the dredge is underway. Once the hoppers have been filled to the desired level with dredged material, the dredge normally proceeds to a preselected disposal site where doors in the bottom of the hull are opened and the dredged material is dumped from the hoppers into the water. Subsequently, the bottom hopper doors are closed and the vessel returns to the dredge site for continuation of dredging operations.

Some hopper dredges are equipped with direct pump out capability for operation where confined disposal procedures are required. These dredges can pump dredged material directly into the diked disposal areas rather than by bottom dumping in open water.

Hoppers are suitable for all but very hard material and are the only dredges suited for rough seas, such as at some coastal entrance channels. This is the second most commonly used dredge with respect to volume.

The sidecasting dredge is a modification of the hopper dredge. These dredges are moving while dredging and disposing of the dredged material simultaneously. Like the hopper dredge they use trailing suction drag arms to pick up material from the bed of a watercourse, but unlike the hopper, they dispose of the material through a pipe above deck to the port or starboard side by hydraulic manipulation of a support (sidecasting) boom. The dredged material is thrown well clear of the dredged channel through pipes ranging from 70 to 100 feet in length, depending on the dredge involved.

The sidecasters are used along the East Coast (particularly North Carolina coastal waters) for the maintenance of narrow inlets which are exposed to the open sea. These projects are relatively small (in volume) and thus do not require the higher production hopper dredges, as long as the dredged material can be placed near the channel. Such shallow channels accommodate barge transportation, fishing fleets, shallow-draft, coastal vessels, and pleasure craft.

Cutterhead Dredges

The cutterhead dredge is a hydraulic pipeline dredge using a mechanical cutter on its suction line. Disposal is through a variable length pipeline into open water or onto land. This type of dredge is suitable for virtually all materials, although the cutter is only required for consolidated materials. The cutterhead swings back and forth while "walking" on its spuds. This is the most commonly used type of dredge.

Dustpan Dredges

The dustpan dredge is a self-propelled, hydraulic pipeline dredge which uses a wide suction head similar in configuration to a vacuum cleaner. Water jets are used to scarify the material and to loosen it from the bottom of the river. Disposal is through a variable length pipeline into open water. The dustpan operates on anchors and pulls itself through a shoal against the river flow. Thus it cannot be used in river pools (slack water) but only in free-flowing rivers. Dustpan dredges are of unique design and especially adapted to remove sand bars and alluvial deposits, such as sand, silt, mud, and loose gravels from the Lower Mississippi, Missouri, and Ohio rivers.

Dipper and bucket dredges are used in specialized situations. Single buckets mechanically lift bottom material and drop this material onto an awaiting scow or on shore. These dredge types have a low rate of production and are used in confined areas or in areas having hard bottom material.

REVETMENT

Today the most common form of bank protection, or revetment, is the emplacement of articulated concrete mattresses, which predominate on the Mississippi south of Memphis.

The mat-laying equipment, like the dredge, is unique to water transportation. It is used to place the articulated mattress on the banks of the Mississippi to protect the levees and maintain the desired navigation alignment. This machinery is owned and operated by the Federal Government. During a normal low-water construction season of 5 months, these plants are capable of reveting approximately 40 miles of bank with a mattress averaging 360 feet wide.

COMMERCIAL WATERBORNE CARRIER FLEET AND PORT TERMINAL CHARACTERISTICS

The vessels involved in the inland. Great Lakes and oceangoing U.S. flag fleet for 1970 and 1980 are displayed in Table B–1. This table shows significant growth on the Mississippi River system and the Gulf Intracoastal Waterway (GIWW) in virtually all categories of vessels which operate on the inland system. The Atlantic, Pacific and Gulf coasts show a numerical decline in all categories of self-propelled vessels and in total capacity for dry cargo; however, tanker capacity and horsepower per individual vessel has increased. On the Great Lakes a significant decline is evident in the total number of self-propelled dry cargo vessels and tankers, but

Table B–1

SALIENT STATISTICS REGARDING UNITED STATES FLAG PASSENGER AND CARGO VESSELS, 1970 AND 1980[1]

Type of Vessel	Total		Atlantic, Gulf, Pacific Coasts		Mississippi River System and GIWW		Great Lakes System	
	1970	1980	1970	1980	1970	1980	1970	1980
Self-Propelled								
Dry Cargo and Passenger								
Number of Vessels	1761	2036	1179	813	230	958	352	265
Horsepower (1000 hp)	7893	8590	6976	6314	187	1507	730	769
Horsepower/vessel	—[2]	—[2]	5917	7766	813	1573	2074	2902
Cargo capacity (1000 tons)	10816	8012	7745	4797	41	213	3030	3001
Cargo capacity/vessel (tons)[1]	—[2]	—[2]	6569	5900	178	222	8608	11325
No of Passengers (Capacity 1000)	166	143	133	93	13	29	20	21
Tankers								
Number of vessels	421	330	377	318	0	0	24	12
Horsepower (1000 hp.)	3096	4161	3045	4139	0	0	31	22
Horsepower/vessel	—[2]	—[2]	8077	13016	0	0	1291	1833
Cargo capacity (1000 tons)	8468	4161	8383	15840	0	0	77	55
Cargo capacity/vessel (tons)	—[2]	—[2]	22236	49811	0	0	3208	4584
Towboats								
Number of vessels	4248	4693	1814	1602	2297	2945	137	146
Horsepower (1000 hp.)	3859	7147	1473	2365	2275	4638	111	144
Horsepower/vessel	—[2]	—[2]	812	1476	990	1575	810	986
Non-Self-Propelled								
Barges and scows, dry cargo								
Number of vessels	15890	27426	3210	4631	12550	22586	130	209
Cargo capacity (1000 tons)	17695	34487	3257	4890	14284	29261	154	336
Cargo capacity/vessel (tons)	—[2]	—[2]	1015	1056	1138	1296	1185	1607
Tankers								
Number of vessels	3281	4166	608	688	2657	3445	16	33
Cargo capacity (1000 tons)	6333	10388	1469	3173	4821	7148	42	68
Cargo capacity/vessel (tons)	—[2]	—[2]	2416	4612	1814	2075	2625	2061

1 U S Army Corps of Engineers, Water Resources Support Center, Waterborne Commerce Statistics Center, "Summary of the United States Flag Passenger and Cargo Vessels Operating or Available for Operation," Annual (Unit values are based upon the data shown in this table)

2 Not applicable.

increases in the average capacity per vessel greatly offset this decline and result in only minimal losses in total capacity for the Great Lakes area. Non-self-propelled barges and tankers have increased in all regions, and the growth is especially significant on the inland waterways where total barge capacity has more than doubled since 1970. Nationally the number of non-self-propelled barges increased from 15,890 to 27,426, or 73 percent, and the number of tankers increased from 3281 to 4166, or 27 percent. In terms of total capacity for non-self-propelled vessels, barges increased by 94 percent and tankers by 64 percent. This is evidence of the trend toward larger capacities among non-self-propelled vessels.

SHALLOW DRAFT CARRIERS OF THE MISSISSIPPI RIVER AND TRIBUTARIES AND GIWW

Shallow draft carriers operate commercially on the inland and intracoastal waterway system, consisting of the Mississippi River and Tributaries (MRT) and the GIWW. This region has the highest concentration of non-self-propelled barges and tankers when compared with the coasts and the Great Lakes.

Self-Propelled Vessels

The self-propelled vessels operating on the inland waterway system and GIWW include a relatively small number of dry cargo vessels and, of course, the fleet of towboats which move all the non-self-propelled barges and tankers on the shallow draft system.

Dry Cargo

Though small in number compared to the inland waterway non-self-propelled barge fleet, self-propelled dry cargo vessels operating on the Mississippi River system and the GIWW have increased sharply between 1970 and 1980. As seen in Table B–1, the number of such vessels has increased from 230 to 958, or 317 percent over the decade. Much of this growth is due to the increased use of specialized vessels in the Gulf of Mexico. These vessels are used primarily to service the drilling and pumping activities of the off-shore petroleum industry.

Towing Vessels

There were 4,693 towing vessels operating in the United States in 1980. Of these, 63 percent operated on the Mississippi River system and

GIWW, 34 percent on the Atlantic, Pacific and Gulf coasts, and 3 percent on the Great Lakes. The number on the MRT has shown significant growth, while the number on the Great Lakes has shown only a slight increase. On the other hand, the number of towing vessels on the coasts have shown an absolute decline in recent years. The MRT vessels have the greatest share of high powered and heavier towboats. The low horsepower vessels exhibit the highest average age. During the 1970 to 1980 period, the total number of towboats serving the shallow draft inland waterways and GIWW increased by 28 percent, but total horsepower increased substantially by 104 percent. The average horsepower per vessel on the shallow draft waterways has increased by 60 percent during this 10 year period. The average new cost of a medium sized towboat in 1981 was about $4.5 million for 5,600 HP, according to the American Waterways Operators Inc. (AWO).

Non-Self-Propelled Vessels

The shallow draft waterways lead by far in the number and total capacity of non-self-propelled vessels. The number of barges and tankers making up the shallow draft inland fleet has increased 71 percent since 1970 and the total capacity has increased by 91 percent, indicating a definite trend toward larger capacity barges and tankers.

Barges

Four types of barges are employed in shallow draft waterborne commerce in the United States: (1) open hopper, (2) covered hopper, (3) deck, and (4) tank. The open and closed hopper and tank design barges, as well as the standard towboat design, are shown in Figure B–1. Based on a study of barges in use on the Mississippi River system and the GIWW, 47 type-and-size categories have been recognized. The size groupings are based on the lengths and widths of the barges. According to the AWO, the approximate cost in 1981 for a 1500-ton capacity covered hopper barge was $286,000, while the cost for a 1500-ton capacity tank barge was about $506,000. One hopper barge is equivalent to 15 100-ton rail cars, or over 57 trucks with a capacity of 26 tons each.

Open hopper barges, which can be used for all types of solid bulk cargoes, dominate the field, accounting for 44 percent of the aggregate tonnage capacity of all barges operating on the inland waterways. Covered hopper barges account for one-quarter of the total tonnage capacity, and tank barges for 22 percent. Deck barges make up 8 percent of the combined capacity.

During the past 10 years, the MRT and GIWW have dominated the growth in the U.S. barge fleet. Table B–2 shows the growth in capacity during the period 1970-1978. The gross carrying capacity has increased 76 percent on the MRT, from 14.3 to 25.1 million tons, and the average carrying capacity has increased 12 percent during this period. Much of this gain was due to the continuing retirement of the standard sized barge (175 feet by 26 feet) and its replacement by the standard jumbo barge (195 feet by 35 feet) which carries 1500 tons at 9-foot draft.

The size and age distribution of U.S. dry cargo open hopper barges in 1979 are shown in Table B–3. As noted, the trend has been toward increasingly larger barge sizes, generally. The largest number of open hopper barges by far are on the MRT, where they are engaged in the large scale movement of coal and other dry bulk cargoes. The trend toward increasingly larger barges is evidenced by the large number of jumbo barges now being utilized on the inland system. These have gradually been replacing the standard barges in popularity, as indicated by the lower average age of the jumbos.

On the Ohio River, for example, a decided trend has been evident toward larger barges, larger tows, and more powerful towboats. Downriver from Huntington, West Virginia about two-thirds of the barges now in use are jumbos; about one-quarter are integrated barges, and most of the remainder are standard barges. Upriver from Huntington the proportion is somewhat different, with jumbos accounting for about half of the total number, standards for about 30 percent, and integrated barges for most of the remainder.

Tows vary in size; the average number of barges per tow is about eight. Coal tows of 20 to 24 standard barges (or 15 jumbo barges) are frequently seen, while some tows may consist of a single barge. Mixed tows, including barges of different sizes, are commonly encountered. Tows of up to 45 barges can be found on the Lower Mississippi River below Cairo, Illinois.

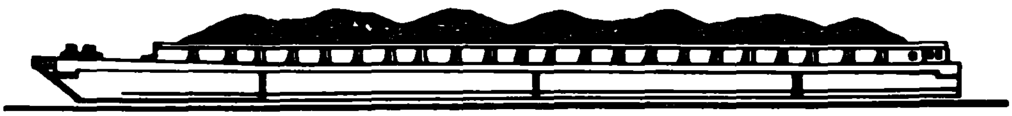
Tankers

The non-self-propelled tankers being utilized on the inland waterway system, like the dry cargo barges, have shown a significant increase in number and capacity since 1970. A trend toward higher capacity vessels has resulted in an increase in capacity of 48 percent, while the total number of tankers has increased by 30 percent during the period. Tankers are widely used on the MRT for the movement of petroleum and petroleum products, as well as for chemicals. Traffic is heaviest on the Lower Mississippi and on the GIWW-West, where there is a high concentration of refineries and chemical plants.

Equipment Performance and Utilization

A significant factor in overall linehaul cost and relative modal efficiency relates to the performance and utilization of the carrier fleet. Reducing downtime lowers costs for the operator and can therefore benefit the shipper. This is also true of improved efficiency, such as in equipment utilization, coordination of backhaul movements when feasible, and efficient movement of traffic through locks.

Figure B-1
PREDOMINANT BARGE AND TOW TYPES

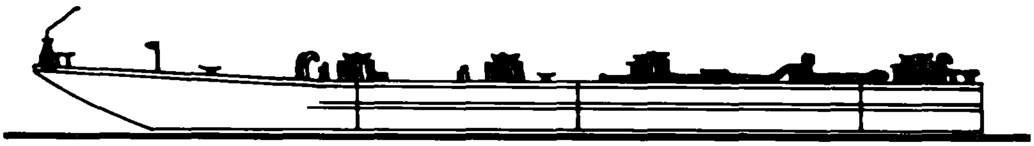


OPEN HOPPER BARGES

TYPE	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
STANDARD	175	26	9	1000
JUMBO	195	35	9	1500
SUPER JUMBO	250-290	40-52	9	2500-3000

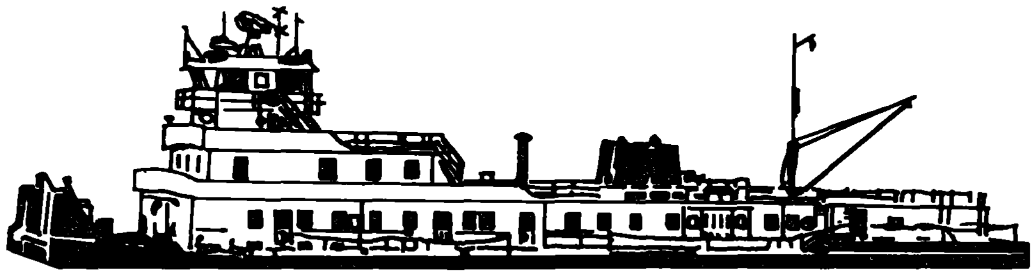
COVERED HOPPER BARGES

TYPE	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
STANDARD	175	26	9	1000
JUMBO	195	35	9	1500



INTEGRATED CHEMICAL AND PETROLEUM BARGES

LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
150-300	50-54	9	1900-3000



TOWBOATS

LENGTH FEET	BREADTH FEET	DRAFT FEET	HORSEPOWER
65-160	24-50	5-9	300-7000

Table B–2

DRY CARGO NON-SELF-PROPELLED BARGES AND SCOWS SERVING THE MISSISSIPPI RIVER SYSTEM AND GULF INTRACOASTAL WATERWAY (MRT) 1970–1978

Dry Cargo Barges and Scows	1970	1971	1972	1973	1974	1975	1976	1977	1978
Number of Vessels									
United States Total	15,890	16,439	17,527	18,804	19,772	21,816	23,164	24,937	24,037
MRT	12,550	13,318	13,985	14,904	15,765	17,345	18,049	19,368	19,809
MRT as Percent of U.S.	79.0	81.0	79.8	79.3	79.5	79.5	77.9	77.7	82.4
Cargo Capacity (Thousands of Short Tons)									
United States Total	17,695	18,272	19,711	21,343	22,647	25,526	27,135	29,455	29,839
MRT	14,284	14,864	15,935	17,293	18,594	21,032	22,255	24,286	25,149
MRT as a Percent of U.S.	80.8	81.3	80.8	81.0	82.1	82.4	82.0	82.5	84.3
Average Capacity (Short Tons)									
United States Total	1,113	1,111	1,124	1,135	1,145	1,167	1,171	1,181	1,241
MRT	1,138	1,116	1,139	1,160	1,178	1,212	1,233	1,254	1,270

U S. Army Corps of Engineers

Table B–3

SIZE AND AGE DISTRIBUTION OF U.S. DRY CARGO OPEN-HOPPER BARGES IN 1979

	Size (feet)	Total Cargo Capacity (short tons)	Number	Average Age
Great Lakes System	+400	79,700	2	9
	+350	4,000	1	65
	+300	3,000	1	15
	245 x 50	7,815	5	8
	195 x 35	153,790	104	27
	175 x 26	21,626	16	31
	150 x 34	9,344	6	26
	120 x 34	9,322	28	29
Total		288,597	163	
Mississippi River and GIWW	+400	34,800	2	2
	+350	27,262	5	15
	+300	198,704	65	15
	245 x 50	3,362,803	1,984	8
	195 x 35	9,758,276	6,537	10
	175 x 26	2,033,386	2,123	21
	150 x 34	400,920	553	25
	120 x 34	480,991	1,179	23
Total		16,297,042	12,448	
Atlantic and Gulf	+400	205,076	12	11
	+350	291,682	35	19
	+300	102,192	20	13
	245 x 50	89,779	41	20
	195 x 35	140,203	99	12
	175 x 26	41,398	25	22
	150 x 34	196,926	140	22
	120 x 34	1,104,101	1,554	14
Total		2,171,357	1,926	
Pacific	+350	203,315	28	19
	+300	268,310	50	11
	245 x 50	309,534	111	13
	195 x 35	18,000	11	24
	175 x 26	118,334	77	16
	150 x 34	113,814	100	21
	120 x 34	187,794	367	17
Total		1,219,101	744	

Corps of Engineers "Transportation Lines"

Downtime

Equipment downtime for both barges and towboats is estimated to be less than 10 percent annually. The primary cause of this downtime is attributed to equipment being held out of service for maintenance and repairs. As is true of most equipment, a positive correlation exists between its age and the incidence of downtime. According to interviews with carriers, barges generally require less downtime than towboats. The most often cited range of annual downtime is 5 to 6 percent for barges and 7 to 9 percent for tow-boats. Downtime for Great Lakes vessels was somewhat higher than for those on the MRT, particularly with respect to self-unloaders which have sophisticated onboard handling equipment and thus require a higher level of maintenance.

Utilization

Equipment utilization fluctuates considerably, depending upon barge type, direction of waterborne commerce, commodity being carried, lock congestion, contract restrictions, etc. The heaviest tonnages of commodities moving in opposite directions on the inland waterways generally require different types of barges and thus do not lend themselves as readily to complementary backhaul movements. For example, coal and grain commonly move downbound on the rivers and utilize hopper barges, while petroleum and chemicals more commonly move upbound, but require integrated tank barges. Overall, utilization for most barge fleets ranges from 40 percent to 70 percent (in actual revenue service). Towboat utilization is estimated to be much higher, averaging between 75 and 80 percent. The main constraints on utilization are: winter conditions, congestion at locks (particularly Lock and Dam 26 on the Lower Upper Mississippi and Gallipolis Lock on the Ohio River), inadequate lock dimensions, and equipment cleaning requirements.

Backhaul

Generally more backhaul opportunities exist for carriers hauling dry cargo, such as coal, than for liquid commodities, but even these are limited. Southbound movements of grain and coal from midwest origins can be partially offset by northbound movements of sugar, alumina, phosphates, salt, sand and imported coke and iron ore. However, many carriers accept only a very small amount of backhaul northbound cargoes on the MRT because of contract restrictions associated with the southbound movements. These carriers have indicated they cannot afford to take the time needed to clean a barge for another commodity, load, haul, and discharge that commodity and still have enough equipment available to meet southbound commitments. In essence, carriers are more concerned about maintaining a high level of equipment efficiency and utilization than they are about achieving a high load factor ratio.

Because there are many advantages associated with long term contracts for the movement of freight, many carriers operate substantial portions of their fleet in dedicated service. Under this arrangement, equipment is typically used to haul one specific commodity between two points on a continual, long-term basis. No backhaul cargoes are accepted in order to maximize cycle turntimes and achieve optimal equipment efficiency. Coal is the principal commodity carried in dedicated service and is commonly moved from coal origins or transloading facilities to power plants. Some open hopper fleets are almost 100 percent allocated to dedicated service.

INLAND TERMINAL FACILITIES

According to the Mid America Ports Study of the Maritime Administration, U.S. Department of Commerce, there are about 1,200 water terminals located in over 100 riverport areas along the Mississippi River and tributaries, comprising close to 1,900 barge berthing facilities. These include 386 general cargo berths, 868 dry bulk cargo berths, and 640 liquid bulk cargo berths. About 70 percent of the terminals are single cargo facilities. Of the single cargo facilities, 36 percent handle liquid bulks; 33 percent, dry bulks; 18 percent, grain; and 13 percent, general cargo.

Conveyor belt systems and the crane clamshell bucket each account for about 20 percent of the total non agricultural dry bulk loading, with the front-end loader accounting for an additional 20 percent of handling equipment. The handling capacity of conveyor belt systems is variable, with a range from 400 tons per hour to 2,000 to 3,000 tons per hour. The crane clamshell handling average is about 200 tons per hour. The front-end loader, while highly mobile, has an even lower handling rate. The highest rated bulk transfer systems are continuous buckets with handling capacities up to 5,000 tons per hour.

The predominant liquid bulk handling equipment is the barge pump and conventional cargo hose connected to onshore transfer systems with a load/unload capability. More than 200 pieces of loading equipment and nearly 30 pieces of unloading equipment were inventoried in the Maritime Administration study.

In terms of storage, these facilities provide 21 million square feet of covered storage for general cargo, over 147 million tons of covered and open storage for dry bulk cargoes, 340 million barrels of tank storage for liquid bulk cargoes, and more than 355 million bushels of elevator storage for grains.

DEEP DRAFT CARRIERS

Projections of deep draft vessel traffic indicate significant increases in the demand for dry bulk carriers, especially for the movement of coal and grain. Petroleum movements, currently accounting for the greatest tonnages in many areas, are projected to decrease in most reaches. The international dry bulk deep draft carriers will therefore be concentrated upon in this overview, as well as U.S. flag vessels in oceanborne trade.

International Dry Bulk Carrying Capacity

Induced primarily by the increased worldwide demand for coal and iron ore movements, the international dry bulk fleet has undergone profound changes in total capacity, size, character, organization and cost of transport. Few vessels are built specifically to carry one commodity. Most international dry bulk shipments are transported by bulk carriers and combination vessels. Bulk carriers are vessels suitable for the transport of various dry bulk commodities such as coal, grain, ore, bauxite and phosphates. Combination vessels are capable of carrying either crude and other petroleum products in liquid form, or coal and other dry bulk commodities. They are also called OBO (ore-bulk-oil) carriers or combined carriers.

The sustained growth in carrying capacity experienced by the international bulk carrier and combined carrier fleets is shown in Table B–4. From a mere 10 million deadweight tons (dwt) in 1962, the pure bulk carrier fleet capacity grew to a 1978 total of some 100 million dwt, or about 150 million dwt if 50 percent of the capacity of the combined carriers is included.

International Dry Bulk Vessel Sizes

The ascendancy of the bulk carrier has been accompanied by an increase in the size of individual ships. Between 1965 and the present, the participation of ships under 20,000 dwt in the coal trades, for example, has declined from 59 percent to 18 percent, while ships over 50,000 tons have increased from 47 percent to 58 percent. Ships in the 20,000-50,000 dwt range experienced an increase in the percent of coal traffic carried from 1967 to 1970, but this category, too, has since been declining and now carries about 24 percent.

The trend toward coal-carrying vessels of larger size is anticipated to continue. By 1985, it is expected that 65 percent of oceanborne coal will be shipped in vessels in excess of 50,000 dwt and as much as 30 percent in vessels in excess of 100,000 dwt. Increases in ship size are made possible by the development and availability of port facilities capable of handling large vessels. Although the United States has the greatest number of dry bulk loading terminals, most are restricted to ships of the 50,000–70,000 dwt (Panamax) size. ("Panamax" refers to vessels of the maximum size still capable of transiting the Panama Canal.) Table B–5 lists the dimensions of ships of various coal-carrying capacities, including drafts. Table III–4, in Section III, listed the controlling depths at principal U.S. ocean ports. It can be seen that ships of 100,000 dwt are excluded from principal coal handling ports on the East Coast because of depth restrictions.

Because of beam and draft restrictions imposed by the Panama Canal and channel depth in principal U.S. Atlantic and Gulf loading ports, bulk carriers of the Panamax size are the preferred vessels in the United States export trade. Large vessels may be loaded at Hampton Roads, but most U.S. movements to Japan still pass through the Panama Canal. While the Panamax size will undoubtedly continue as the most frequently employed size during the next few years, as port facilities improve dry bulk carriers in excess of 100,000 dwt will be used more extensively. Within the next 10 years, deepwater coal terminals for the larger ships will be available in all the major coal exporting areas except, perhaps, the United States. By the year 2000 it is estimated that the common ship size will

Table B–4

INTERNATIONAL DRY BULK CARRIER CAPACITY, SELECTED YEARS, 1962–1978
(Million Deadweight Tons)

Year	Dry Bulk Carriers	Combined Carriers	Total Dry Bulk Fleet*
1962	10.0	1.7	10.8
1965	19.3	2.8	20.7
1967	30.9	4.4	33.1
1970	55.1	12.4	61.3
1972	61.7	15.6	69.5
1975	97.8	42.1	118.9
1977	116.6	46.8	140.0
1978	129.6	48.3	153.7

*Assumes one-half of the combined carrier capacity is dry bulk

Table B–5

DIMENSIONS OF SELECTED SHIPS BY COAL-CARRYING CAPACITY

Coal-Carrying Capacity (dwt)	Overall Length (feet)	Beam (feet)	Draft (feet)
40,000	630	105	35
60,000	760	105	40
100,000	910	116	48
150,000	980	133	56
200,000	1,020	150	62

be about 150,000 dwt for journeys where this size can be used. However, the capacities of some ports and the Panama Canal will limit the size of ship that can be used on certain journeys. In any case, the availability of ocean shipping will not be a constraint on the ocean transport of dry bulk commodities.

U.S. Flag Ocean Vessels

The change from 1970 to 1980 in the U.S. flag oceanborne fleet of barges and self-propelled cargo vessels is shown in Table B–1. Fewer barges are used in this trade generally. Equipment sizes are more variable, although tank barges are generally larger than those used in the inland system. The open hopper dry cargo barge, sizes of which are shown in Table B–3, comprises over 95 percent of the dry cargo barges. Tugs tend to be smaller than towboats, averaging 1476 horsepower in 1980. However, this is because most of the tugs are harbor tugs rather than linehaul tugs. An important concept in use in the domestic ocean trade is the integrated-tug-barge for bulk cargoes. In addition to flexibility in equipment utilization, the integrated-tug-barge has different manning requirements, making it more economical than the self-propelled vessels of similar capability.

Self-Propelled

The most apparent trend, as noted earlier, has been the decline in the total number of self-propelled vessels serving in the U.S. flag fleet. This is partly due to the significant expansion of the domestic pipeline network. However, the capacity figures in Table B–1 offset the numerical decline considerably, as fewer but notably larger vessels have come to dominate this market. For example, while the number of tankers operating in the coastal areas has declined from 377 in 1970 to 318 in 1980, the average capacity per vessel has more than doubled. This provides a total tanker capacity for the coasts which is 89 percent greater in 1980 than in 1970. Much of this increase has been needed to serve the dramatic growth in petroleum movements between Alaska and the West Coast. Self-propelled dry cargo vessels, on the other hand, have witnessed a decline in total number, total capacity, and in capacity per vessel.

Tankers compose 75 percent of the total non-self-propelled vessel capacity in the U.S. flag oceanborne fleet. However, tankers account for only 28 percent of the fleet, not including tugs and towboats. Channel restrictions on domestic vessel size are minimal and there are no locks to contend with except for the Panama Canal. The basic technological trends in the domestic ocean trade area since World War II include:

—Larger vessel size
—Higher operating speeds
—Unitized cargo
—Integrated tug-barge.

Significant advances are expected in the future in three areas:

—Further application of integrated-tug-barges
—Engine room improvements in fuel efficiency
—Slower design operating speeds for new vessels in liner trades.

Non-Self-Propelled

Among the non-self-propelled vessels of the U.S. flag oceanborne fleet, increases have occurred in both the total number and the total capacity of the dry cargo barges as well as tankers. The dry cargo barges have increased in total number by around 44 percent, while the average capacity of individual vessels has shown only a very minor increase from 1015 to 1056 tons.

The total number of non-self-propelled tankers serving the coasts has shown a very small increase over the decade (from 608 to 688); however, the average individual vessel capacity and the total tanker capacity have shown significant increases on the order of 91 and 116 percent, respectively. Therefore the trend in the coastal areas among non-self-propelled vessels has been toward increases in total number and very significant increases in total vessel capacities.

DEEP DRAFT TERMINAL FACILITIES

There are 173 major coastal ports of which 102 have depths of 28 feet or greater. These ocean ports have over 1,400 marine terminals and over 2,900 deep draft ship berthing facilities. Almost half of these berthing facilities are located in 15 port cities whose populations exceed 500,000, while 75 percent of the total berthing facilities are in 48 cities whose populations exceed 100,000.

More than 60 percent of the terminals are privately owned and operated by various industries. These facilities are usually designed to handle a single commodity or group of commodities as an integral part of a firm's production process.

On the other hand, public ports and terminals handle bulk cargo, general cargo that historically moves in breakbulk form, and more recently, in unitized form. The ownership distribution of U.S. terminal facilities is illustrated in Table B–6. Public ports are owned by a wide variety of governmental agencies, ranging from local government and state authorities to Federal and quasi-governmental organizations. Local and state governments have a particular interest in port activity because this often represents a dominant economic factor for the port city and surrounding area.

Of the seaport berthing facilities, 12 percent are general cargo berths, 25 percent are dry cargo berths, and 25 percent are liquid bulk cargo berths. Container, Roll on/Roll off and barge carrier facilities account for less than eight percent.

GREAT LAKES SYSTEM

The predominant self-propelled vessel serving the domestic Great Lakes trade is the lake carrier.

Table B–7 displays the vessels and associated capabilities for the years—1951, 1961, 1971 and 1978. The total capacity and number of vessels have decreased since World War II. However, average vessel size increased 109 percent as old vessels were retired and replaced by vessels sized to more fully utilize the greater seaway depths (27 feet) obtained for major harbors and the new larger lock chambers on the St. Marys River. The most recent, the new Poe Lock, was opened to traffic in 1968 and has dimensions of 110 by 1200 feet. The season extension programs of recent years have also increased vessel utilization, allowing fewer vessels to handle the same commerce. Also displayed in this table is the increased importance of self-loaders. This is the only vessel type which has experienced an increase in aggregate capacity since World War II. The increase in self-unloaders (including conversions) has been undertaken to reduce vessel turn around time. These vessels are also able to call at ports with limited unloading facilities.

As was seen in Table B–1, the total number of self-propelled dry cargo and tanker vessels on the Great Lakes has decreased significantly between 1970 and 1980. Among tankers, there has also been an absolute decline in total tanker capacity, despite increases in the average capacity per vessel. However, among the dry cargo self-propelled vessels, the average vessel capacity has increased by 32 percent. This increase has virtually offset the decrease in the number of dry cargo vessels and resulted in only a very small decrease in the total dry cargo capacity between 1970 and 1980.

There are relatively few non-self-propelled vessels on the Great Lakes; however, the number has increased between 1970 and 1980. Among barges, the average vessel capacity has increased. This has resulted in more than doubling the total non-self-propelled dry cargo barge capacity, while the total number of vessels in this category increased by 61 percent, from 130 to 209. The number of non-self-propelled tankers, though very few, more than doubled over the decade from 16 to 33.

Tugs and towboats in use on the Great Lakes are both smaller and older than those in use on the rivers. Average size was about 1000 HP in 1980. These data are consistent with the smaller number of barges per tow on the Lakes and the stable market for Lakes shipping.

The domestic Great Lakes fleet has been shaped by its operating conditions and its markets. The loss of packaged goods and other higher value cargo to other surface modes has left a fleet oriented primarily to serving the needs of the steel industry and electric utilities. Ore, coal and limestone dominate Lake commerce. The future

Table B–6
OWNERSHIP OF TERMINAL FACILITIES*
(Estimated)

Type of Ownership	Number of Terminals	Percent of U S. Total
Private (Profit-making organizations)	1,488	62.0
Local Government Agencies	576	24.0
State Government Agencies	288	12 0
U.S. Government Agencies (Non-Military)	43	1.8
Private (Non profit-making organizations)	6	0.2
TOTAL	2,401	100 0

*Marcus, 1977

Table B–7
SELF-PROPELLED LAKE VESSELS IN DOMESTIC TRADE

Vessel Type/Trade	1951		1961		1971		1978*		% Change 1951–1978	
	No of vessels	Capacity (1000 tons)	No of vessels	Capacity (1000 tons)	No of vessels	Capacity (1000 tons)	No of vessels	Capacity (1000 tons)	No of vessels	Capacity (1000 tons)
Bulkers Ore/Coal	265	2,636	210	2,792	135	2,042	135	2,657		
Self-Unloaders Bulk Freight	42	331	53	502	50	559				
Bulkers Mixed Trade	43	183	23	114	5	21	12	72		
Tankers	29	115	26	113	17	73	8	57		
Total	379	3,265	312	3,521	207	2,695	155	2,786	–59%	–15%
Average Vessel Carrying Capacity	8,600 tons		11,200 tons		13,000 tons		18,000 tons		109%	

Annual Reports, Lake Carriers Association, various years.

* Data for 1978 varies significantly from previous years A separate count of self unloaders is no longer maintained by the Association The figures also include 4 barges, including one 1,000 foot integrated tug barge

fleet will be strongly influenced by these factors as well. Future technological trends are likely to include:

—Continued replacement of older, smaller vessels with larger vessels

—Continued addition of self-unloaders

—Vessel modifications for winter conditions

—Engine room efficiencies to improve fuel consumption

—Possible further adaptation of integrated-tug-barge concepts.

RELATIONSHIP OF VESSEL CAPACITY AND WATERBORNE COMMERCE 1970, 1979 AND 1980

The U.S. flag vessels calling at U.S. coastal ports have shown increases only in tanker capacity and this relates directly to the new movement of crude petroleum from Alaska to the lower 48 states. This Alaskan crude petroleum movement increased from 0 in 1970, to 10 million tons in 1977, and to 65 million tons in 1979. The Great Lakes vessel capacity in domestic waterborne commerce has remained almost constant from 1970 to 1980. The most marked increases in vessel capacity, motive power and waterborne commerce is for the Mississippi River and Tributaries and GIWW; see Table B–8.

The increase in towboat horsepower from 1970 to 1980 for the MRT and GIWW was from 2.3 to 4.6 million horsepower, or 104 percent. During the same period, dry cargo barge vessel capacity increased from 14.3 to 29.3 million tons, or 105 percent. In contrast, the waterborne commerce carried on the MRT, measured in ton-miles, increased 53 percent from 126 to 193 billion ton-miles. This 53 percent increase in ton-miles was comprised of a 23 percent increase in commodity tonnage and a 24 percent increase in length of haul. It can therefore be concluded that the river barge industry presently has a substantial over capacity and could handle almost twice as much waterborne commerce based on the 1970–1980 data.

An example of the ability of the barge industry to quickly utilize excess capacity is shown in Table B–9, which compares total U.S. coal exports and those of the Lower Mississippi River: Baton Rouge to Gulf reach for 1970–1981. This reach saw a remarkable increase in coal export tonnage, from 1.4 to 3.8 to 14.0 million tons for 1979, 1980 and 1981 respectively. The tripling in coal exports from 1980 to 1981 was made possible by the direct transfer of coal from shallow draft barges to oceangoing vessels in the deep draft channel of the Mississippi River at New Orleans, rather than using landside transfer facilities.

Table B–8

TOWBOAT HORSEPOWER, BARGE CAPACITY AND WATERBORNE COMMERCE; MRT AND GIWW 1970, 1979 AND 1980

Item	Annual Total			Percent Increase		
	1970	1979	1980	1970–79	1970–80	1979–80
Vessels[1]						
Towboats Total HP (1000)	2,275	4,224	4,638	86	104	10
Non Self-Propelled Dry Cargo Barges. Total Capacity (1000 tons)	14,284	27,110	29,261	90	105	8
Waterborne Commerce, MRT[2]						
Billions of Ton Miles	126	184	193	46	53	5
Millions of Tons	297	371	366	25	23	–1
Average Length of Haul: Miles	424	496	527	17	24	6

1 U.S Army Corps of Engineers, "Summary of the U S. Flag Passenger and Cargo Vessels Operations or Available for Operation," Annual

2. U S Army Corps of Engineers, *Waterborne Commerce of the United States*, Part 5.

Table B–9

COAL EXPORTS: U.S. AND SELECTED PORT REACHES 1970, 1979, 1980 AND 1981[1]

(Millions of Tons)

Port Area	1970	1979	1980	1981
U S Total	71.3	65.7	91.3	112.2
Great Lakes Ports	18.3	18.9	16.8	17.7
Ocean Ports Excluding New Orleans, Miss R	52.5	42.4	64.9	80.5
New Orleans (Lower Miss R. B R to Gulf)	0.2	1.4	3.8	14.0

1. U S. Army Corps of Engineers, Waterborne Commerce Statistics Center

OTHER WATERWAY USES

The Corps of Engineers is charged with improving, operating and maintaining the nation's waterways for more reasons than just fostering waterborne commerce. It is also committed to assisting recreational boating and shore-based recreation, enhancing environmental quality as well as fish and wildlife resources, controlling floods, developing hydropower, providing storage or access for municipal/industrial or agricultural (irrigation) water supply, and providing flow to maintain water quality.

The commitments to these other water uses, as well as commercial navigation, are based in legislative authority. All or a combination of some of these uses may be recognized during the planning stages for Corps projects and may be incorporated as authorized project purposes. In other situations, particularly with regard to older navigation projects, authorized project purposes often only include commercial and recreational navigation. Other uses, like water supply and hydropower, may be accommodated as incidental uses allowed through the Corps' permit system. Incidental uses are usually made subordinate to navigation uses. Through such methods, the Corps can develop water resources that meet the needs of a variety of users, thus insuring the economically efficient use of those resources to the benefit of the public at large.

COMMERCIAL AND RECREATIONAL NAVIGATION USERS

In most situations commercial and recreational uses of a waterway are not in conflict. The improvement of many waterways has also enhanced its ability to meet recreation interests through careful planning and implementation. Sometimes, though, meeting the needs of a variety of users having different interests can be a problem, especially when the density of users approaches the limits of the resource's ability to satisfy users' demands. For example, some waterways and ports near high population centers experience congestion during summer months (especially weekends and holidays) because increased recreational traffic is added to existing commercial traffic. The navigation channels, locks, and landside facilities simply become overcrowded. In a few instances, congestion can result in competition for lockage service, space for fleeting areas, for turning basins and mooring, and space for landside facilities like marinas and picnic areas versus commercial docking facilities.

Additionally, recreational users require certain aesthetic surroundings and water quality standards that may be spoiled by heavy commercial traffic underway or by the presence of commercial fleeting and docking areas. Conflicting requirements become more visible in congested circumstances.

Waterways and ports where combined commercial and recreational traffic volumes may result in congestion and conflict, include portions of the following: Upper Mississippi, Lower Upper Mississippi, Upper Ohio, Verdigris, San Francisco Bay, Florida coastal channels and Chesapeake Bay.

ADDITIONAL USERS AND POTENTIAL CONFLICTS

Some waterways and the reservoirs that feed them may experience other conflicting demands from a variety of users. Examples of the kinds of conflicts that can occur include simultaneous needs for hydropower releases, navigation releases, releases for water quality maintenance, maintenence of water level for flood control, withdrawals for water supply, and water availability for general recreation, including swimming, fishing, boating, and related shore-based activities like camping and picnicking.

Hydropower, Low Water Conditions and Flood Control

In a few instances releases for hydropower may increase downstream flow or produce high water levels, interfering temporarily with commercial and recreational navigation as well as general recreational activities. Such is the case on the Columbia-Snake Waterway below Bonneville Dam.

Other possible conflicts with navigation occur on the Alabama River and at Barkley Dam on the Cumberland River. Hydropower releases at these locations are primarily for peaking power generation and the timing of releases may not coincide with the needs of navigation.

The needs for navigation releases to supplement low flows, releases to preserve water quality downstream and releases for hydropower production may not occur at the same time. During periods of low available water in storage, competition for the timing of releases may result, and conflicts over priority of use may ensue. Furthermore, any releases during periods of limited water availability could draw down the level of the reservoir to the detriment of recreational users on the lake, and municipal/industrial or agricultural users that depend on withdrawals from the reservoir for water supply and irrigation. Competition for a limited resource under these circumstances becomes most visible during drought conditions when the various needs for water usually increase, and the available supply decreases.

Efforts have been made in a number of areas to minimize the impacts associated with divergent water use demands. Reservoirs like Tygart Lake for the Monongahela River endure seasonal drawdowns due to releases for navigation. Recreational users, the main users of the reservoir, have adapted to the predictable lowering of water levels by utilizing floating boat docks, movable concession stands, and similar devices. Also, the time of the releases corresponds to the end of the summer recreation season. Potential conflicts are minimized due to these and other factors. On the other hand, at Lake Sidney Lanier, a reservoir near Atlanta for the Chattahoochee River, recreation interests are so extensive that concerns for the effects of low water levels for the summer season play a large role in determining the volume of releases for navigation, even though navigation is an authorized purpose and, technically, recreation is not.

The Alabama, Apalachicola and Missouri rivers represent waterways where increased water consumption, particularly by irrigation, and possibly by municipal/industrial users could aggravate existing low flow problems, jeopardizing all other uses of these waterways, including navigation.

With all these possible competing uses, there still remain requirements for flood control. Water levels in reservoirs and channels must be maintained to reserve space to accommodate flood water at appropriate times. Additionally, there are the everpresent concerns for the environment and enhancement of fish and wildlife. Fluctuating water levels due to water releases or withdrawals can contribute to bank erosion, deterioration of shoreline archeological sites, or instability and possibly destruction of the shoreline habitat. Water releases may disturb depth, temperature, flow and oxygen regimes of downstream aquatic habitats.

Water Supply and Water Quality

Navigation, as one component of many projects which have multipurpose objectives, is also indirectly associated with broader issues relating to water supply and water quality. In recent years the Corps, as a water resource agency, has become increasingly involved in such issues and in the efforts to more effectively plan and design multipurpose projects which will aid in achieving water supply and water quality objectives.

The 1948 Water Pollution Control Act, and the 1956 amendment to it, provided for the Public Health Service to embark upon a program of basin-wide comprehensive planning. These planning efforts were later linked through the Water Resources Council to the national, multipurpose comprehensive planning of water and related land resources authorized during the Kennedy Administration.

Drought in parts of the nation has demonstrated that municipal and industrial water supplies are only marginally adequate in many communities. There are many areas of the humid eastern United States where existing surface storage reservoirs cannot any longer assure a reliable water supply for their service regions without infringing on competing multipurpose storage allocations. It is increasingly evident that long range multipurpose water resource planning for navigation and other water uses, will need to give increasing weight to water supply and water quality concerns.

Summary of Other Waterway Uses

It becomes obvious that the operation of the waterways, complete with their ports and reservoirs, can be complicated due to the requirements of different uses that are made of them. Competition for limited resources can result in conflicts over priority of use. Prioritization may be set in advance, or may be decided on a case by case basis through evaluation of gains and losses to each user from alternative courses of action.

The nation's waterways can and do serve several interests simultaneously. The Corps operates and maintains the waterways to serve all these interests. Problems can arise, though, when non-complementary demands are made that approach the limits of the waterways' ability to satisfy them. In such circumstances, special techniques like lockage scheduling may be employed, special groups may be established like the reservoir control center in the Corps' North Pacific Division, or structural or operational changes may be made to deal with these problems.

APPENDIX C

COMMODITY CLASSIFICATIONS AND CODE NUMBERS

APPENDIX C

COMMODITY CLASSIFICATIONS AND CODE NUMBERS

Table C–1
COMMODITY CLASSIFICATIONS AND CODE NUMBERS

Major Commodity Group	Reporting Group	Analysis Group	Commodities Included (CCDWC Code Number)[1]
Agricultural Products			
	Farm Products		
		Corn	0103
		Wheat	0107
		Soybeans	0111
		Other Farm Products	0101, 0102, 0104, 0105, 0106, 0112, 0119, 0121, 0122, 0129, 0131, 0132, 0133, 0134, 0141, 0151, 0161, 0191
	Food and Kindred Products		
		Vegetable Oils	2091
		Grain Mill Products	2041, 2042, 2049
		Other Food Products	2011, 2012, 2014, 2015, 2021, 2022, 2031, 2034, 2039, 2061, 2062, 2081, 2092, 2094, 2095, 2099
Chemicals and Fertilizers			
		Sodium Hydroxide	2810
		Crude Tar, Oil and Gas Products	2811
		Alcohols	2813
		Benzene and Toluene	2817
		Sulphuric Acid	2818
		Other Chemicals	2812, 2816, 2819, 2821, 2822, 2823, 2831, 2841, 2851, 2861, 2876, 2891
		Nitrogenous Chemical Fert.	2871
		Potassic Chemical Fert	2872
		Phosphatic Chemical Fert	2873
		Other Fert Products	2875, 2879
Metals and Ores			
	Metallic Ores		
		Iron Ore and Concentrates	1011
		Other Ores (including Bauxite)	1021, 1051, 1061, 1091
	Primary Metal Products		
		Coke	3313
		Iron and Steel Primary Forms	3314
		Steel Mill Products (shapes, plates, pipe, and tube)	3315, 3316, 3317
		Other Primary Metal Products	3311, 3312, 3318, 3319, 3321, 3322, 3323, 3324
Coal			
		Coal and Lignite	1121
Petroleum			
	Crude Petroleum		
		Crude Petroleum	1311
	Petroleum and Coal Products		
		Gasoline	2911
		Jet Fuel and Kerosene	2912, 2913
		Distillate	2914
		Residual	2915
		Other Petroleum and Coal Products, nec	2916, 2917, 2918, 2921, 2951, 2991
Forest Products			
	Lumber and Wood Products		
		Logs (including Pulpwood)	2411, 2415
		Rafted Logs	2412
		Lumber and Plywood	2421, 2431
		Other Lumber and Wood Products	2413, 2414, 2416, 2491
	Pulp, Paper and Allied Products		
		Pulp	2611
		Other Pulp and Paper Products	2621, 2631, 2691

Major Commodity Group	Reporting Group	Analysis Group	Commodities Included CCDWC Code Number[1]
Other Commodities			
	Non Metallic Minerals		
		Sand, Gravel, and Crushed Rock	1442
		Limestone	1411
		Phosphate Rock and Other Fertilizers	1471, 1479
		Sulphur	1492, 1493
		Other Nonmetallic Minerals	1412, 1451, 1491, 1494, 1499
	Stone, Clay, Glass, and Concrete Products		
		Cement	3241
		Other Stone, Clay, Glass Prod.	3211, 3251, 3271, 3281, 3291
	Waste and Scrap		
		Metal Scrap	4011, 4012
		Other Scrap	4022, 4024, 4029
	Other Commodites, not elsewhere classified (nec)		
		Marine Shells	0931
		Miscellaneous	
		Forest Products	0841, 0861
		Fish	0911, 0912, 0913
		Ordnance	1911
		Tobacco	2111
		Textiles	2211, 2212, 2311
		Furniture	2511
		Printed Matter	2711
		Rubber Products	3011
		Leather	3111
		Fabricated Metal	3411
		Machinery	3511, 3611
		Transportation Equipment	3711, 3721, 3731, 3791
		Instruments, Optical Goods, etc	3811
		Miscellaneous Manufacturers	3911
		Water	4111
		Shipments not identified	4112
		LCL Freight	4113
		Department of Defense Cargo	9999
		Water Improvement Materials	4118

1 For a detailed description of Commodity Classification for Domestic Waterborne Commerce (CCDWC), see U S. Army Corps of Engineers, *Waterborne Commerce of the United States*, Annual, Parts 1–5.

Table C–2

WATERBORNE AGRICULTURAL FLOWS FORECASTS BY REACH[1]

(Millions of Tons)

Reach	1977 Base Year	2003 High Use[2]	2003 Low Use	2003 Bad Energy	2003 Misc.
Upper Miss	13.2	33.3	29.2	36.1	33.4
Lower Upper Miss	36.0	78.6	68.5	83.1	78.8
L. Miss Cairo to B R.	46.4	102.2	89.9	103.3	104.9
L. Miss. B.R. to Gulf	101.8	226.7	200.0	228.6	229.5
Illinois Waterway	17.6	37.4	32.3	42.9	37.4
Missouri River	2.0	3 6	3.2	3.0	3.7
Ohio River System	7 2	12.2	11.1	12.7	13.5
Tennessee River	2.4	3.5	3.1	2.9	3.9
Arkansas River	1.2	2.4	2.3	1.8	4.1
Gulf Coast-West	24.7	57.0	56.1	54.9	57.0
Gulf Coast-East	6 5	12.1	10.9	11.4	12.3
Mobile River and Trib.	2.8	11.4	10 8	9.3	11.6
South Atlantic Coast	2.9	5.8	5.7	5.7	5.8
Middle Atlantic Coast	24.8	53.0	49.4	57.6	53.0
North Atlantic Coast	1.0	2.3	2.2	2.2	2.3
Great Lakes System	12.1	27.2	23.2	28.0	27.2
Washington/Oregon Coast	3.0	12.8	11.2	14.7	12.8
Columbia-Snake Waterway	10.4	22.0	22.2	19.3	22.0
California Coast	9.5	22.9	22.0	23.5	22.9
Alaska	0.5	0.9	.9	0.9	.9
Hawaii	3.3	6.3	6.3	6.4	6.3
Caribbean	3.0	5.0	5.0	5.1	5.0
Total[3]	202.4	458.6	418.7	463.0	461.7

1 Agricultural commodities include two reporting commodities — farm products and food and kindred products.
2 The Baseline and High Coal Export forecasts are identical to the High Use forecast for agriculture.
3. Reaches are not additive because many individual shipments pass through more than one reach This figure reflects the national total not the sum of reaches

Table C–3

WATERBORNE CHEMICAL/FERTILIZER FLOW FORECASTS[1]

(Millions of Tons)

Reach	1977 Base Year	2003 High Use[2]	2003 Low Use	2003 Bad Energy	2003 Misc.
Upper Miss.	2.1	5.1	5.2	5.8	5.1
Lower Upper Miss	6.9	15.4	15.1	16.3	15.6
L. Miss: Cairo to B.R.	14.9	26.8	25.9	27 8	28.8
L. Miss. B R to Gulf	25.8	46 7	44.8	46 7	48 7
Illinois Waterway	4.2	9.6	9.2	10.1	9.7
Missouri River	0.5	0.9	0.9	0.7	.9
Ohio River System	9.6	18.7	17 4	18.9	20.7
Tennessee River	2 6	6 3	5.8	6.3	6.7
Arkansas River	0 6	1.2	1.2	1.3	2.1
Gulf Coast-West	29.5	52.3	49.2	50 9	53 2
Gulf Coast-East	8.6	16.1	15.6	15.6	16.7
Mobile River and Trib	1.2	6.1	5.7	6.0	6.5
South Atlantic Coast	4.1	6.8	6.5	5.5	6.8
Middle Atlantic Coast	11.0	19 5	18 8	18.8	19.5
North Atlantic Coast	0.8	1.5	1.4	1.5	1.5
Great Lakes System	1.2	2.4	2.1	2.1	2.4
Washington/Oregon Coast	2.3	4.2	4.0	4.4	4.2
Columbia-Snake Waterway	2.1	3.7	3.4	3.7	3 7
California Coast	3.5	5.3	5.3	5.2	5.3
Alaska	0.8	1.1	1.1	1 2	1.1
Hawaii	0.3	0.4	0.4	0.3	.4
Caribbean	4.2	8.7	8.1	8.5	8 7
Total[3]	77.8	139 2	133.5	135.3	142.4

1. The chemical/fertilizer flows include only the reporting commodity chemicals Phosphate rock and other fertilizers are reflected in the non-metallic minerals reporting commodity.
2. Baseline and High Coal Export are identical to the High Use forecast for chemicals/fertilizer.
3 Reaches are not additive because many individual shipments pass through more than one reach. This figure reflects the national total not the sum of reaches.

Table C-4
WATERBORNE METALS AND ORES FLOW FORECASTS BY REACH[1]
(Millions of Tons)

Reach	1977 Base Year	2003 High Use[2]	Low Use	Bad Energy	Misc.
Upper Miss.	0.4	0 6	0.6	0.6	.6
Lower Upper Miss.	2.9	5.0	5.4	4 9	5.2
L. Miss: Cairo to B.R.	6.7	10.7	11.6	10.6	12.5
L. Miss: B.R. to Gulf	18.8	34.2	36.6	34.4	35.9
Illinois Waterway	10.3	20.1	19.0	19.7	20.3
Missouri River	0.1	0.1	0.2	0.1	.1
Ohio River System	5.1	8.0	7.7	7.8	9.1
Tennessee River	1.3	2.1	1.6	2.1	1.8
Arkansas River	1.1	1.7	1.7	1.6	2.9
Gulf Coast-West	12.8	21.9	23.3	21.8	22.1
Gulf Coast-East	1.3	2.8	3.1	2.8	2.9
Mobile River and Trib.	11.0	29.7	22.3	27.6	29.8
South Atlantic Coast	3.0	5.9	5.6	5.6	5.9
Middle Atlantic Coast	20.1	29.5	28.0	29 4	29.5
North Atlantic Coast	0.8	1.3	1.9	1.4	1.3
Great Lakes System	76.8	176.2	150.5	169.8	176.3
Washington/Oregon Coast	0.7	0.9	1.3	1.0	.9
Columbia-Snake Waterway	0.6	1.1	1.7	1.2	1.1
California Coast	3.2	6.1	8.8	6.4	6.1
Alaska	0.6	0.8	0.9	0.8	.8
Hawaii	0.2	0.2	0.3	0.2	.2
Caribbean	1.5	2.3	2.5	2.3	2.3
Total[3]	149.6	302.7	278 5	294.9	305.0

1. Metal and ores includes two reporting commodities, metallic ores and primary metal products.
2 The Baseline and High Coal Export forecasts are identical to High Use for metals and ores.
3 Reaches are not additive because many individual shipments pass through more than one reach This figure reflects the national total not the sum of reaches.

Table C-5
WATERBORNE COAL FLOW FORECASTS BY REACH
(Millions of Tons)

Reach	1977 Base Year	2003 Baseline	High Use	Low Use	Bad Energy	High Coal Export	Misc.
Upper Miss.	6.9	19.5	22.3	16.5	18.3	22.3	22.8
Lower Upper Miss.	10.7	41.3	46.6	37.8	38.4	48.9	48.8
L. Miss: Cairo to B.R.	11.9	43.5	52.3	25.8	57.4	67.8	60.4
L. Miss: B.R. to Gulf	11 8	46.0	59.8	26.5	68.7	102.6	66.9
Illinois Waterway	9 6	19.2	22.1	18.5	19.3	22.1	22.4
Missouri River	0 0	0.0	0.0	0.0	0.0	0.0	0.0
Ohio River System	100.1	228.2	265 9	205.0	246.6	280.2	295.1
Tennessee River	10.1	44.4	56.9	42.8	45.8	63.9	59.8
Arkansas River	0.5	5.3	5.8	1.9	8.0	6.7	10.2
Gulf Coast-West	0.3	8.8	12.2	0.3	17.3	27.2	12.7
Gulf Coast-East	8.7	40 8	45 9	34.5	34.8	46.3	48.1
Mobile River and Trib.	12.7	52.3	70.7	51 4	59.1	111.0	73.7
South Atlantic Coast	0.0	0.0	0 0	0.0	0.0	0.0	0.0
Middle Atlantic Coast	37.3	89.1	120.3	91.3	102.0	165.7	120.3
North Atlantic Coast	0 0	3.0	3.0	3.0	3.0	3.0	3.0
Great Lakes System	42.6	80.4	105 7	79.3	97.9	105 7	105.9
Washington/Oregon Coast	0.0	0.0	0.0	0.0	0.0	11.8	0.0
Columbia-Snake Waterway	0.0	0.0	0 0	0.0	0.0	0.0	0.0
California Coast	0.0	0.0	0.0	0.0	0.0	9.8	0.0
Alaska	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hawaii	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Caribbean	0.0	0 0	0.0	0 0	0.0	0.0	0.0
Total[1]	211.8	513.7	642.8	476.0	577.3	805 2	677.4

1. Reaches are not additive because many individual shipments pass through more than one reach. This figure reflects the national total not the sum of reaches.

Table C–6
WATERBORNE PETROLEUM FLOW FORECASTS BY REACH[1]
(Millions of Tons)

Reach	1977 Base Year	2003 High Use[2]	2003 Low Use	2003 Bad Energy	2003 Misc.
Upper Miss.	3.7	3.5	3.3	3.2	3.5
Lower Upper Miss.	12.8	12.2	11.7	11.3	12.6
L. Miss. Cairo to B.R.	27.9	23.5	22 1	21.3	25.2
L. Miss: B R. to Gulf	158.1	136.2	139.1	120.4	137 6
Illinois Waterway	9.0	7.8	7.4	7.2	8.0
Missouri River	0.4	0.6	0.6	0.5	.6
Ohio River System	22 7	18.8	17.8	17.8	20.9
Tennessee River	3.6	4.7	2.9	2.9	3 4
Arkansas River	2.1	1.3	1.1	1.1	2.2
Gulf Coast-West	240.6	196.7	200.0	168.7	197.3
Gulf Coast-East	45.8	36 2	33.1	30.5	36.4
Mobile River and Trib.	10.3	12 1	11.3	11.3	12.2
South Atlantic Coast	34.9	26 4	24.1	23.1	26.4
Middle Atlantic Coast	298.6	177.6	160.2	154.9	177.6
North Atlantic Coast	79.6	51.6	48.3	46.7	51.6
Great Lakes System	11.5	7.9	7.4	7.2	7.9
Washington/Oregon Coast	24.0	57.6	48.3	47 7	57.6
Columbia-Snake Waterway	6.2	5.2	4.3	4.1	5.2
California Coast	106.5	72.6	44.3	42.3	72.6
Alaska	21.9	75.1	75.8	84.6	75.1
Hawaii	8.7	7.9	7.9	7.8	7.9
Caribbean	77.8	51.5	27.3	45.3	51.5
Total[3]	958.2	722.8	646.7	602.1	725 9

1 Petroleum includes two reporting commodities, crude petroleum, and petroleum and coal products.
2 The High Coal Export and Baseline forecasts are identical to High Use for Petroleum
3. Reaches are not additive because many individual shipments pass through more than one reach This figure reflects the national total not the sum of reaches

Table C–7
WATERBORNE FOREST PRODUCTS FLOW FORECASTS BY REACH[1]
(Millions of Tons)

Reach	1977	2003 Baseline[2]
Upper Miss.	0.0	0.0
Lower Upper Miss.	0.2	0.3
L. Miss: Cairo to B.R.	0.9	1.2
L. Miss: B.R. to Gulf	1.9	3.4
Illinois Waterway	0 2	0.3
Missouri River	0.0	0.0
Ohio River System	0.1	0.1
Tennessee River	0.5	0.7
Arkansas River	0.1	0.2
Gulf Coast-West	0.9	1.6
Gulf Coast-East	0.7	1.1
Mobile River and Trib.	0.9	1.3
South Atlantic Coast	4.0	5.6
Middle Atlantic Coast	3.7	4.3
North Atlantic Coast	0.4	0.5
Great Lakes System	1.0	1.4
Washington/Oregon Coast	26.6	24.9
Columbia-Snake Waterway	17.4	19 4
California Coast	3 9	3.5
Alaska	3.4	4.0
Hawaii	0.5	0.7
Caribbean	0.5	0 8
Total[3]	64.4	70.5

1. Forest Products include two reporting commodities, lumber and wood products and pulp, paper, and allied products
2 Only one forecast was developed for forest products. Miscellaneous adjustments increase the L Miss Cairo to B.R , L. Miss: B R to Gulf, Arkansas and total by 0.1 million tons over Baseline
3. Reaches are not additive because many individual shipments pass through more than one reach. This figure reflects the national total, not the sum of reaches

Table C-8
WATERBORNE OTHER FLOW FORECASTS BY REACH[1]
(Millions of Tons)

Reach	1977 Base Year	2003 Baseline	High Use[2]	Low Use	Bad Energy	Misc.
Upper Miss.	4.6	3.9	3.9	3.9	3.9	3.9
Lower Upper Miss.	8.0	9.1	9 1	8 9	9.0	9 3
L. Miss· Cairo to B.R.	14.8	14.5	14.5	14.4	14.5	15.4
L. Miss: B.R. to Gulf	25 9	41.6	41.6	41.6	43.5	48.4
Illinois Waterway	9.6	9.0	9.0	8.9	8.9	9.0
Missouri River	3 7	2.6	2.6	2.6	2.6	2 6
Ohio River System	27.8	21.5	21.5	21.2	21.4	23.7
Tennessee River	6.0	5.3	5 3	4.8	5.3	5.1
Arkansas River	3.7	2.5	2.5	2.5	2 5	4.4
Gulf Coast-West	32.4	47.4	47.4	46.6	47.1	47.7
Gulf Coast-East	37.1	42 9	53.9	43.1	44.8	60.5
Mobile River and Trib.	5.2	6.1	6.1	6.0	6.0	6.2
South Atlantic Coast	10.8	19.0	20.5	17.5	18.2	20.5
Middle Atlantic Coast	41.1	64.8	64.8	57.9	60.5	64.8
North Atlantic Coast	4.8	8.8	8.8	7.3	7.7	8.9
Great Lakes System	44.5	90 4	90.4	81.3	86.4	90.4
Washington/Oregon Coast	11.7	20.8	20.8	19 7	20.4	20.8
Columbia-Snake Waterway	6.8	7.2	7.2	6 9	7.1	12.3
California Coast	11 6	33.1	33.1	31.1	32.5	33 1
Alaska	1.6	4.2	4.2	3.7	4.0	4 2
Hawaii	2.3	6.1	6.1	5.5	5 8	6.1
Caribbean	2.6	6.2	6.2	5 8	6.1	6 2
Total[3]	250.9	378 1	390 6	355.9	369.4	406.2

1 Other group includes reporting commodities — non-metallic minerals, stone, clay, glass and concrete products, waste and scrap, and other commodities
2 High Use is the same as High Coal Export
3. Reaches are not additive because many individual shipments pass through more than one reach This figure reflects the national total not the sum of reaches.

APPENDIX D

NATIONAL WATERWAYS REACH SUMMARIES

Appendix D

NATIONAL WATERWAYS REACH SUMMARIES

INTRODUCTION

This appendix displays salient information for each of the 22 reaches of the United States waterways. Included are illustrations, text and tabulations discussed below.

ILLUSTRATIONS

The map of each reach is based on one of the four NWS regional maps (Maps 16–19) contained in Appendix G. The line graphs display the envelope of the minimum and maximum projections of waterborne commerce based on the extremes of the seven forecasts discussed in Sections IV and V of this report. The bar graphs are based upon the High Use forecast unless otherwise stated. Waterway profiles are shown for those reaches with extensive lock and dam systems and are based upon information in Corps district, division, and Office of the Chief of Engineers (OCE) reports.

TEXT AND TABULATIONS

The discussion for each reach contains information in text and tabular form such as the following: (1) physical characteristics, (2) dredging, including volume and cost (in 1977 dollars), (3) lock dimensions and capacities (if calculated; if there is more than one chamber at a lock, single capacity figure represents both), (4) commercial traffic, including the range between the maximum and minimum forecasts for that reach by the year 2003, (5) traffic linkages with other waterways during 1977 (based on Table D–1), (6) types of vessels using waterway, (7) recreational and other water uses, (8) environmental concerns, (9) current status of the waterway, and (10) the capability and constraints of each reach in terms of handling projected waterway traffic.

The source of the data on the physical characteristics of the waterways is the inventory of the U.S. waterway system developed by the National Waterways Study, with the cooperation of the Corps districts, division, OCE and the staff of the Board of Engineers for Rivers and Harbors. The sources of data for the other information are reports produced by the prime contractor, A. T. Kearney, Inc. in conjunction with Data Resources, Inc. and Louis Berger and Associates (see Appendix H). Supplemental information for the textual material was obtained from Corps district and division reports, Chief of Engineers annual reports, the Corps state series on water resources development, waterborne commerce data tapes, other sources, and analysis by the NWS staff.

LINKAGE WITH OTHER REACHES

The matrix shown in Table D–1 was developed to aid in the analysis of the traffic linkages among the various reaches. Total waterborne commerce for 1977 among the river and coastal reaches and foreign areas is shown in this table. The *rows* of the matrix show for each reach the amount of traffic that originates as waterborne shipments and exports. The total for each row is then shown in the last column on the right of the table. The *columns* list the receipts and imports for each reach, with some of the receipts and exports shown at the bottom line of each column. As an example, Reach 1 (the Upper Mississippi River) originated 11.9 million tons destined for Reach 4 (the Lower Mississippi: Baton Rouge to Gulf). That was part of the total of 21.8 million tons of shipments originating in Reach 1. This reach received 2.6 million tons from Reach 4, out of the total Reach 1 receipts of 16.6 million tons. Reach 1 shows intra-reach traffic of 6.2 million tons.

Examination of the matrix shows the high degree in traffic linkages of most of reaches 1 through 12, which include the Mississippi River and Tributaries, the Gulf Coast-East and West, and the Mobile River and Tributaries. Linkages between coastal reaches are readily apparent, especially shipments from the Gulf Coast-West (row) to the following reaches (in millions of tons): South Atlantic, 15.5; Mid Atlantic, 23.9; North Atlantic, 11.8; and California, 1.0. Shipments to the Mid Atlantic Coast (column) from the Pacific coast reaches are as follows (in thousands of tons): Alaska, 54.5; Hawaii, 25.3; Washington-Oregon Coast, 108.1; Columbia/Snake Waterway, 8.4; and California Coast, 579.0. Foreign trade data are reported in rows 23 and 24 and columns 23 and 24.

As a summary of traffic linkages, the commodity flow maps in Appendix G depict the density of the traffic flows for major commodity groups and the total for all commodities. The waterways of the United States interchange a very high level of traffic among the major rivers, the coasts, and the Great Lakes. Coastal and Great Lakes reaches with deep water ports engage in trade with nations throughout the world.

Table D–1
WATERBORNE COMMERCE: ORIGIN TO DESTINATION, BY NWS REACHES, 1977
TOTAL OF ALL COMMODITIES (1,000 tons of 2,000 lbs)

Origin / Destination	Upper Miss	Lower Upper Miss	Lower Miss: Cairo to B.R.	Lower Miss: B.R. to Gulf	Illinois WW	Missouri River	Ohio River
No. Name	1	2	3	4	5	6	7
1. U Miss R	6218.9	350.1	1405.2	11930.2	583.5	7.0	326.7
2. LU Miss R	4935.1	3293.5	1376.8	5086.7	3270.7	133.9	2467.1
3. L M Cairo-BR	165.0	138.6	2515.9	6277.4	227.4	32.4	1245.4
4. L M BR-Gulf	2648.0	1492.4	9047.9	22187 3	3720.3	492.8	10152.2
5. Illinois WW	93.8	466.6	498 1	14638 8	11037.6	210.0	431.7
6. Missouri R	27.5	116.0	38.7	1252.3	197.6	3512.1	84.1
7 Ohio R	989 1	1516 0	5283.0	9008 8	1165.4	27.0	112365.6
8. Tenn R	268.1	116.4	1699.0	1131 3	158.1	26.8	555.7
9. Arkansas R	162.8	32.9	226.8	1432.4	229.1	0	169.6
10. Gulf Coast-W	774.5	1050.0	2090.8	13092 5	2780.1	179.1	5345.1
11. Gulf Coast-E	130.9	193.8	259.7	10149.9	485 1	4.3	716.1
12. Mobile R & Trib	77.2	3.8	355.2	2331.8	3.9	0	137.7
13 South Atlantic	0	0	0	9.4	0	0	0
14 Mid Atlantic	0	0	0	388 0	0	0	0
15. North Atlantic	0	0	0	23.3	0	0	0
16. Great Lakes System	80.9	171.2	68.4	94 6	7389.4	9.3	84.7
17. Wash/Ore Coast	0	0	0	0	0	0	0
18. Columbia/Snake	0	0	0	0.1	0	0	0
19. Calif Coast	0	0	0	115.3	0	0	0
20. Alaska	0	0	0	95.7	0	0	0
21. Hawaii	0	0	0	136.5	0	0	0
22. Caribbean	0	0	0	129.3	0	0	0
23. Overseas & Pac Can	0	0	0	96553 9	1992 2	0	0
24. GL & SLS Can	0	0	0	0	1580.8	0	0
TOTAL RECEIPTS AND IMPORTS	16,571.7	8,941.2	24,865.4	196,065.4	34,820 7	4,634.8	134,081.9

LEGEND
+ 1,000 to 50,000 tons
– 1 to 999 tons
0 No traffic

Tennessee River	Arkansas River	Gulf Coast-West	Gulf Coast-East	Mobile River & Trib.	South Atlantic Coast	Mid Atlantic Coast	North Atlantic Coast
8	9	10	11	12	13	14	15
457.8	5.3	54.6	292.1	173.8	0	0	0
844.6	53.5	212.4	175.0	14.6	1.0	0	0
57.4	79.3	160.3	212.4	24.8	0	0	0
1525.2	1708.1	9307.0	7636.7	1096.1	2128.6	7189.5	2065.2
633.7	60.4	426.3	216.7	114.9	0	0	0
377.4	0	2.2	4.3	0	0	0	0
4828.1	89.9	1214.9	3130.8	394.3	0	0.5	0
5892.2	6.8	105.4	351.6	22.5	0.9	0	1.1
125.5	4056.6	90.0	74.2	29.8	0	0	0
2432.5	514.6	54519.2	10626.2	1688.1	15546.4	23900.9	11804.6
95.1	195.7	3289.2	11390.3	2009.9	2312.6	313.6	292.7
138.9	5.1	2965.0	3109.0	14277.9	118.2	54.4	0
0	0	80.2	135.0	415.5	9517.3	1360.1	9.6
0	0	1234 5	270.7	0.4	2587.0	129879.0	21788.9
0	0	16.7	0.7	0	12 1	1758.4	8103.0
72.0	41.0	106.6	7.3	0	0	21.9	0
0	0	9.7	5.6	0	0.3	108.1	0
0	0	0	0	0	9.7	8.4	0
0	0	171.5	58.8	0	39.0	579.0	129 2
0	0	0	0	0	0	54.5	0
0	0	0	0	0	0	25.3	0
0	0	1124.4	943.6	153.5	5216.4	15946.7	5078.2
0	0	137104.2	18323.3	8167 2	20701 0	168692.0	33996.7
0	0	0	0	0	0	0	0
17,480.6	6,816.3	212,195.2	56,964.2	28,583.4	58,190.6	349,892.2	84,269.1

Table D–1 (Continued)

WATERBORNE COMMERCE: ORIGIN TO DESTINATION, BY NWS REACHES, 1977

TOTAL OF ALL COMMODITIES (1,000 tons of 2,000 lbs)

Origin — No. Name / Destination	Great Lakes System 16	Wash/ Oregon Coast 17	Columbia Snake WW 18	Calif Coast 19
1. U Miss R	0	0	0	0
2 LU Miss R	99.2	0	0	0
3 L M Cairo-BR	6.9	0	0	0
4. L M BR-Gulf	314.1	0	4.4	307.7
5. Illinois WW	3686 0	0	0	0
6. Missouri R	0	0	0	0
7. Ohio R	209.8	0	0	0
8. Tenn R.	156.1	0	0	0 8
9. Arkansas R	5.3	0	0	0
10 Gulf Coast-W	90.4	41 3	192 7	1028 6
11. Gulf Coast-E	1 4	0	0	26.3
12. Mobile R & Trib	0.7	0	0	0
13. South Atlantic	0	0	–	160.8
14. Mid Atlantic	1647.6	1 3	0	275.1
15. North Atlantic	–	0	0	0
16. Great Lakes S	101442.4	0	0	0
17. Wash/Ore	0	17294.8	361.2	2680.2
18. Columbia/Snake	0	293.5	21592.9	259.0
19. Calif Coast	0	3155.4	3290.0	31399.6
20. Alaska	0	4036 5	299.5	11618 3
21. Hawaii	0	168.8	79.7	2586.2
22 Caribbean	0	0	27.8	106.9
23. O & Pac Can	5439.8	20018.9	4045.3	60186.6
24. GL & SLS Can	23815.4	0	0	0
TOTAL RECEIPTS AND IMPORTS	136,915.1	45,010.6	29,893.5	110,636.2

LEGEND

\+ 1,000 to 50,000 tons

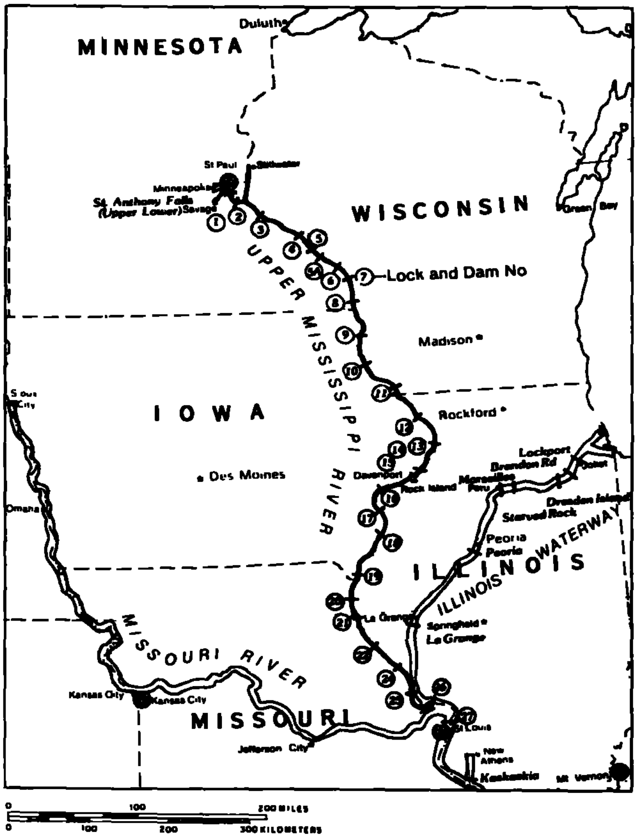
– 1 to 1,000 tons

0 No traffic

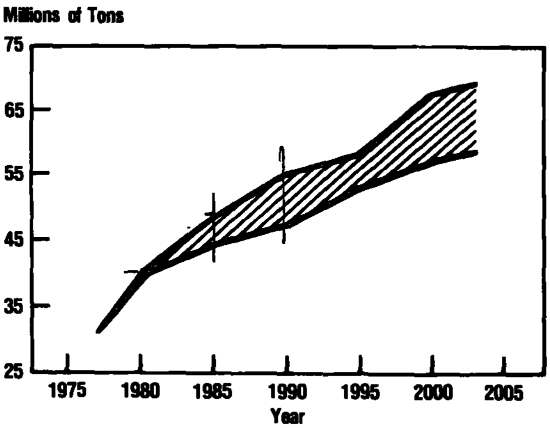
Alaska	Hawaii	Caribbean	Overseas, and Pacific Canada	Great Lakes St. Law SW: Canada	TOTAL SHIPMENTS AND EXPORTS
20	21	22	23	24	25
0	0	0	0	0	21,805.2
0	0	0	0	0	21,964.1
0	0	0	0	0	11,143.0
0	0	291.7	59289.1	0	143,604 4
0	0	0	1193.7	1377.3	35,085.6
0	0	0	0	0	5,612.2
0	0	0	0	0	140,223.0
0	0	0	0	0	10,492.7
0	0	0	0	0	6,636.1
0	0	438.5	35405.9	0	183,542.0
0	0	370.1	22130.0	0	54.366.8
0	0	290.8	5520.9	0	29,390.6
0	5.9	769.6	8618.2	0	21.081.8
0	62.9	1852.0	56756.7	0	216,744.1
0	0	0	1307.0	0	11,221.1
0	0	0	7461 6	26303.1	143,354.3
1856.2	283.5	0	18060 4	0	40,660.0
27.0	215.8	0	12821.4	0	35,227 8
813.0	3246.2	239.1	15981 8	0	59,217.8
3380.6	0	0	5024.2	0	24,509.3
0	2413.1	0	146.6	0	5,556.3
0	0	3678.4	1462.8	0	33.869.0
1618.7	5926 4	51645.5	0	0	634.411.7
0	0	0	0	0	25,396.2
7,695.4	12.153.8	59575.7	251,180.6	27680.4	1,915.114 0

Figure D-1

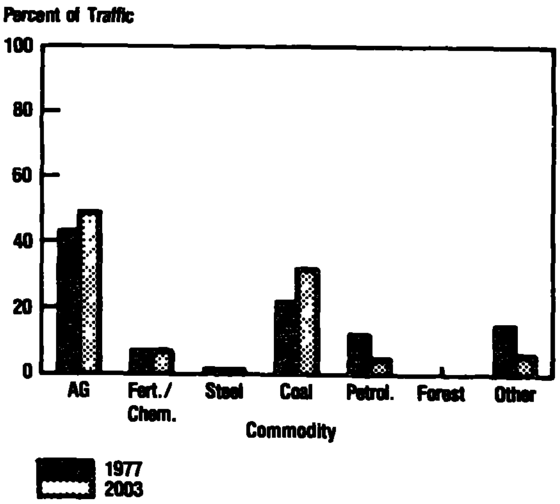
REACH 1, UPPER MISSISSIPPI RIVER
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note: Sites of locks and dams are shown by a name or number.

REACH NUMBER 1
UPPER MISSISSIPPI RIVER
(Minneapolis, Minnesota, to Mouth of Illinois River)

1. *Physical Characteristics*. The authorized and controlling depth is 9 feet; the controlling width is 200 to 300 feet (200 to 400 authorized); and the length is 637 miles. Due to river ice, the navigation season extends from 3 April to 1 December in the upper portion and from 25 March to 31 December in the lower portion. No recurring problems of water availability affect navigation.

2. *Dredging*. The average annual dredging volume (1973 to 1977) was 2.6 million cubic yards at an average cost of $2.7 million, or $1.0 per cubic yard.

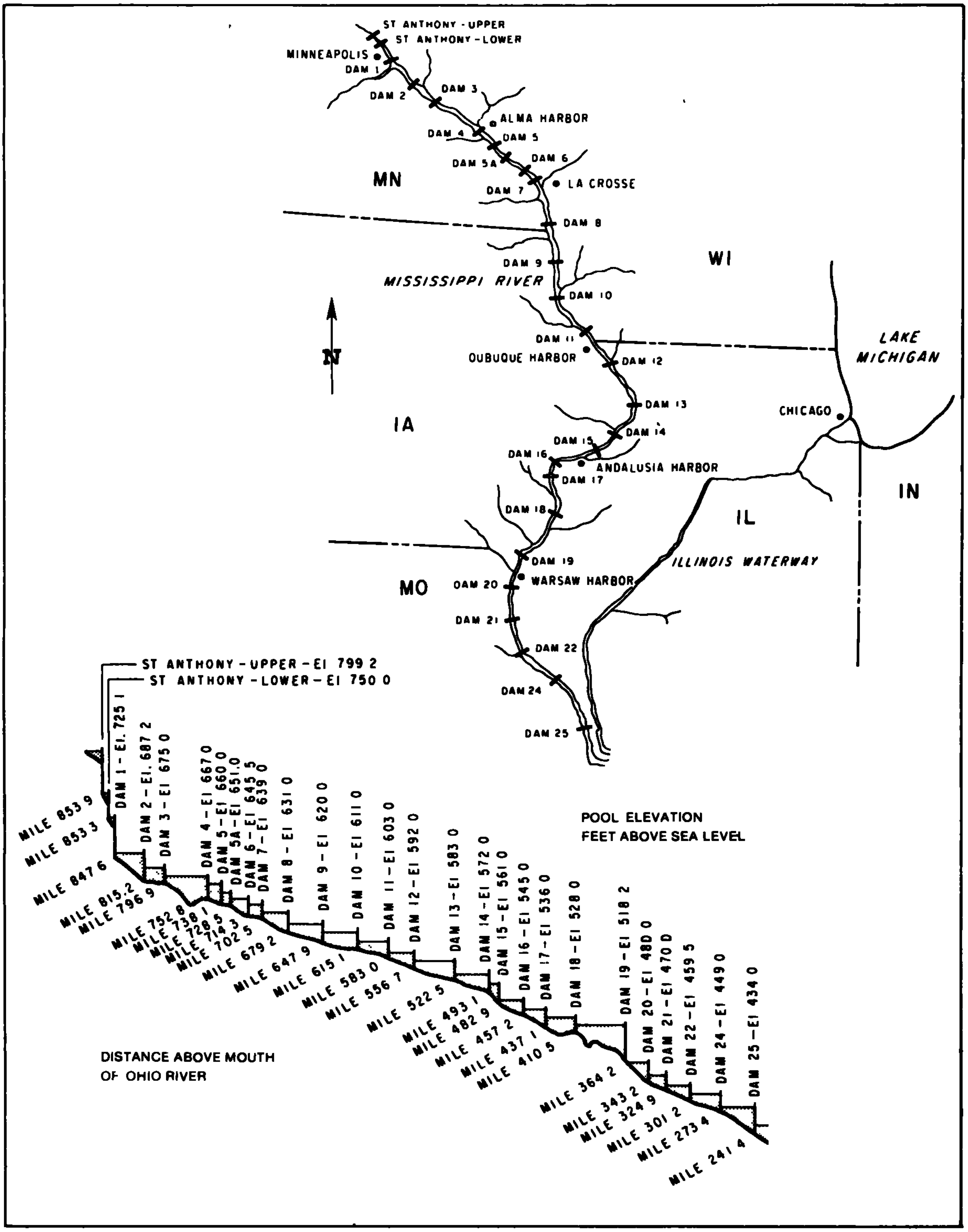
3. *Lock Dimensions and Capacity*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
Upper St. Anthony Falls	56	400	49	1963	9–12
Lower St. Anthony Falls	56	400	25	1959	9–12
No. 1	56	400	38	1930	19–22
	56	400	38	1932	
No. 2	110	500	12	1930	36
	110	600	12	1948	
No. 3	110	600	8	1938	48
No. 4	110	600	7	1935	48–49
No. 5	110	600	9	1935	48–49
No. 5a	110	600	5	1936	49
No. 6	110	600	6	1936	49–50
No. 7	110	600	8	1937	49–50
No. 8	110	600	11	1937	49–50
No. 9	110	600	9	1938	48–50
No. 10	110	600	8	1936	48–50
No. 11	110	600	11	1937	48–50
No. 12	110	600	9	1938	48–51
No. 13	110	600	11	1938	48–51
No. 14	80	320	11	1922	54–57
	110	600	11	1939	
No. 15	110	600	16	1934	54–57
	110	360	16	1934	
No. 16	110	600	9	1937	53–56
No. 17	110	600	8	1939	55–58
No. 18	110	600	10	1937	55–58
No. 19	110	1200	38	1957	67
No. 20	110	600	10	1936	59–60
No. 21	110	600	10	1938	60–61
No. 22	110	600	10	1938	50
No. 24	110	600	15	1940	59–60
No. 25	110	600	15	1939	59–60

4. *Commercial Traffic*. The 1977 traffic of 30.9 million tons is projected to increase between 90 and 125 percent, or 58.8 to 69.4 million tons, by 2003, depending on the forecast. As shown in the Figure D–1, the agriculture commodities (principally corn, soybeans, and wheat) are the driving force in the projection, comprising about 13 million tons or 42 percent of the 1977 traffic, and between 29 and 36 million tons in 2003. These grain shipments are predominately destined for export through Lower Mississippi River ports, although they are labeled as "domestic" commodity movements on this leg of the journey overseas. Coal ranks as the number two commodity, increasing from 6.9 million tons in 1977 to 22.3 million tons by 2003 under the High Coal Export scenario. Petroleum products show traffic of about 3 to 4 million tons throughout the projection period.

5. *Linkage With Other Reaches*. Almost 55 percent (11.9 out of 21.8 million tons) of all the shipments originating along the Upper Mississippi River in 1977 were destined for the Lower Mississippi: Baton Rouge to Gulf reach. Grains constitute 10.4 of that 11.9 million tons and much is transferred to deep draft ships for export. Intra-segment movements were 6.2 million tons in 1977. Other major receivers of outbound shipments from this reach and the reaches that are origins of the receipts on the Upper Mississippi River are listed in the tabulation that follows.

Figure D-2
PROFILE OF UPPER MISSISSIPPI RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

	SHIPMENTS			RECEIPTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	4	L. Miss: B.R. to Gulf	54.7	1	Intra-Reach	37.5
2	1	Intra-Reach	28.5	2	Lower Upper Miss.	29.8
3	3	L. Miss: Cairo to B.R.	6.4	4	L. Miss: B.R. to Gulf	16.0
4	5	Illinois Waterway	2.7	7	Ohio River System	6.0
5	8	Tennessee River	2.1	10	Gulf Coast-West	4.7
6	2	Lower Upper Miss.	1.6	8	Tennessee River	1.6
TOTAL: (Thousands of Tons)			21,805.2			16,571.7

6. *Types of Vessels.* The 9-foot deep channel is utilized by tows with an average size of 7 to 9 barges. The common maximum tow sizes is 15 barges. The average barge carries about 1,450 tons of cargo or about 11,600 tons for an 8 barge tow.

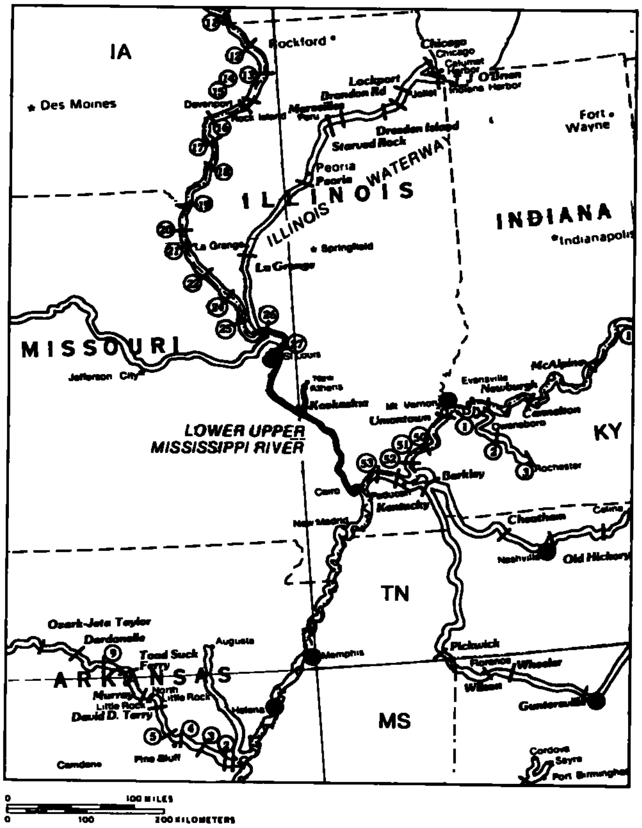
7. *Recreation and Other Water Uses.* Recreational boating, water supply, fish and wildlife habitat, aesthetics, and cooling water used by power generating plants and industries are major non-commercial water uses. Conflicts between recreation boats and commercial traffic for use of the locks in this segment are very prevalent during the summer months. A fairly high accident rate has occurred in this reach.

8. *Environmental Concerns.* Dredged material disposal problems are present because: (1) the states of Minnesota and Wisconsin require upland disposal sites; and (2) Minnesota has effluent standards for placement sites. Water quality problems are present in upper reaches (above Lake Pepin) due to municipal/industrial discharges and agricultural run-off and sedimentation. Close environmental monitoring is required by the presence of national wildlife refuges, wetlands, endangered and threatened species, and a water fowl migration route. Deposition of dredged materials in sloughs, backwater areas, wetlands, fish and wildlife habitat, etc., may pose environmental problems. However, considerable progress is being made through the GREAT (Great River Environmental Action Team) River Study of the Mississippi River main stem to find new and more acceptable uses of these materials in a manner which is both economically and environmentally feasible.

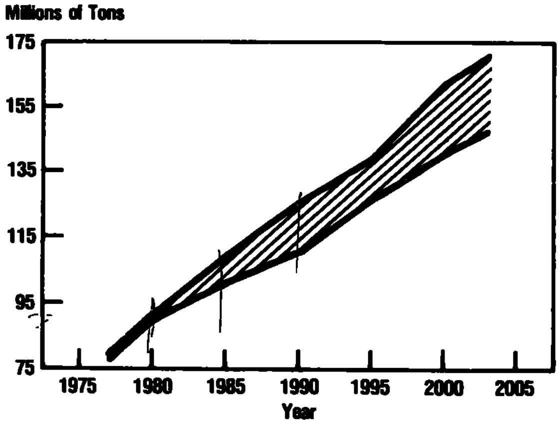
9. *Status of the Waterway.* The 9-foot project is complete. Rehabilitation of Lock and Dam 1 is complete. This reach is included in the Upper Mississippi River Basin Commission Master Plan.

10. *Capability.* All locks in the reach, except Upper and Lower St. Anthony Falls and Lock 19, will be 55 to 86 years old by 2003. Lock 22 has a capacity of about 50 million tons, which may be achieved before the year 2003. Locks 18, 20, 21, 24 and 25 have capacities between 55 and 61 million tons, which can handle traffic up to 2003, but they are expected to be congested by that year. Acceleration of enlargement and replacement schedules for all these locks is essential to provide needed water transportation for the agricultural, energy and other economic sectors of this region. No serious channel constraints affect this segment, however, eight bridge sites and one lock pose notable hazards to vessel traffic safety. Maintenance of the 9-foot channel can be a problem due to the restrictions imposed on dredging activities. Actual dredging requirements are expected to continue at about 2.6 million cubic yards annually.

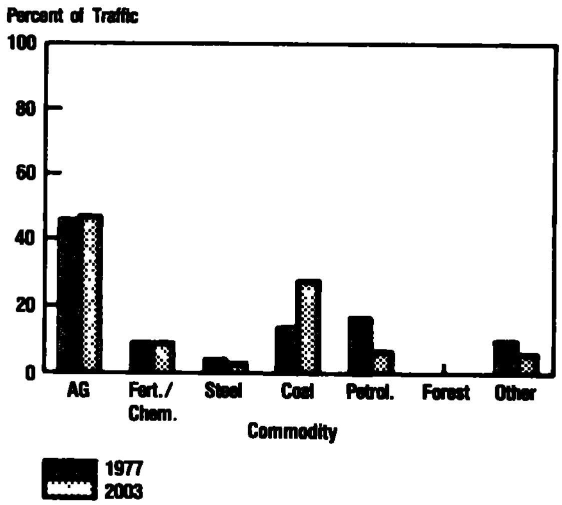
Figure D-3
REACH 2, LOWER UPPER MISSISSIPPI RIVER
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note: Sites of locks and dams are shown by a name or number.

REACH NUMBER 2
LOWER UPPER MISSISSIPPI RIVER
(Mouth of Illinois River to Mouth of Ohio River, Cairo, IL)

1. *Physical Characteristics*. The project and controlling depth is 9 feet; the controlling width of the navigation channel is 200 to 300 feet; and the length is 220 miles. The navigation season is the entire year, except for unusually cold periods; an average of one day per year Lock 26 is closed due to ice. Waterflow under drought conditions is insufficient to maintain authorized channel dimensions. Five months (October through February) are the potential critical low-flow months under present conditions. This could increase to 8 months (July through February) by the year 2000 due to the impact of water consumption upstream, primarily for irrigation along the Missouri River and tributaries.

2. *Dredging*. Average annual dredging (1973 to 1977) was 6.1 million cubic yards at a cost of $3.2 million or $0.53 per cubic yard.

3. *Lock Dimensions and Capacity*.

Lock Name of Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
L&D 26 Main chamber	110	600	24	1938	70–75
L&D 26 Aux. chamber	110	360	24	1938	
L&D (under constr.)	110	1200	24	1989	92–100
L&D 27 Main chamber	110	1200	21	1953	142–158
L&D 27 Aux. chamber	110	600	21	1953	
Kaskaskia	84	600	32	1973	30–35

4. *Commercial Traffic*. The traffic is projected to increase from 77.5 million to between 147.7 and 170.0 million tons from 1977 to 2003. Additional information regarding the traffic is shown in Figure D–3. The major commodities are: grain (corn, soybeans, and wheat); coal; petroleum products (gasoline, residual and distillate fuel oil); and fertilizers and chemicals (phosphate rock, nitrogenous chemical fertilizers and basic chemicals). Much of the grain traffic on this reach is destined for export although it is labeled as domestic on this leg of the journey to international markets.

5. *Linkage With Other Reaches*. This reach serves as the critical artery from the Illinois Waterway, the Upper Mississippi and Missouri rivers to the Lower Mississippi River, the Ohio River, and other tributaries. In 1977, 72 percent of the traffic using this reach was through traffic, 50 percent downbound and 22 percent upbound. Another 10 percent of the traffic originated in this reach and exited downbound, whereas 9 percent moved upbound out of this reach. This reach links the grain producing areas served by the Illinois, the Upper Mississippi, and the Missouri rivers to the Lower Mississippi River ports for export worldwide. Fertilizers are shipped from southern origins to farms in the north. Energy commodities move through the reach in both directions. Iron and steel products move downbound from the Chicago area steel mills to destinations on most all rivers south of the reach, whereas iron and steel scrap moves in the reverse direction. The linkages of shipments and receipts of this reach are shown in the following tabulation:

	SHIPMENTS			RECEIPTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	4	L. Miss: B.R. to Gulf	23.2	2	Intra-Reach	36.8
2	1	Upper Miss.	22.5	7	Ohio River System	17.0
3	2	Intra-Reach	15.0	4	L. Miss: B.R. to Gulf	16.7
4	5	Illinois Waterway	14.9	10	Gulf Coast-West	11.7
5	7	Ohio River System	11.2	11	Illinois Waterway	5.2
6	3	L. Miss: Cairo to B.R.	6.3	2	Upper Miss.	3.9
TOTAL: (Thousands of Tons)			21,964.1			8,941.2

6. *Types of Vessels*. Tows utilize the 9-foot deep channel and have an average tow size of 10.4 barges above St. Louis. The common maximum tow size is 25 barges. Large tows are assembled downstream from Lock 27 for the open river trip to the Lower Mississippi River, whereas larger upbound tows are broken up below Lock 27 for movement upstream.

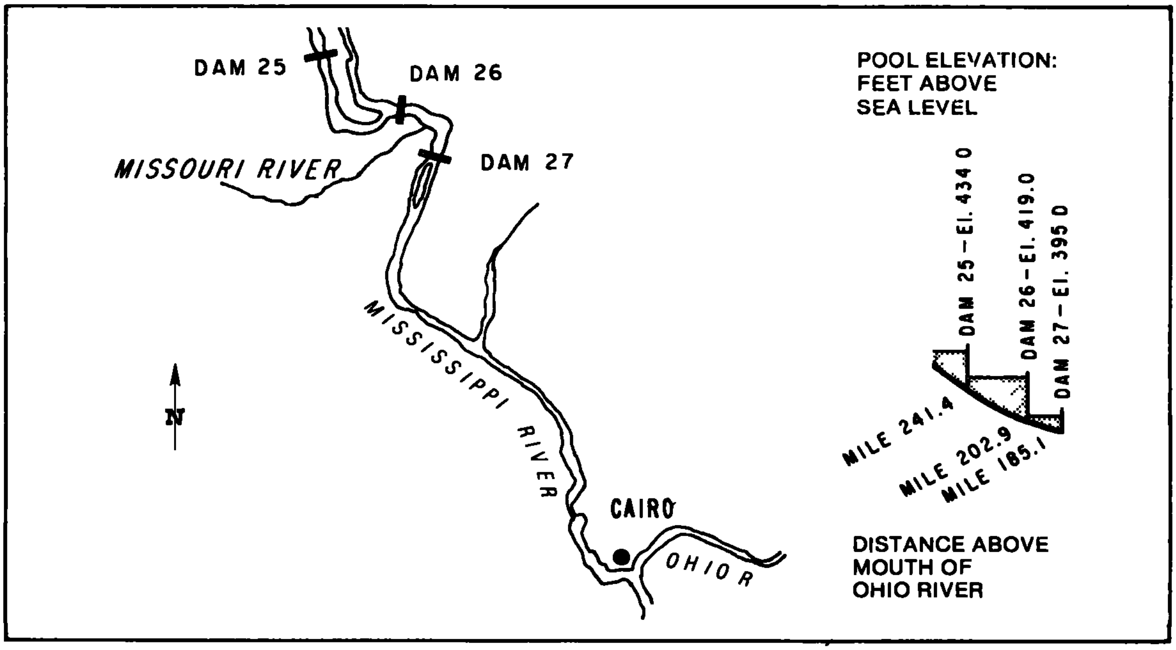
7. *Recreational and Other Water Uses*. Improvements in the reach were authorized for commercial navigation. The present users, however, include recreational navigation; general recreation; municipal, commercial, and industrial water uses; and cooling water for power and industrial plants. Irrigation upstream, especially on the Missouri River, is the most significant other water user with potential conflicts.

8. *Environmental Concerns*. Water quality deterioration due to urban/industrial discharges, along with turbidity, high sedimentation loads, and low dissolved oxygen levels, occurring prior to 1970, has been reduced. River regulating works encroach upon aquatic habitats in certain side channels (the Corps has notched some dikes to aid in the reestablishment of the habitat). Kaskaskia River dredged material placement may be a problem because available sites are nearing capacity.

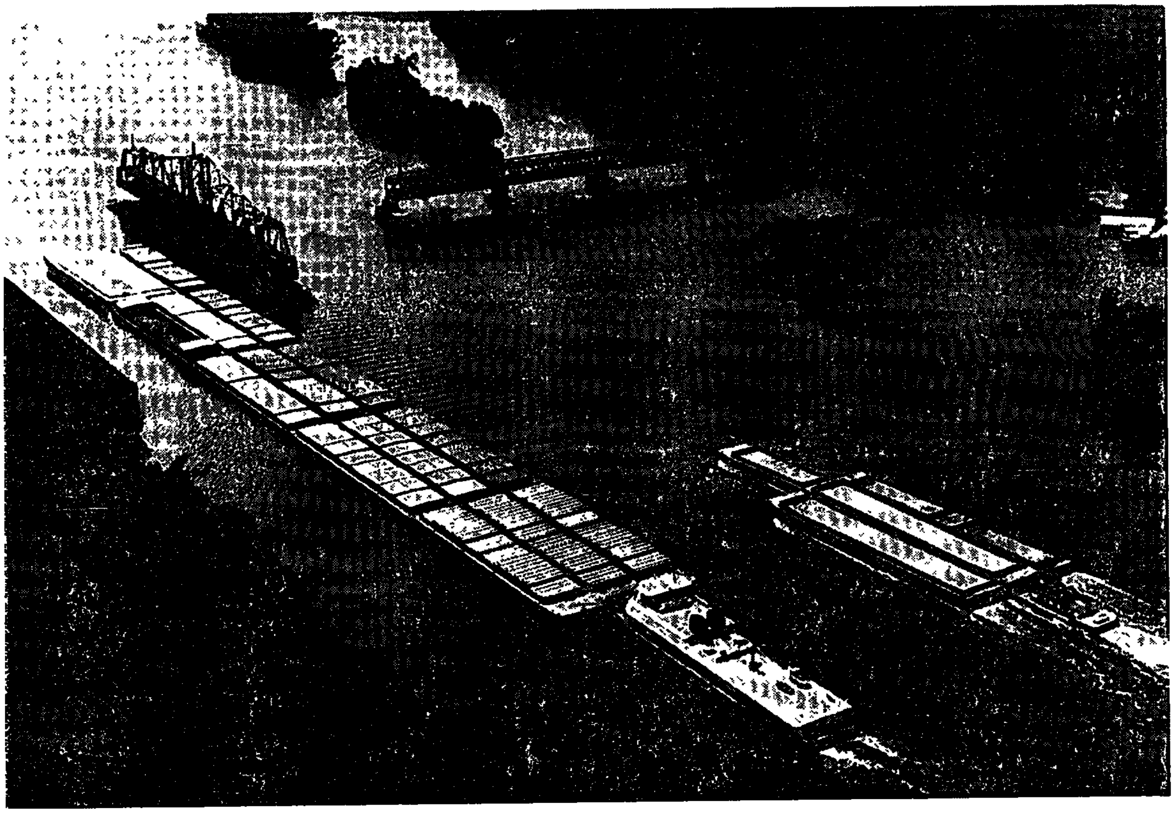
9. *Status of the Waterway*. A new lock (1200 × 110 feet) and dam are under construction to replace the old L&D 26 and is scheduled to be opened to navigation in 1989. Shippers report very serious southbound delays at L&D 26. All the primary waterway industries are affected by long delays at L&D 26, but the lock capacity is a special problem for the agricultural and coal industries. The predominant southbound tonnage at L&D 26 is grain, oilseeds, and grain products. The predominant northbound tonnage is coal. Channel work on the Kaskaskia River is scheduled for completion in 1984. The Upper Mississippi River Basin Commission Master Plan (January 1982), with Corps participation, recommended a second chamber at the new Lock 26 site.

10. *Capability*. The new single lock (1200 × 110 feet) at L&D 26 will have a capacity of about 92 to 100 million tons per year when completed in 1989. This capacity will be reached in the 1990s under all the forecasts. L&D 27 has a capacity of 142 to 158 million tons, which can handle projected traffic up through 2003, but it will be experiencing congestion by that time under five forecasts. No serious channel constraints affect this segment, however five bridge safety problems have been identified. Maintenance dredging is expected to remain fairly constant at about 6.1 million cubic yards annually.

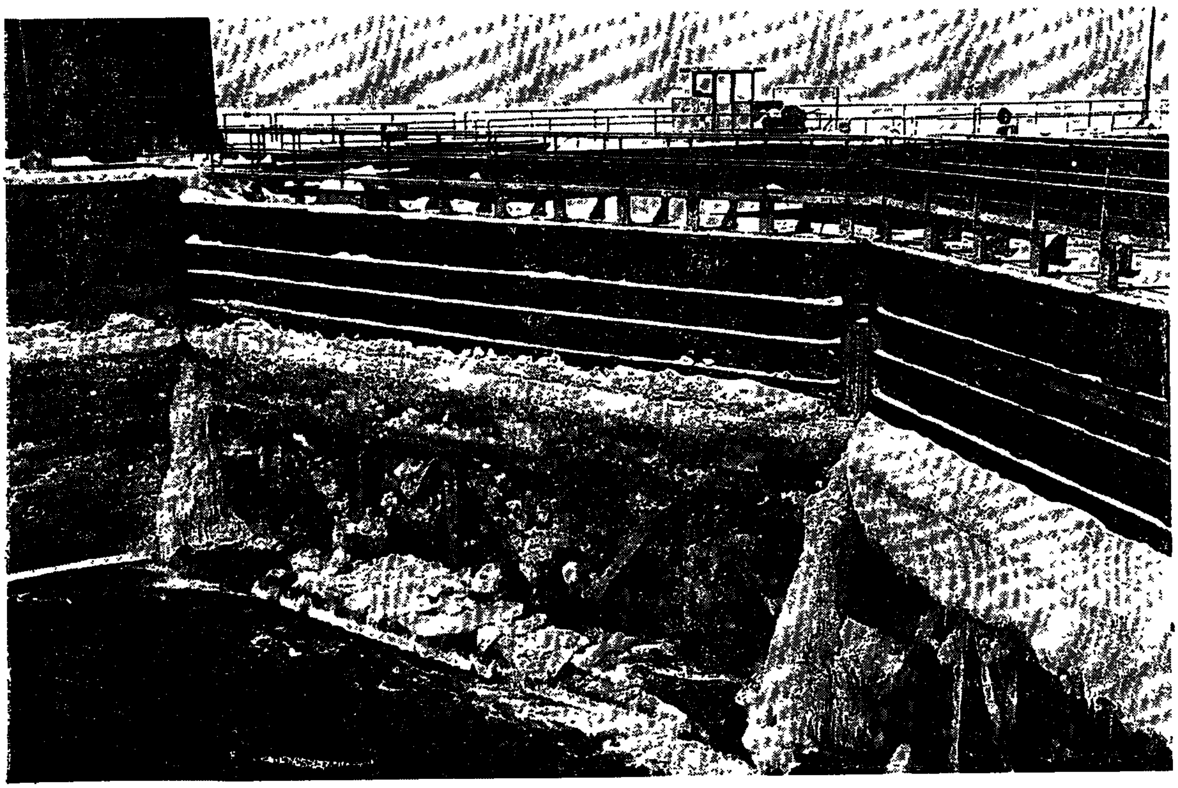
Figure D-4
PROFILE OF LOWER UPPER MISSISSIPPI RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.



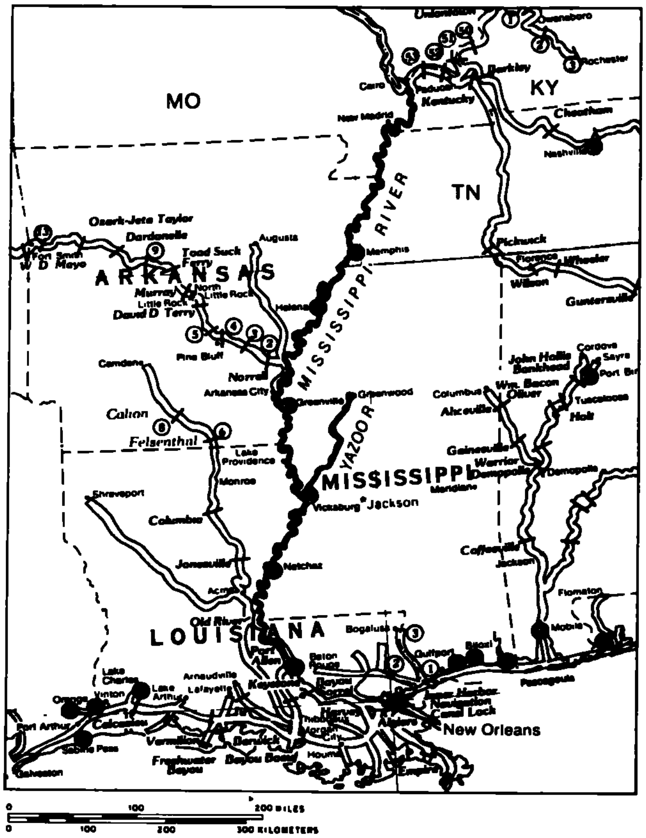
Fifteen-barge tows such as this one are not uncommon on the Upper Mississippi River.



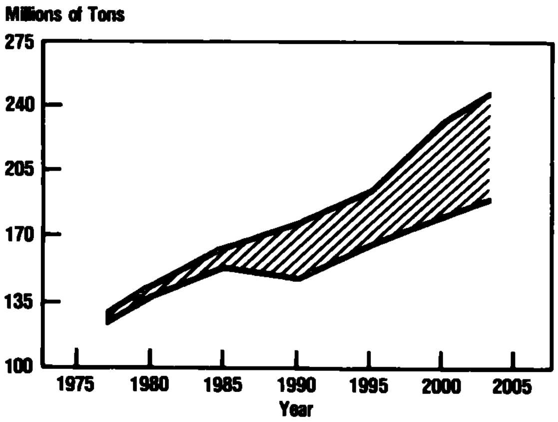
Ice can be a serious problem for navigation, especially at locks. This view is of Lock and Dam 26 on the Mississippi River.

Figure D-5

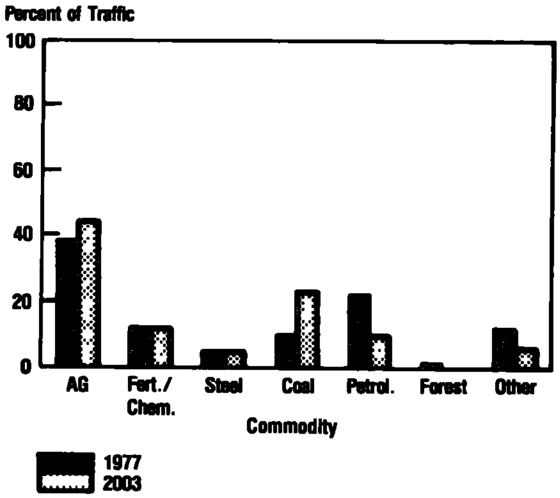
REACH 3, LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note. Sites of locks and dams are shown by a name or number.

REACH NUMBER 3

LOWER MISSISSIPPI RIVER: CAIRO TO BATON ROUGE

1. *Physical Characteristics.* The authorized and controlling depths are 12 and 9 feet respectively; the controlling width is 300 feet; and the length is 723 miles. River stages vary with discharge throughout the year and can vary as much as 30 to 40 feet during the year. River velocities also vary with discharge as well as location. The river rises about 280 feet in elevation from Baton Rouge to Cairo. Shoals usually develop in the late summer and early fall.

2. *Dredging.* The average annual dredging (1973 to 1977) was 43.9 million cubic yards at an average annual cost of $12.3 million or $0.28 per cubic yard.

3. *Commercial Traffic.* An increase in commercial traffic from about 123 million tons in 1977 to between 190.7 and 248.4 million tons by 2003 is projected. The mixture of commodities prevailing in 1977 is projected to be maintained through 2003. Coal movements are expected to increase from 12 million tons to between 25.8 and 67.8 million tons, while petroleum is anticipated to decrease from 28 million tons to between 21.3 and 25.2 million tons. Agriculture is projected to remain the major commodity, increasing from 46.4 million tons in 1977 to between 89.9 and 104.9 million tons by 2003.

4. *Linkage with Other Reaches.*

	SHIPMENTS			RECEIPTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	4	L. Miss: B.R. to Gulf	56.3	4	L. Miss: B.R. to Gulf	36.4
2	3	Intra-Reach	22.6	7	Ohio River System	21.2
3	7	Ohio River System	11.2	3	Intra-Reach	10.1
4	5	Illinois Waterway	2.0	10	Gulf Coast-West	8.4
5	11	Gulf Coast-East	1.9	8	Tennessee River	6.8
6	1	Upper Miss.	1.5	1	Upper Miss.	5.7
TOTAL: (Thousands of Tons)			11,143.0			24,865.4

5. *Type of Vessels.* Towboats with up to 12,000 horsepower and over 40 barges navigate this portion of the river. The maximum tow size is generally around 45 barges.

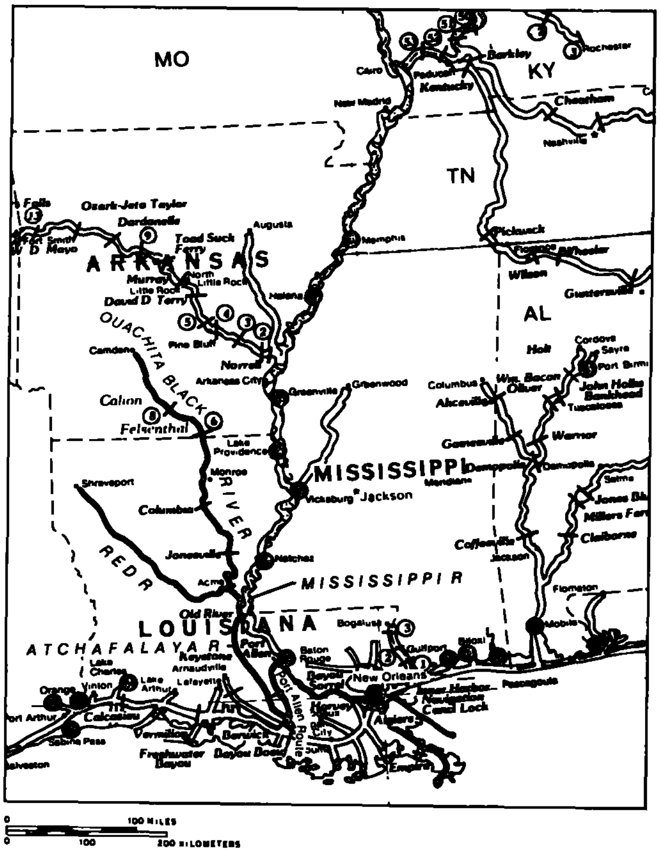
6. *Recreation and Other Water Uses.* Present uses include recreational navigation; general recreation; municipal, commercial, and industrial water uses; cooling water for power and industrial plants; and irrigation.

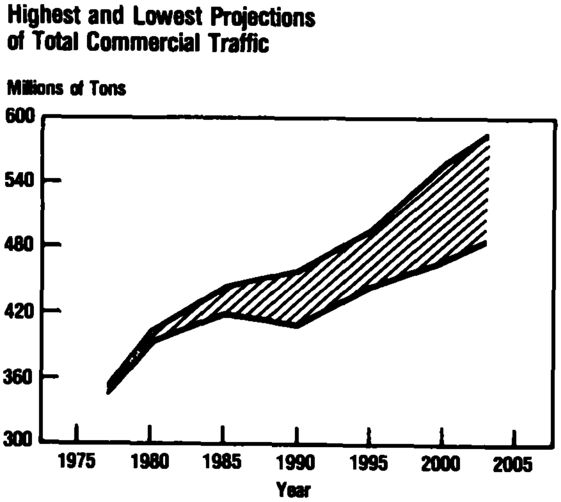
7. *Environmental Concerns.* Channelization has resulted in a modification of aquatic habitat. Though dredge quantities are large, they are small when compared to the total amount of sediment transported by the river. Reported volumes of dredged material have decreased in recent years.

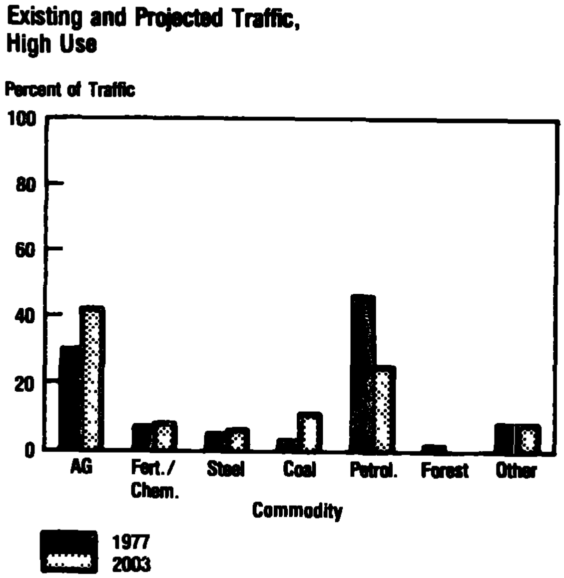
8. *Status of the Waterway.* The Mississippi River regulating works are underway and are scheduled for completion in 1992. These river training works significantly contribute to maintenance of the year round navigation channel between Cairo and Baton Rouge. The Belzoni Bridge on the Yazoo River is scheduled for completion in 1982.

9. *Capability.* Tows comprising more than 40 barges or 50,000 tons operate in this reach. Bridges at four locations have been identified as safety hazards, including Memphis, Greenville, Vicksburg, and Natchez. Safety problems relating to channel configuration have been noted near Vicksburg and near Greenville. Localized studies of these bridge and channel safety problems are needed to determine the magnitude of the hazards and whether mitigating actions are required. Maintenance dredging on this reach is expected to remain at about 44 million cubic yards annually.

Figure D-6
REACH 4, MISSISSIPPI RIVER: BATON ROUGE TO GULF
Map and Waterborne Commerce Graphs







Note Sites of locks and dams are shown by a name or number.

REACH NUMBER 4
LOWER MISSISSIPPI RIVER:
BATON ROUGE TO GULF

1. *Physical Characteristics*. For the 233 mile main stem, the project and controlling depth and width are 40 feet and 500 feet respectively. The elevation ranges from sea level to about 20 feet above mean sea level. Other projects in this reach include the Ouachita-Black, Atchafalaya, Baton Rouge-Morgan City Bypass (Port Allen Route) and the Red River project to Shreveport, Louisiana. Authorized project depths and widths are 9 × 100 feet on the Ouachita-Black (currently available for 208 miles); 12 × 150 feet on the Atchafalaya (162 miles); 12 × 125 feet on the Baton Rouge-Morgan City Bypass (64 miles); and 9 × 200 feet on the Red. The Ouachita-Black and Red River projects are currently under construction.

2. *Dredging*. The average dredging (1973 to 1977) was 61.7 million cubic yards at an average annual cost of $25.6 million, or $0.42 per cubic yard.

3. *Lock Dimensions and Capacity*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
Ouachita & Black Rivers					
Jonesville	84	600	30	1972	26
Columbia	84	600	18	1972	26
Felsenthal (Under cons)[1]	84	600	18	1983	26
Calion (Under cons)[2]	84	600	12	1983	26
Red River					
L&D 1	84	600	–	1985	21–22
Old River					
Old River	74	1200	65	1963	59–62
Baton Rouge-Morgan City Bypass					
Port Allen	84	1200	45	1961	27–35
Bayou Sorrel	56	800	21	1951	nc

nc = not calculated
1. Replacement for existing Lock No. 6 built in 1923.
2. Replacement for existing Lock No. 8 built in 1926.

4. *Commercial Traffic*. Total traffic is projected to increase from about 344 million tons in 1977 to between 492.1 and 591.4 million tons by 2003. The predominate commodities are expected to remain agriculture and petroleum. Tonnages will increase in all commodity groups except petroleum, which is projected to drop from the 1977 level of 158.2 million tons to between 120.4 and 139.1 million tons by 2003. This reach is forecast to export 38 percent of the nation's trade in farm products, import 23 percent of the crude petroleum, and handle up to 17 percent of the nation's coal exports. The Defense scenario tested for 1990 displayed a 21 million increase in domestic traffic, coupled with a 27 million ton drop in foreign trade.

5. *Linkage With Other Reaches.*

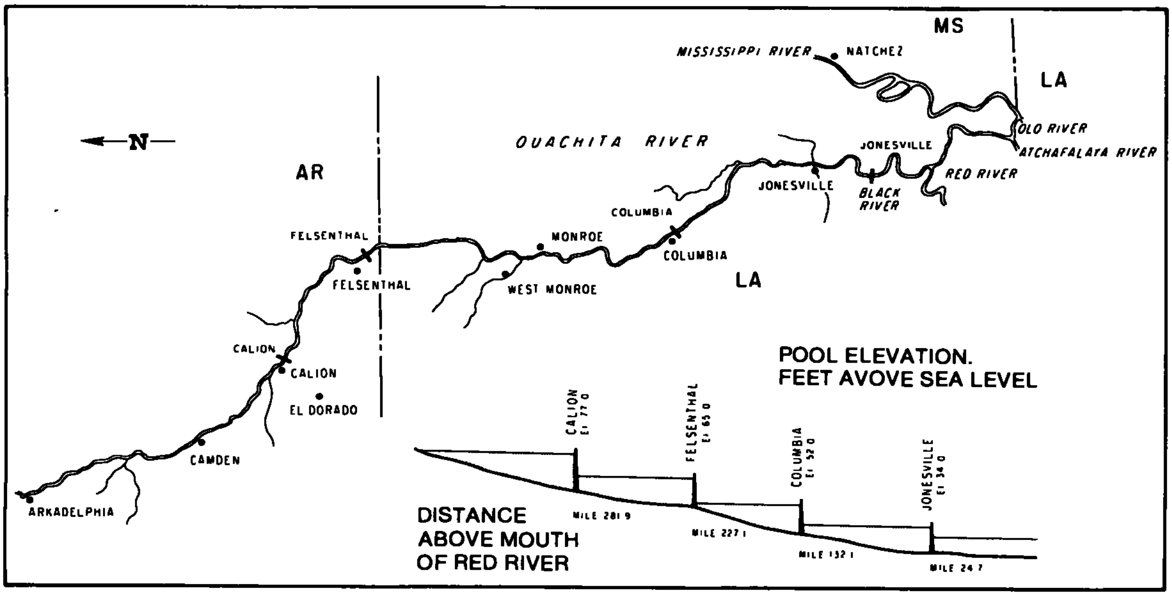
	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	23	Overseas and Pacific Canada	41.3	23	Overseas and Pacific Canada	49.2
2	4	Intra-Reach	15.5	4	Intra-Reach	11.3
3	7	Ohio River System	7.1	5	Illinois Waterway	7.5
4	10	Gulf Coast-West	6.5	10	Gulf Coast-West	6.7
5	11	Gulf Coast-East	5.3	1	Upper Miss.	6.1
6	14	Mid Atlantic	5.0	7	Ohio River System	4.6
TOTAL: (Thousands of Tons)			143,604.4			196,065.4

6. *Types of Vessels.* Tow sizes vary considerably from the Ouachita-Black to the Mississippi. Tows of 40 or more barges are not uncommon on the Lower Mississippi, while on the smaller waterways of this reach 2–5 barge tows are generally found. Oceangoing deep draft navigation traverses from the Gulf up to Baton Rouge.

7. *Recreation and Other Water Uses.* High recreation use is experienced in the Columbia and Jonesville pools of the Ouachita-Black. There is medium to high recreational navigation throughout the reach. Irrigation and industry combine for about 80 percent of the consumption in the Ouachita-Black basin. Irrigation accounts for about 80 percent of the consumption on the Red River. Water supply and power plant cooling account for additional other water uses.

8. *Environmental Concerns.* The Mississippi in this region is polluted, turbid and carries a high sediment load. Severe shoaling occurs at Gulf/river bars. Municipal and industrial water intakes are vulnerable to an encroaching saltwater wedge during low flows. Environmentally sensitive areas include highly productive wetlands, bottomland forests, marshes, and national wildlife refuges. Flood control aspects of the Atchafalaya basin preclude development along the flood plain and banks of that reach.

Figure D-7
PROFILE OF OUACHITA AND BLACK RIVERS NAVIGATION POOLS



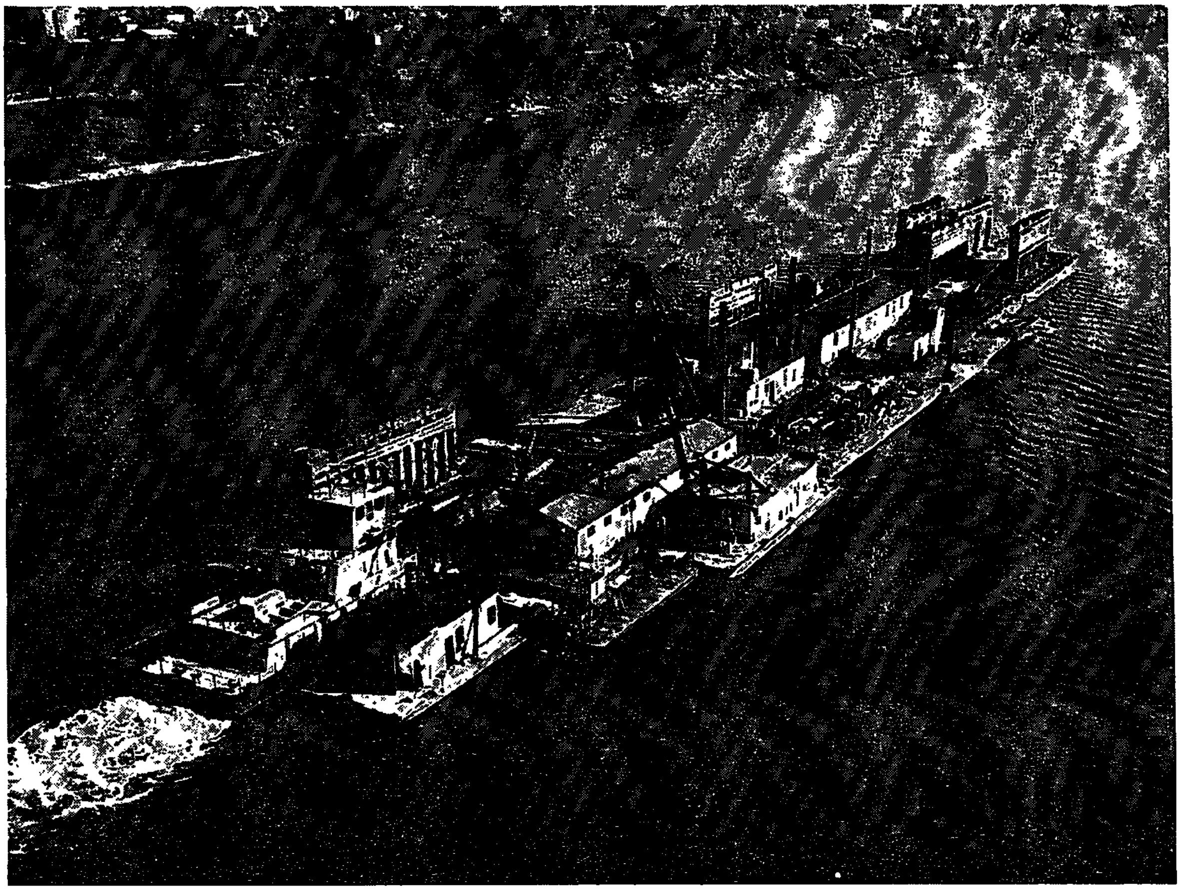
Note: Sites of locks and dams are shown by a name or number.

9. *Status of the Waterway.* The Red River 9-foot project is underway with completion scheduled for 1994. It will replace the obsolete 6-foot channel. Red River emergency bank work is scheduled to be completed in 1984. Felsenthal and Columbia locks on the Ouachita River are scheduled to be completed in 1983, replacing Locks 6 and 8. Currently 9-foot navigation is available on the Ouachita only as far as the vicinity of the Arkansas-Louisiana state line. The Board of Engineers for Rivers and Harbors approved a report on deepening the channel between Baton Rouge and the Gulf to 55 feet in March 1982.

10. *Capability.* Maintaining authorized depths on the deepwater segment of the Mississippi requires careful monitoring and frequent dredging. In the Mississippi the mix of shallow draft and deep draft vessel traffic coupled with magnitude of traffic (over 20 percent of the nation's waterborne commerce) makes this one of the most hazardous reaches in the nation. Sharp bends and terminals pose problems near Donaldsonville and Belle Chasse. Four bridges pose notable safety hazards.

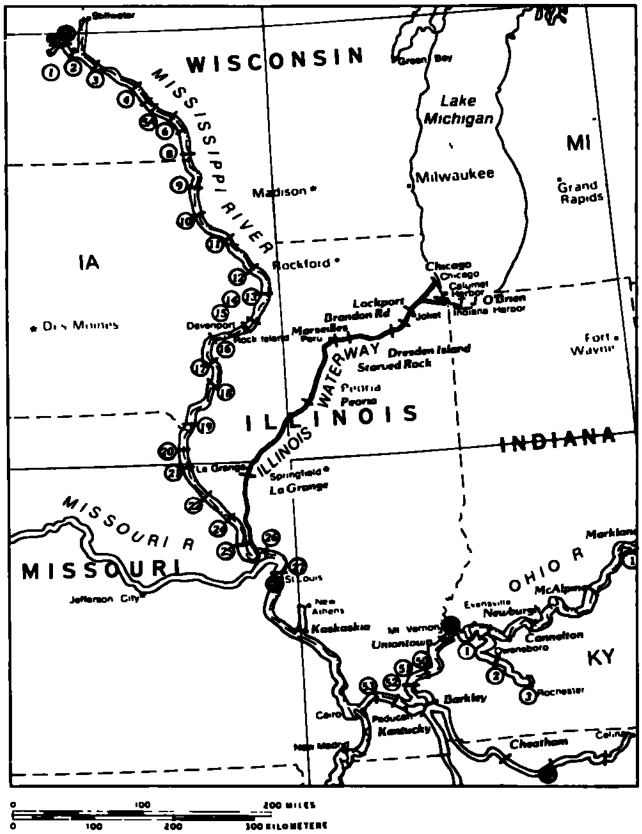
In terms of safety, congestion and the mixture of deep and shallow draft vessels pose notable hazards between Baton Rouge and the Gulf on the Mississippi. Bridge safety problems were identified along stretches of the river at Baton Rouge and at New Orleans, as well as at Morgan City on the Bypass. Channel configuration safety problems were cited at three locations. These could be alleviated through improved navigation aids.

Should a deeper draft channel be implemented between Baton Rouge and the Gulf, the magnitude of additional dredging would be around 60 million cubic yards above the current reach figure of 61.72 million cubic yards. There will also be additional dredging requirements associated with the Ouachita-Black and Red River 9-foot projects, once these are completed.

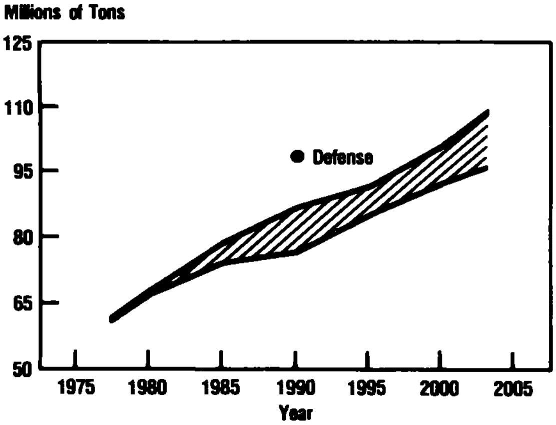


The Corps Repair Fleet

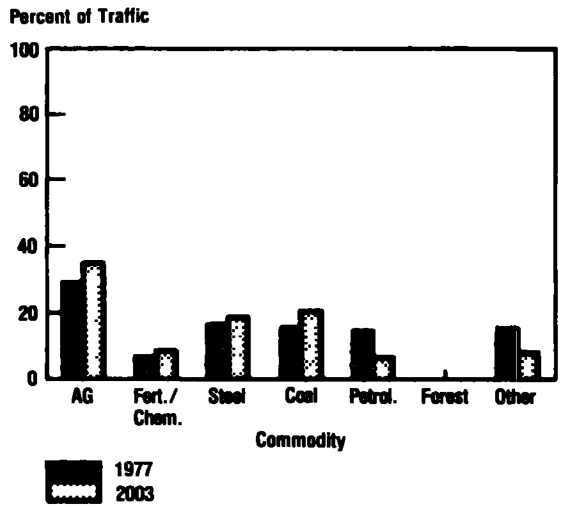
Figure D-8
REACH 5, ILLINOIS WATERWAY
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note Sites of locks and dams are shown by a name or number

1. *Physical Characteristics*. The project and controlling depth is 9 feet; the controlling width is 110 to 160 feet (225–300 authorized); and the length, including the two branches to Lake Michigan, is 357 miles. The lift of the system is about 200 feet from the confluence of the Mississippi to Lake Michigan. Navigation is year-round, but with ice causing problems in severe winters.

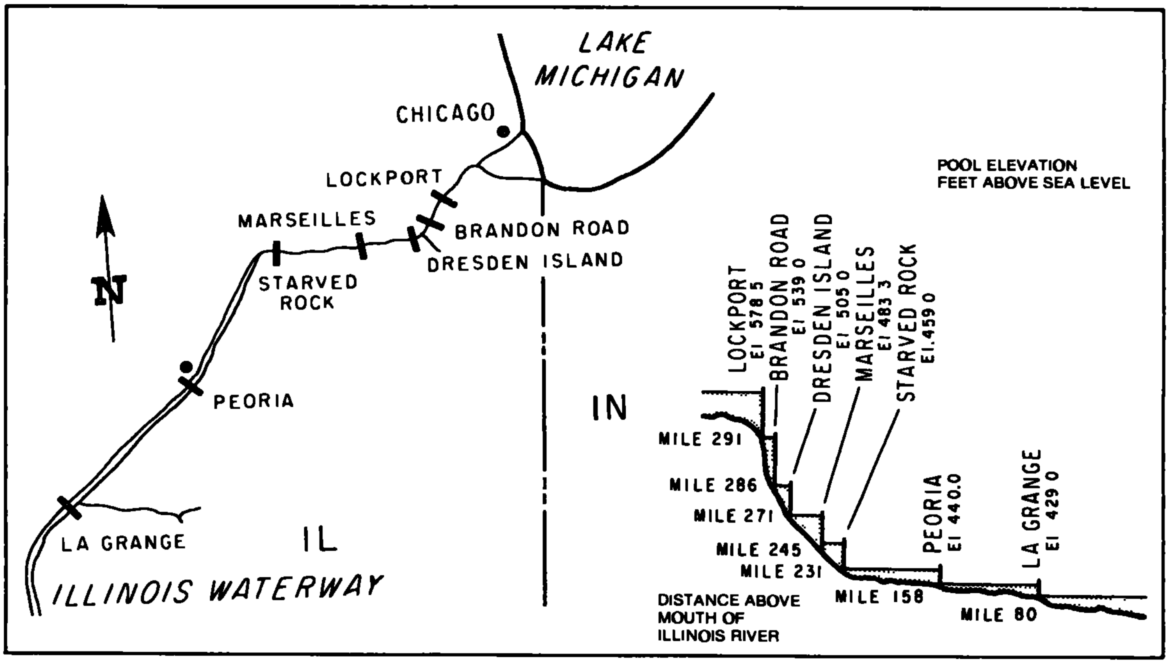
2. *Dredging*. The average annual dredging (1973 to 1977) was 2.5 million cubic yards at an average annual cost of $1.7 million or $0.68 per cubic yard.

3. *Lock Dimensions and Capacity*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
LaGrange	110	600	10	1939	46–49
Peoria	110	600	11	1939	44–52
Starved Rock	110	600	19	1933	42–43
Marseilles	110	600	24	1933	33–38
Dresden Island	110	600	22	1933	42–46
Brandon Road	110	600	34	1933	33–38
Lockport	110	600	40	1933	33–38
T.J. O'Brien	110	1000	5	1960	27–37

4. *Commercial Traffic*. Commercial traffic is projected to increase from the 1977 level of 60.4 million tons to a range of about 96 to 108 million tons in 2003. The commodity mix, which is well balanced, is expected to continue with an increase in all commodity groups except petroleum, which is projected to decline from 9 million tons to between 7.2 and 8.0 million tons by 2003. The assumed defense emergency scenario tested for year 1990 displayed a surge of 19 million tons of additional traffic on the Illinois compared to peacetime conditions.

Figure D-9
PROFILE OF ILLINOIS RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

5. *Linkage with other Reaches.*

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	4	L. Miss: B.R. to Gulf	41.7	5	Intra-Reach	31.7
2	5	Intra-Reach	31.5	16	Great Lakes System	21.2
3	16	Great Lakes System	10.5	4	L. Miss: B.R. to Gulf	10.7
4	24	Great Lakes and St. Lawrence, Canada	3.9	2	Lower Upper Miss.	9.4
5	23	Overseas and Pacific Canada	3.4	23	Overseas and Pacific Canada	5.7
6	8	Tennessee River	1.8	24	Great Lakes and	4.5
TOTAL:	(Thousands of Tons)		35,085.6			34,820.7

6. *Types of Vessels.* Barges with tows are the major commercial transport vessels. Average tow sizes are about 6 barges, however, sizes range from 1 to 15 barges.

7. *Recreation and Other Water Uses.* High general and navigational recreation use. Other uses include water quality and hydropower.

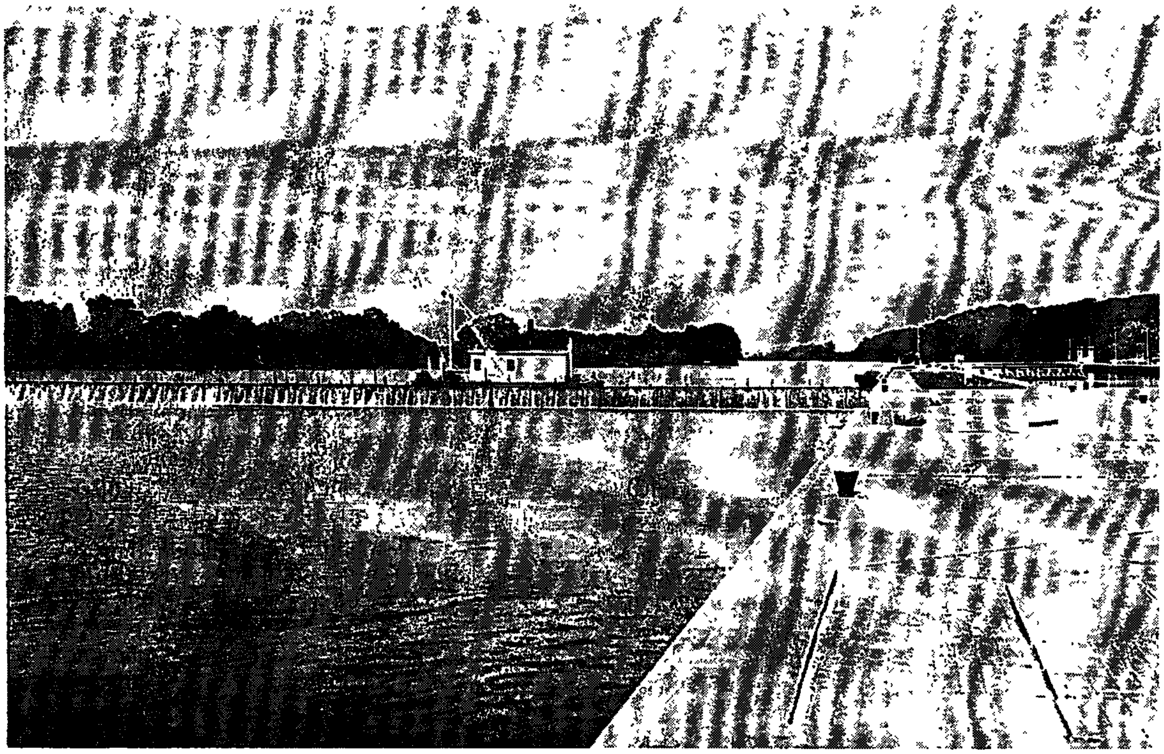
8. *Environmental Concerns.* Water quality deterioration has been attributed to municipal effluent, industrial discharge, sedimentation, and agricultural runoff. Environmentally sensitive factors include sedimentation of flood plain lakes and wetlands, presence of many migratory waterfowl, and loss of flood plain terrestrial habitat to agriculture.

9. *Status of the Waterway.* The Illinois Waterway Duplicate Locks Project was recently deauthorized. The Calumet-Sag widening project remains 95 percent complete. Acme Bend, on the Calumet-Sag channel, remains to be modified.

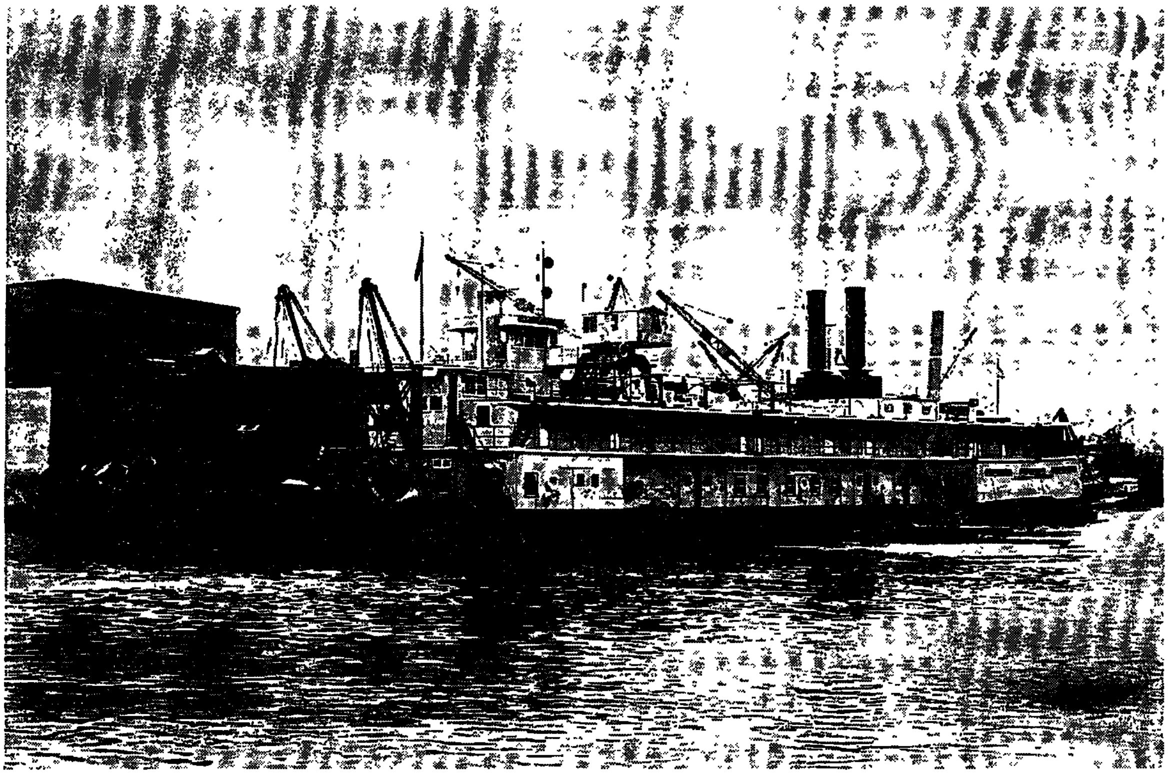
10. *Capability.* All locks except O'Brien are likely to be highly congested by the year 2003. LaGrange, Peoria and Marseilles locks constitute secondary constraints by 2003 under low flow conditions. Starved Rock, Dresden Island, Brandon Road and Lockport are all congested under three or more scenarios by 2003. Studies for increasing capacity at all these locks need to be initiated to meet projected traffic levels.

Five bridges present extreme safety hazards while 12 other bridges are also hazardous to navigation. The Marseilles rock-cut canal lies in the upper approach to Marseilles Lock and allows only one-way traffic. The Butterfly Dam at Lockport is also a navigation hazard and requires study.

Dredging is expected to continue at the historic level of about 2.5 million cubic yards annually.

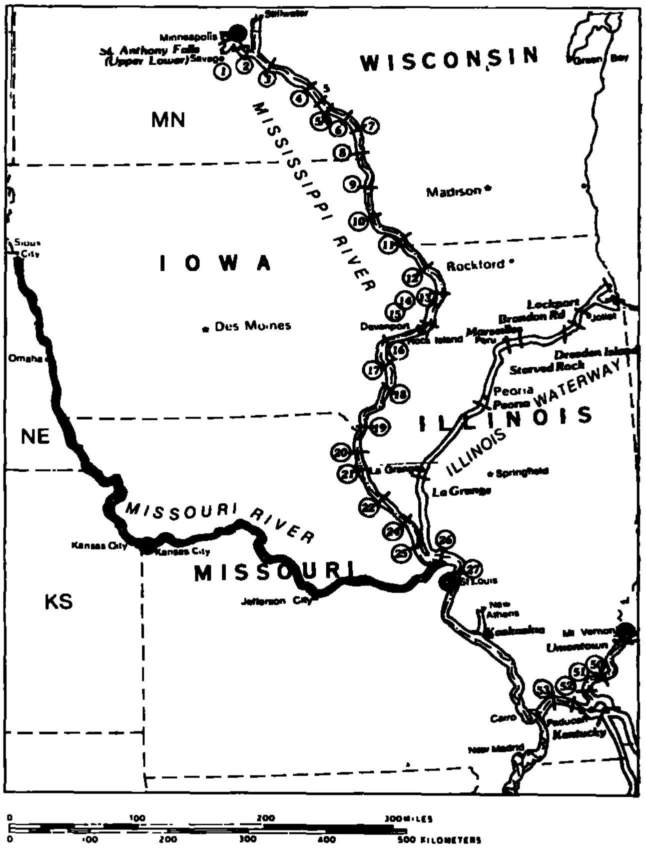


Peoria Lock and Dam wickets and I-wall.

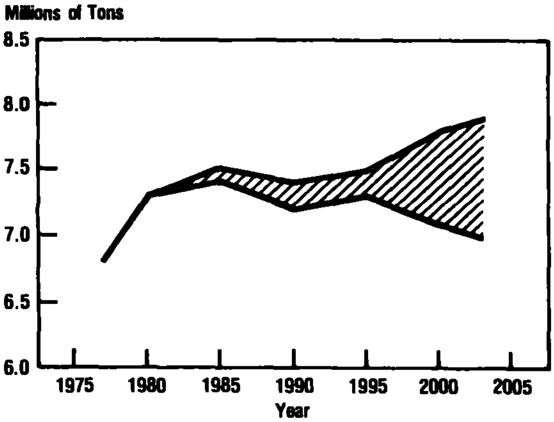


Dredge "Ste. Genevieve" on the Lower Illinois River.

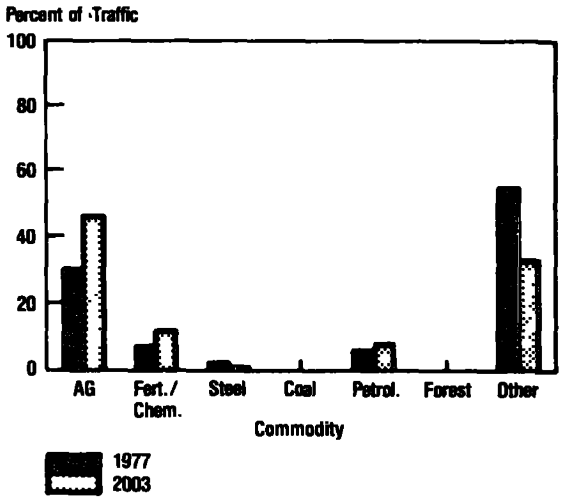
Figure D-10
REACH 6, MISSOURI RIVER
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note: Sites of locks and dams are shown by a name or number

REACH NUMBER 6
MISSOURI RIVER

1. *Physical Characteristics*. The authorized project depth is 9 feet. During the 1978 navigation season the project provided the following channel dimensions: Sioux City, Iowa to Miami, Missouri, a limiting depth of 9 feet and a limiting width of 300 feet; Miami to the mouth, a limiting depth of 8.5 feet and a limiting width of 250 feet. The length is 735 miles. Upstream dams and lakes provide regulated flows for navigation and there are no locks on the waterway. The normal 8-month navigation season is from 1 April to 1 December.

2. *Dredging*. The average annual dredging (1973 to 1977) was 1.3 million cubic yards at an average annual cost of $1.2 million or $0.91 per cubic yard.

3. *Commercial Traffic*. It is projected that commercial traffic will increase in the short term from the 1977 level of 6.7 million tons to between 7.0 and 7.9 million tons, but then remain relatively static through 2003. Major commodity groups are projected to remain agriculture and miscellaneous commodities. All groups are expected to remain the same or increase slightly, though tonnage in the miscellaneous group is projected to decrease from 3.7 million tons to 2.6 by 2003.

4. *Linkage With Other Reaches*.

	SHIPMENTS			RECEIPTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	6	Intra-Reach	62.6	6	Intra-Reach	75.8
2	4	L. Miss: B.R. to Gulf	22.3	4	L. Miss: B.R. to Gulf	10.6
3	8	Tennessee River	6.7	5	Illinois Waterway	4.5
4	5	Illinois Waterway	3.5	10	Gulf Coast-West	3.9
5	2	Lower Upper Miss.	2.1	2	Lower Upper Miss.	2.9
6	3	L. Miss: Cario to B.R.	0.7	3	L. Miss: Cairo to B.R.	0.7
TOTAL: (Thousands of Tons)			5,612.2			4,634.8

5. *Types of Vessels*. Towboats average six barges per tow, with a maximum generally being nine barges. However, because of current, higher horsepowers are often required to push Missouri tows.

6. *Recreation and Other Water Uses*. Uses include navigation, flood control, general recreation, fish and wildlife, irrigation, hydropower, water quality, and water supply. Future withdrawals for irrigation may shorten the navigation season.

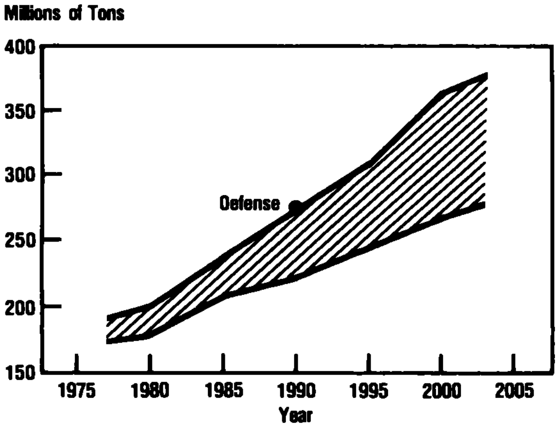
7. *Environmental Concerns*. Fish and wildlife habitats has been affected by the navigation/flood control project. High sediment load is a concern, but the condition has abated with completion of the reservoir system.

8. *Status of the Waterway*. The river training efforts are essentially complete.

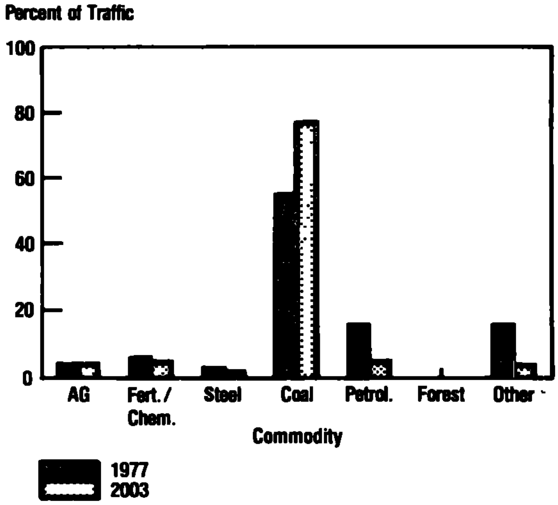
9. *Capability*. The navigation season on the Missouri River is limited to about 8 months by winter ice and by storage for other upstream uses of water. The swift current and channel curvature dictate the tow size and horsepower operating on the river. Dredging requirements are not forecast. However, historically before river training works were complete, as much as 1 million cubic yards had been removed annually. No traffic congestion is forecast on the Missouri River.

Figure D-11
REACH 7, OHIO RIVER SYSTEM
Map and Waterborne Commerce Graphs

Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, Misc. Sensitivity



Note: Sites of locks and dams are shown by a name or number

1. *Physical Characteristics*. For the main stem the project and controlling depth is 9 feet; the controlling width is 240 to 300 feet (300 to 500 authorized). The elevation rises about 430 feet from the mouth of the Ohio to the upper pool on the Monongahela (which is the highest elevation of the entire national waterways).

2. *Dredging*. The average annual dredging (1973 to 1977) was 2.7 million cubic yards at an average annual cost of $3.8 million or $1.38 per cubic yard.

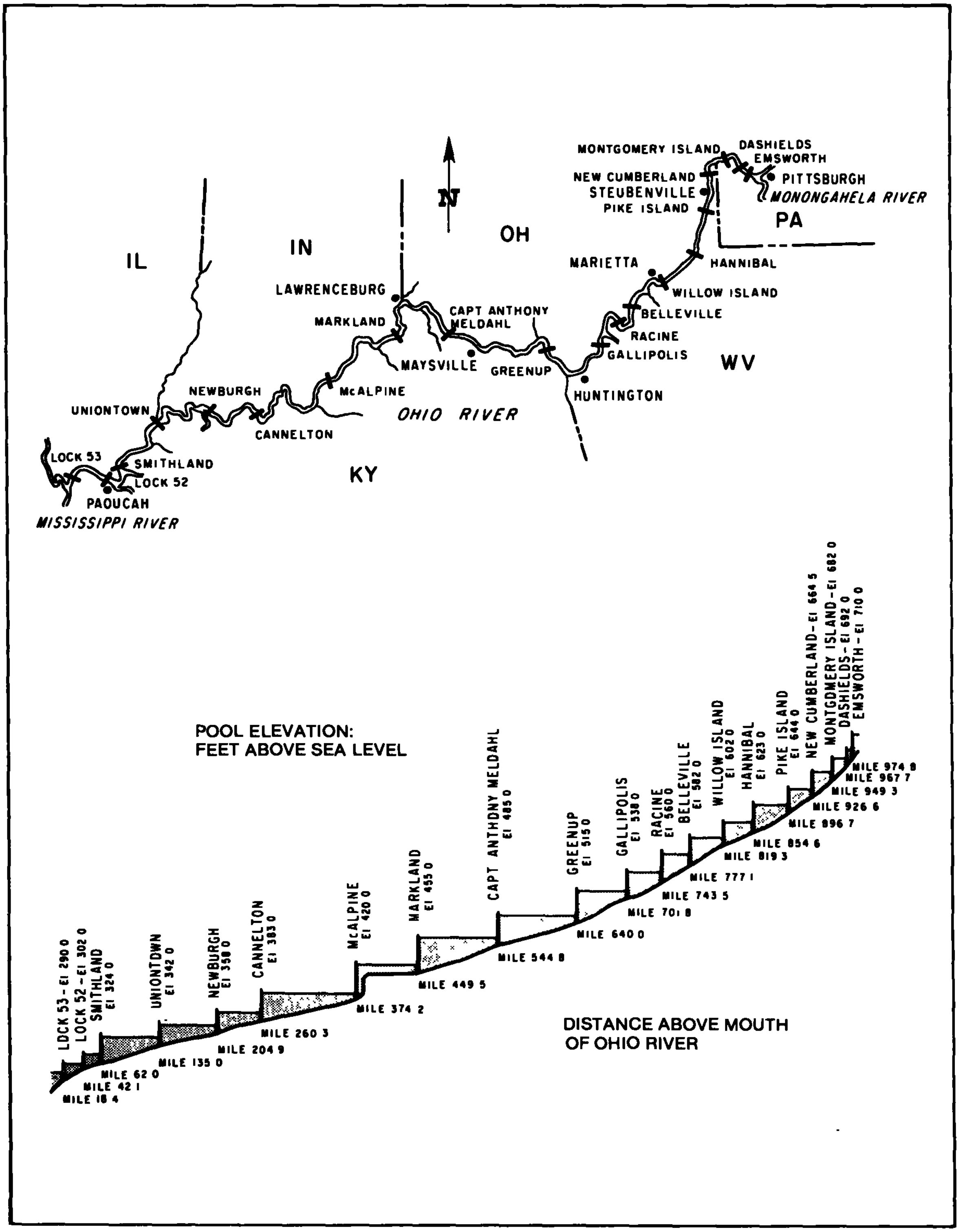
3. *Lock Dimensions and Capacity*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
Ohio River					
Emsworth	110	600	18	1921	35–48
	56	360	18	1921	
Dashields	110	600	10	1929	39–54
	56	360	10	1929	
Montgomery	110	600	18	1936	37–39
	56	360	18	1936	
New Cumberland	110	1200	21	1959	104–125
	110	600	21	1959	
Pike Island	110	1200	21	1968	100–115
	110	600	21	1968	
Hannibal	110	1200	21	1972	110–132
	110	600	21	1972	
Willow Island	110	1200	20	1972	107–130
	110	600	20	1972	
Belleville	110	1200	22	1968	104–126
	110	600	22	1968	
Racine	110	1200	22	1971	107–138
	110	600	22	1971	
Gallipolis	110	600	23	1937	58–64
	110	360	23	1937	
Greenup	110	1200	30	1959	100–129
	110	600	30	1959	
Meldahl	110	1200	30	1962	97–133
	110	600	30	1962	
Markland	110	1200	35	1963	89–133
	110	600	35	1963	
McAlpine	110	1200	37	1961	82–116
	110	600	37	1961	
Cannelton	110	1200	25	1972	107–157
	110	600	25	1972	
Newburgh	110	1200	33	1975	104–128
	110	600	33	1975	
Uniontown	110	1200	22	1975	114–127
	110	600	22	1975	
Smithland	110	1200	22	1980	177–214
	110	1200	22	1980	
L&D 52	110	600	12	1928	
(temporary)	110	1200	12	1969	114–120
L&D 53	110	600	13	1929	
(temporary)	110	1200	13	1980	114–120

Monongahela River					
L&D 2	110	720	9	1951	50–74
	56	360	9	1953	
L&D 3	56	720	8	1907	37–57
	56	360	8	1907	
L&D 4	56	720	17	1932	37–62
	56	360	17	1932	
Maxwell	84	720	20	1964	59–95
	84	720	20	1964	
L&D 7	56	360	15	1925	17–27
L&D 8	56	360	19	1925	18–25
Morgantown	84	600	17	1950	25
Hildebrand	84	600	21	1959	25
Opekiska	84	600	22	1964	11
Allegheny River					
L&D 2	56	360	11	1934	15–16
L&D 3	56	360	14	1934	15–16
L&D 4	56	360	11	1927	16–17
L&D 5	56	360	12	1927	16
L&D 6	56	360	12	1928	16
L&D 7	56	360	13	1930	16
L&D 8	56	360	18	1931	16
L&D 9	56	360	22	1938	16
Kanawha River					
Winfield	56	360	28	1937	22–26
	56	360	28	1937	
Marmet	56	360	24	1934	21–22
	56	360	24	1934	
London	56	360	24	1934	20–23
	56	360	24	1934	
Kentucky River					
L&D 1	38	145	8	1839	6
L&D 2	38	145	14	1839	6
L&D 3	38	145	13	1844	6
L&D 4	38	145	13	1844	6
L&D 5	38	145	15	1844	6
L&D 6	52	147	14	1894	6
L&D 7	52	147	15	1897	6
L&D 8	52	146	18	1900	6
L&D 9	52	148	18	1907	6
L&D 10	52	148	17	1907	6
L&D 11	52	148	18	1906	6
L&D 12	52	148	17	1910	6
L&D 13	52	148	17	1915	6
L&D 14	52	148	17	1917	6
Green River					
L&D 1	84	600	12	1956	46
L&D 2	84	600	14	1956	46
L&D 3	36	138	17	1836	nc
Cumberland River					
Barkley	110	800	57	1964	39–43
Cheatham	110	800	25	1964	37–40
Old Hickory	84	400	60	1954	19
Cordell Hull	84	400	59	1973	19

nc = not calculated

Figure D-12
PROFILE OF OHIO RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

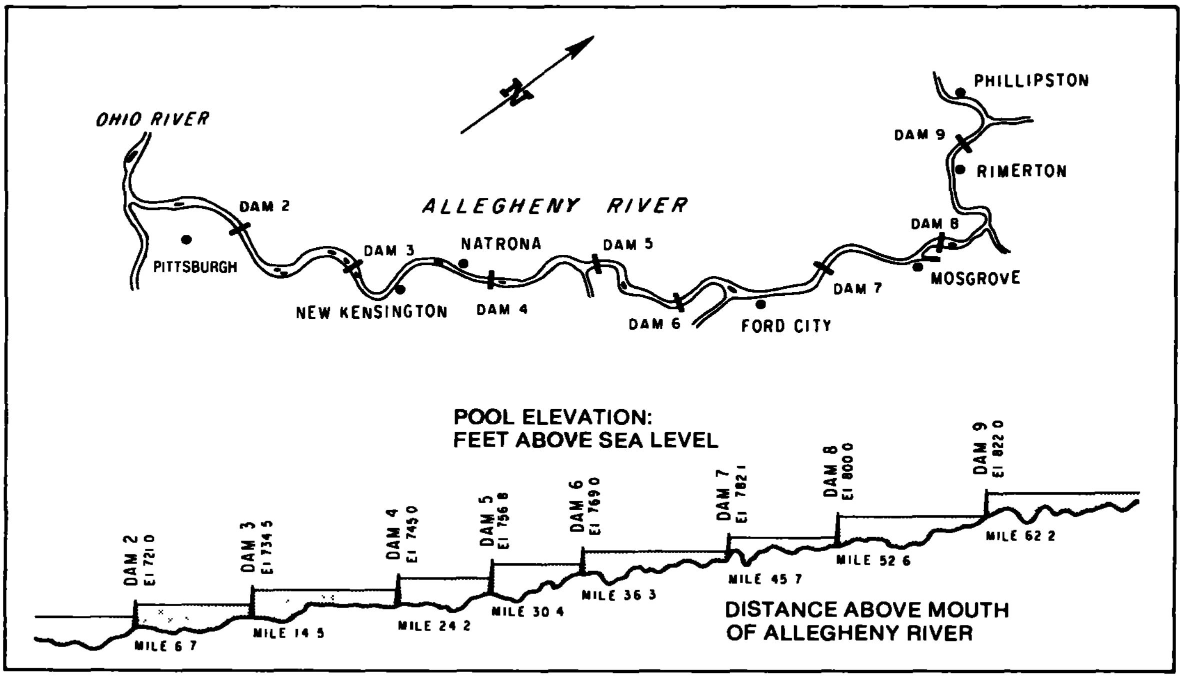
4. *Commercial Traffic.* Projections show an increase from about 182 million tons in 1977 to between 280.3 and 382.9 million tons by 2003. The major commodity, coal, is projected to increase from the 1977 level of 100.5 million tons to between 205.0 and 295.1 million tons by 2003. All other commodity groups are projected to experience some increase, though their balance may shift slightly, except petroleum and miscellaneous commodities which are expected to experience slight decreases in tonnage. The Defense scenario tested for 1990 resulted in a 29 million ton traffic surge.

5. *Linkage With Other Reaches.*

	SHIPMENTS				RECEIPTS		
	Destination Reach			Origin Reach			
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total	
1	7	Intra-Reach	80.1	7	Intra-Reach	83.8	
2	4	L. Miss: B.R. to Gulf	6.4	4	L. Miss: B.R. to Gulf	7.6	
3	3	L. Miss: Cairo to B.R.	3.8	10	Gulf Coast-West	4.0	
4	8	Tennessee River	3.4	2	L. Miss: Cairo to B.R.	1.8	
5	11	Gulf Coast-East	2.2	11	Gulf Coast-East	0.5	
6	2	Lower Upper Miss.	1.1	5	Illinois Waterway	0.3	
TOTAL:	(Thousand of Tons)		140,223.0			134,081.9	

6. *Types of Vessels.* Towboats with barges are the principal haulers. Average tow sizes vary considerably on the Ohio River and its tributaries. Frequently, tows are enlarged when entering the Ohio River from the tributaries. Average tow size on the Ohio River ranges from 7 to 10 barges. The maximum is generally 15 barges as controlled by the larger of twin locks. Tow sizes on the tributaries range from 1 on the Kentucky River to a maximum of 9 on the Kanawha.

Figure D-13
PROFILE OF ALLEGHENY RIVER NAVIGATION POOLS



7. *Recreation and Other Water Uses.* Uses include navigation, flood protection, general recreation, boating, hydropower, water supply, and water quality enhancement.

8. *Environmental Concerns.* Primary concerns are bank erosion from all causes, as well as water quality deterioration due to mine drainage, agricultural runoff, municipal discharge, industrial sediments, and sulfur oxides released during the decomposition of coal within sediments.

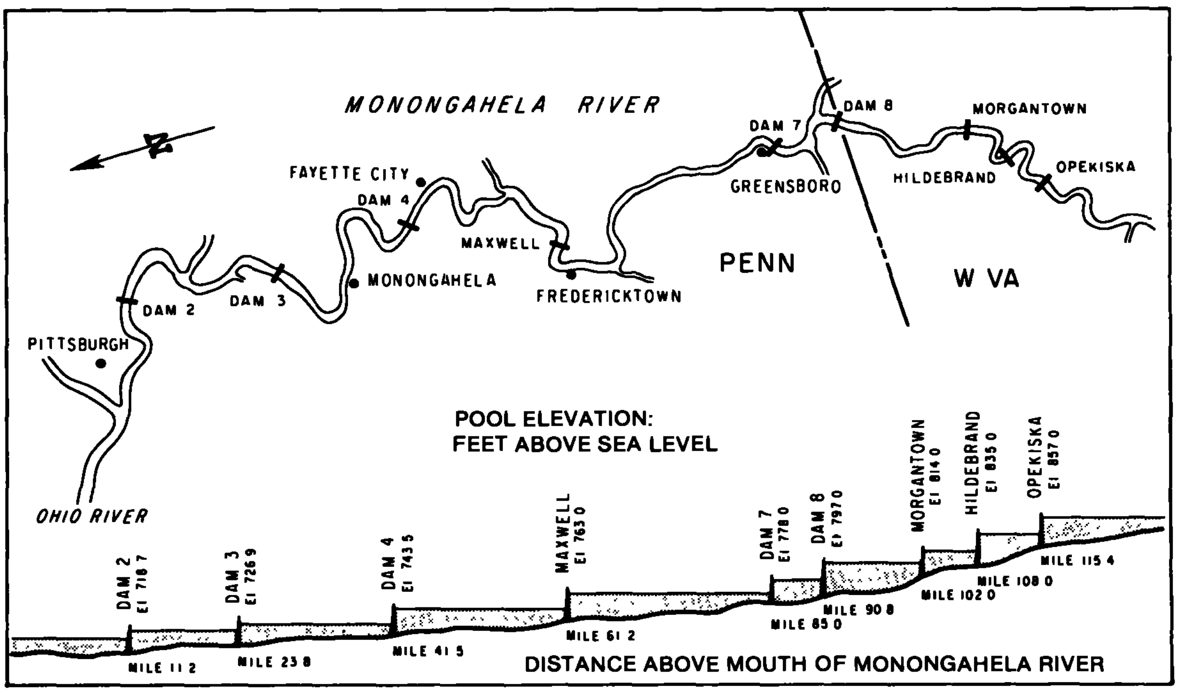
9. *Status of the Waterway.* A 1200-foot temporary lock at No. 53 and two 1200-foot locks at Smithland were opened to navigation in 1980. Lock No. 52 was supplemented by a 1200-foot temporary chamber in 1969. An enlargement of Gallipolis, a projected primary constraining lock by 1995, is currently awaiting authorization for construction. The lock is considered a key constraint for the coal, electric utility and steel industries.

10. *Capability.* Traffic flow on the Ohio River, a complementing "mainline" waterway to the Lower Mississippi, is adversely affected by 16 locks during the planning period. According to NWS research, Gallipolis reaches physical capacity by the 1990s and is considered a primary constraint. Uniontown is an additional primary constraint by 2000. By 1995, substantial delay and congestion at L&Ds 52 and 53 are expected during low flow conditions when the locks must be used. Capacity limitations at Montgomery, McAlpine, Newburgh, and L&Ds 52 and 53 constitute secondary constraints at all these sites between 2000 and 2003. The locks at Dashields and Emsworth are projected to be highly congested by 2003. If the High Coal Export scenario were to be realized, they would both reach their capacities before year 2003. Obsolescence is a serious problem at the aged Monongahela Locks 3, 4, 7 and 8, and at Winfield and Marmet Locks on the Kanawha River. Channel deepening on the Ohio is an option for increasing tonnage handling capability and thus postponing serious congestion at other locks on this river.

Navigation safety problems exist at eight locks: Emsworth, Dashields, Montgomery, New Cumberland, Gallipolis, Greenup, Markland and Newburgh. Seven congested channel locations along the river and 12 bridges also pose safety problems for navigation. Additional aids to navigation should be investigated for these sites.

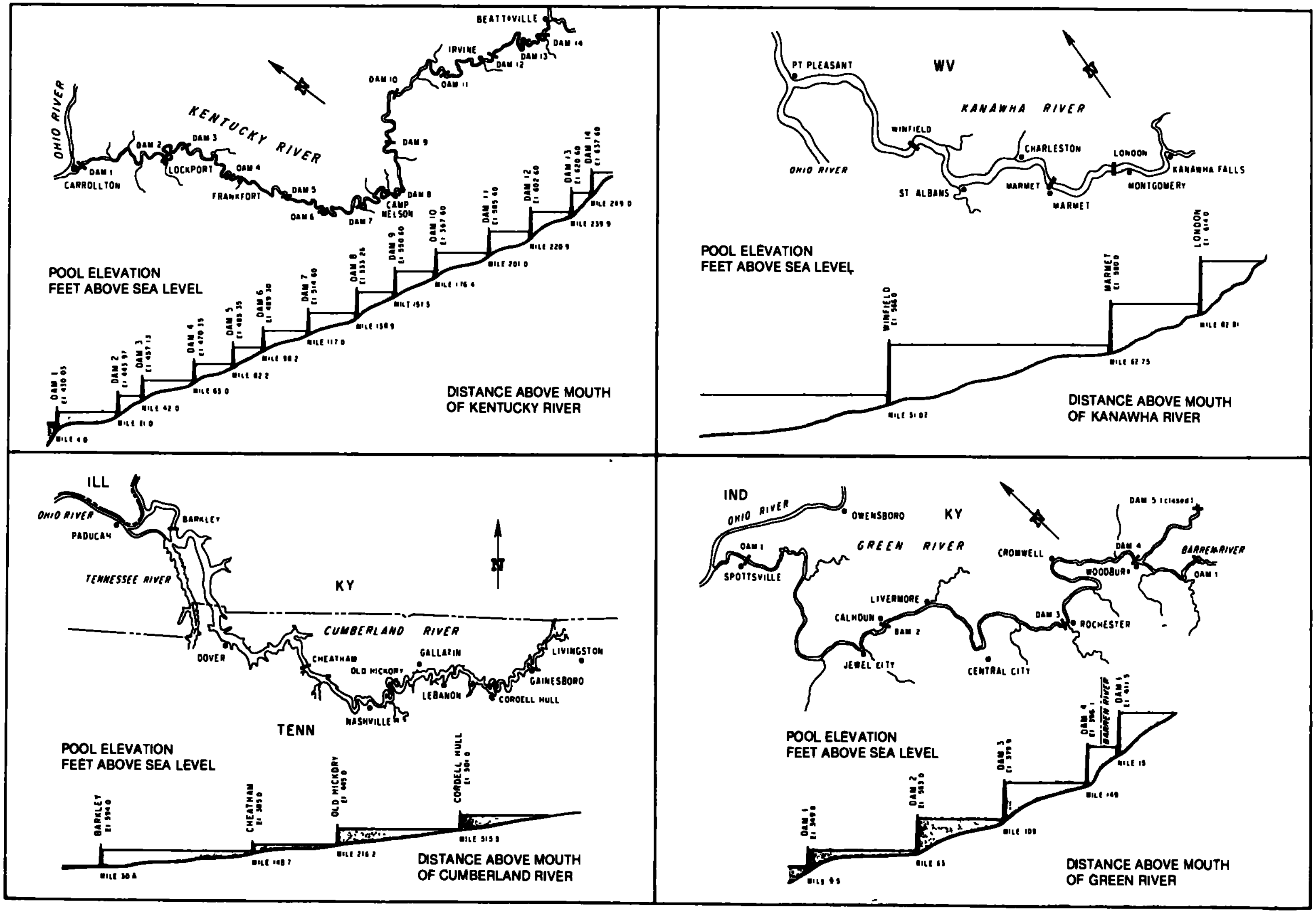
If channel deepening were to be implemented on this reach, the additional dredging would amount to about 0.8 million cubic yards annually. For the total Ohio River System, dredging would then be approximately 3.5 million cubic yards.

Figure D-14
PROFILE OF MONONGAHELA RIVER NAVIGATION POOLS

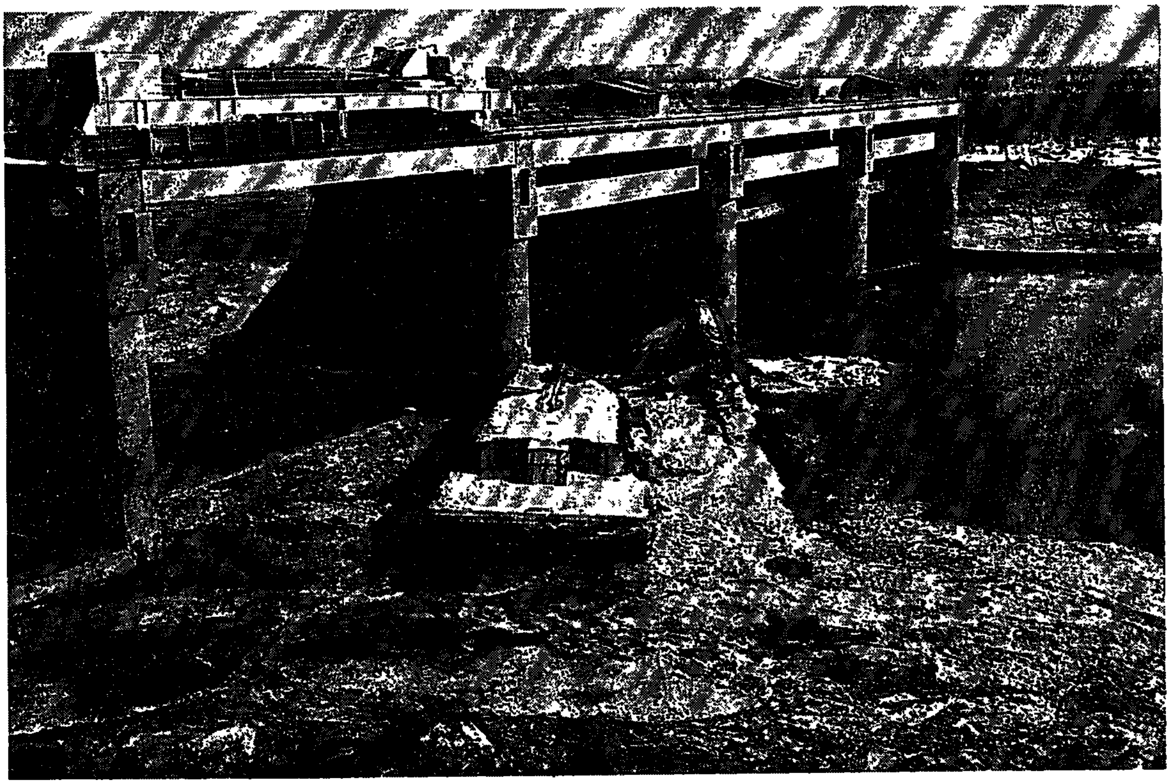


Note: Sites of locks and dams are shown by a name or number.

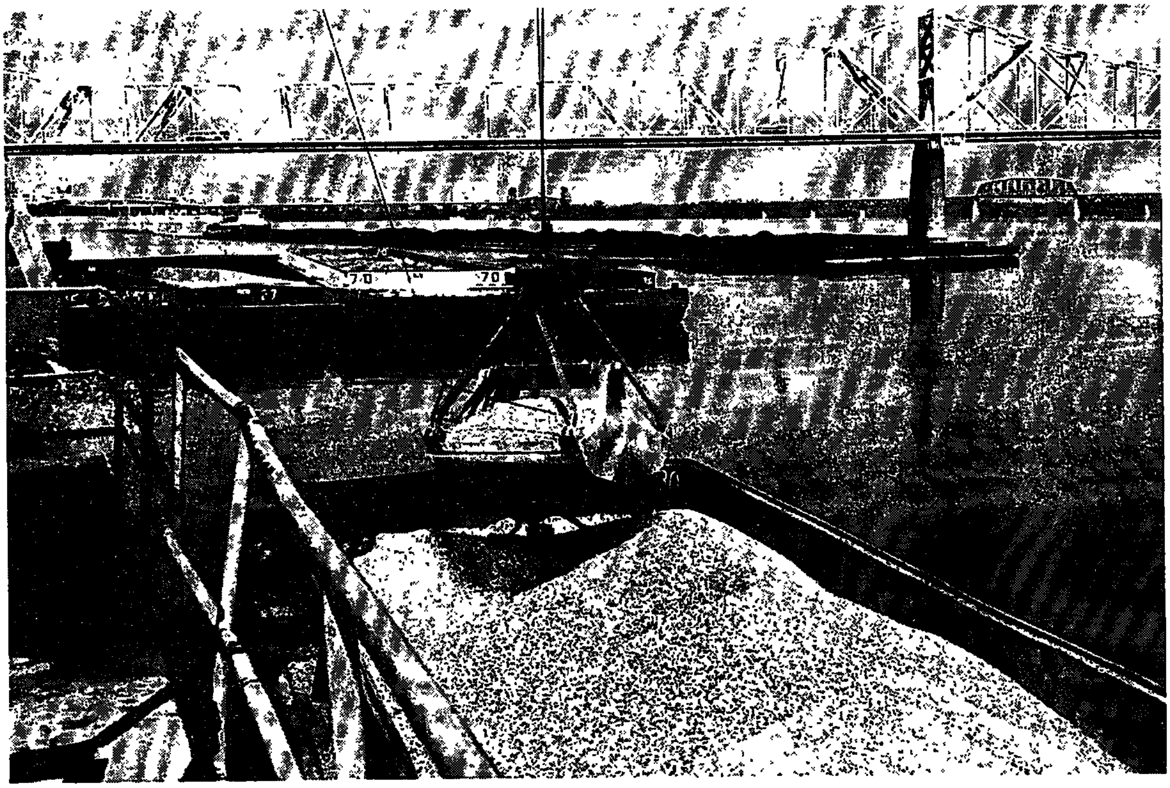
Figure D-15
PROFILES OF KENTUCKY, KANAWHA, CUMBERLAND AND GREEN RIVERS NAVIGATION POOLS



Note. Sites of locks and dams are shown by a name or number.



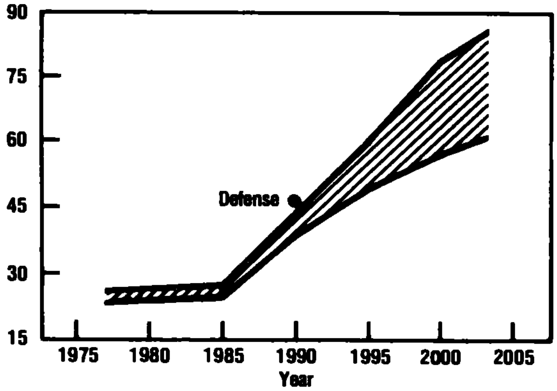
Barges wedged in the tainter gates at McAlpine Locks and Dam.



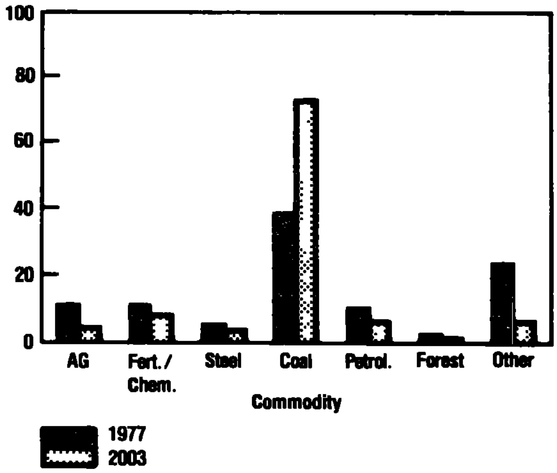
Gravel barge being loaded at Louisville, Kentucky.

Figure D-16
REACH 8, TENNESSEE RIVER
Map and Waterborne Commerce Graphs

Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note. Sites of locks and dams are shown by a name or number.

REACH NUMBER 8
TENNESSEE RIVER

1. *Physical Characteristics.* The controlling depth varies from 8 to 11 feet (9 authorized); the controlling width is 150 to 250 feet; and the length is 711 miles, including the navigable portion of the Clinch River. From the confluence with the Ohio to the head of navigation the river rises 496 feet through nine locks.

2. *Dredging.* The average annual dredging (1973 to 1977) was 0.03 million cubic yards at an average annual cost of $0.05 million or $1.73 per cubic yard.

3. *Lock Dimensions and Capacity.*

Lock Name of Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
Kentucky	110	600	56	1944	36–47
Pickwick	110	600	55	1937	34(old)
(under construction)	110	1000	55	1983	61(new)
Wilson	60	300	94	1927	
	110	600	94	1959	37–54
Wheeler	110	600	48	1963	33–51
	60	400	48	1934	
Guntersville	110	600	39	1965	32–53
	60	360	39	1937	
Nickajack	110	600	39	1967	33–39
Chickamauga	60	360	49	1939	7–10
Watts Bar	60	360	58	1941	7–10
Ft. Loudon	60	360	72	1943	7–10
Melton Hill (Clinch R.)	75	400	58	1963	7–10

4. *Commercial Traffic.* Projections for this reach show stable traffic through 1985 between 22 and 25 million tons. From 1985 to 2003 an increase is projected to between 61.7 and 86.4 million tons, with the surge in growth coinciding with the opening of the Tennessee-Tombigbee Waterway. The major commodity is expected to continue to be coal, which is anticipated to increase from the 1977 level of 8.5 million tons to between 42.8 and 63.9 million tons by 2003, accounting for over 70 percent of the total tonnage that year. The mix of other commodity groups is expected to remain the same. Most of these are projected to experience slight increases, though they will account for a lesser proportion of total tonnage.

5. *Linkage With Other Reaches.*

	SHIPMENTS			RECEIPTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	8	Intra-Reach	56.2	8	Intra-Reach	33.7
2	3	L. Miss: Cairo to B.R.	16.2	7	Ohio River System	27.6
3	4	L. Miss: B.R. to Gulf	10.8	10	Gulf Coast-West	13.9
4	7	Ohio River System	5.3	4	L. Miss: B.R. to Gulf	8.7
5	11	Gulf Coast-East	3.4	2	Lower Upper Miss.	4.8
6	1	Upper Miss.	2.6	1	Upper Miss.	2.6
TOTAL:	(Thousand of Tons)		10,492.7			17,480.6

6. *Types of Vessels.* The average tow sizes range from 1 to 7.7 barges, and the maximum tow size is around 15 barges.

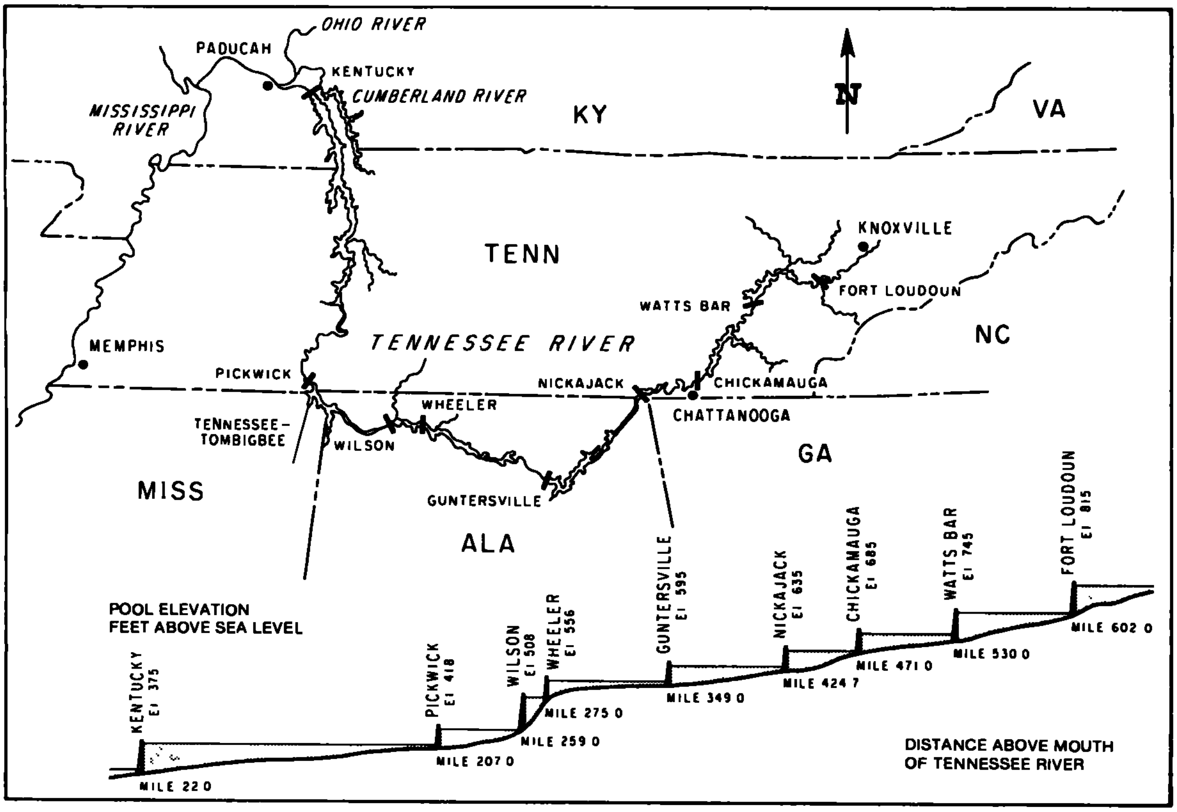
7. *Recreational and Other Water Uses.* Other uses include extensive recreation, flood protection, hydropower, water supply, and boating.

8. *Environmental Concerns.* Deteriorated water quality due to past industrial discharges has made fish inedible in very localized areas of the river. Thermal stratification occurs in reservoirs resulting in low dissolved oxygen. Heavy aquatic growth in reservoirs produce high BOD. Fluctuating lake levels are a cause for concern among adjacent landowners.

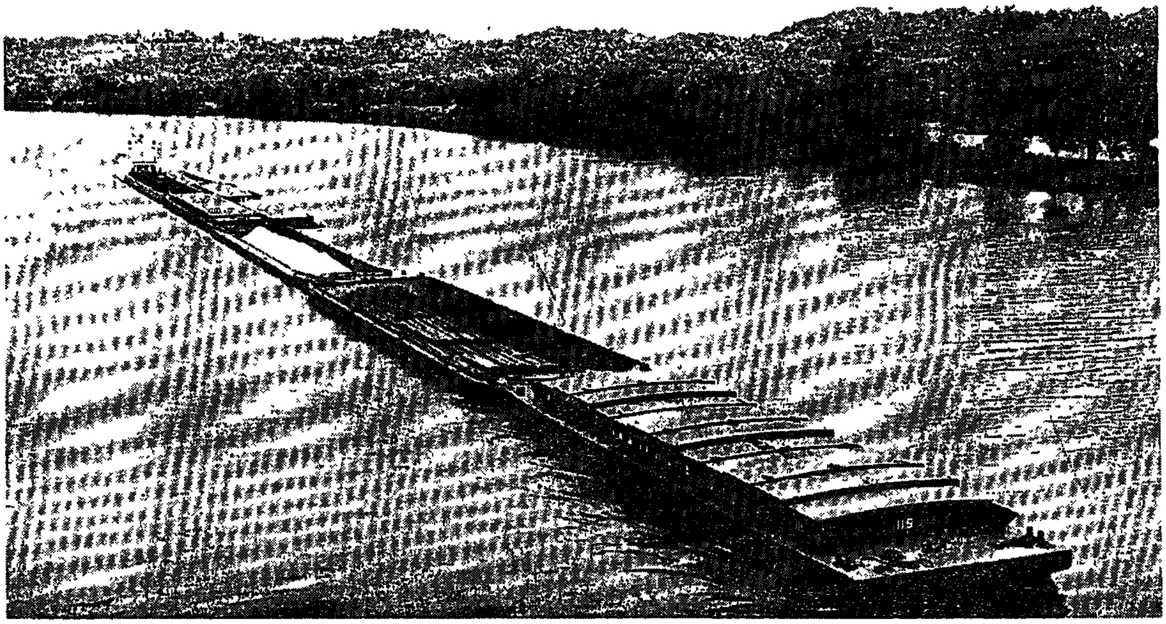
9. *Status of the Waterway* Currently the existing 600 × 110-foot Pickwick Lock on the Tennessee River is being supplemented with a new 1000 × 110-foot facility. Lock completion is scheduled for 1983. The Tennessee-Tombigbee Waterway, which will permit direct barge navigation between the Tennessee and Tombigbee Rivers and on to the Gulf at Mobile, is scheduled for completion in 1986.

10. *Capability.* Congestion at Kentucky Lock on the Tennessee River is forecast to make it a secondary constraint by 2000 under the High Coal Export scenario. At Decatur, Alabama and Chattanooga, Tennessee congestion in the channel contributes to hazardous vessel operating conditions. Four bridges also contribute to vessel safety problems, particularly one at Bridgeport, Alabama and one at mile 78. Dredging is expected to remain at about 0.03 million cubic yards annually

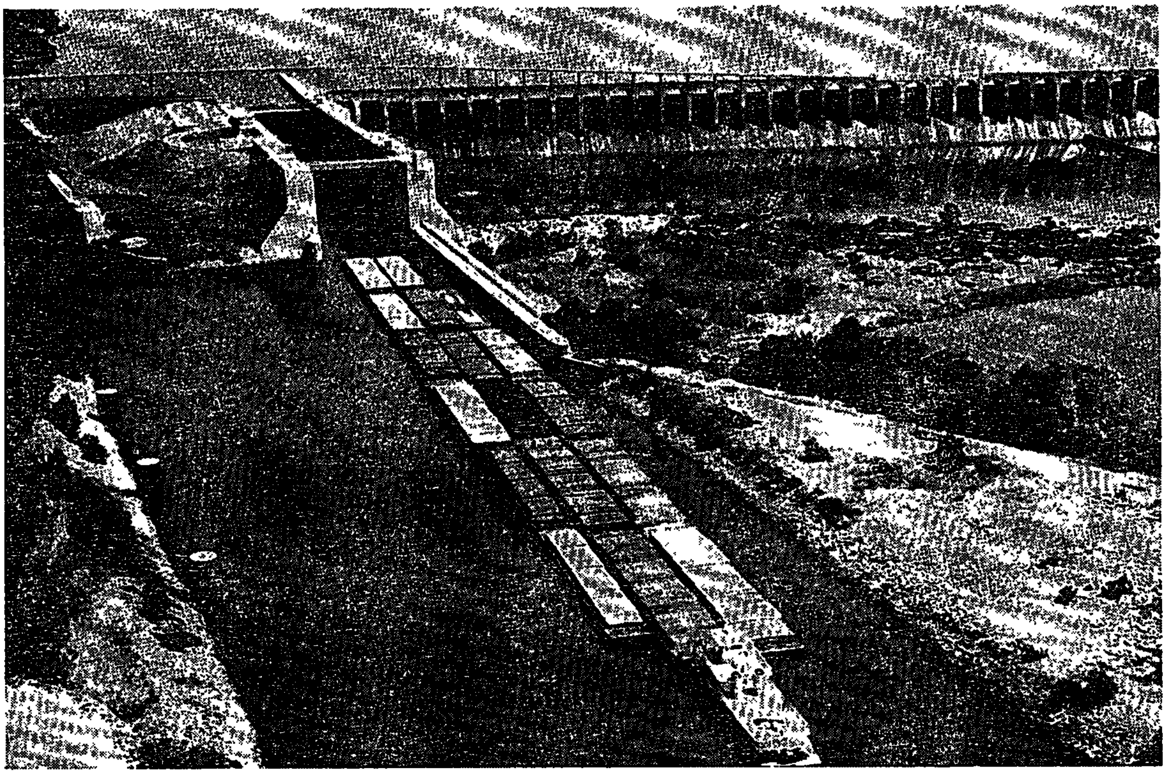
Figure D-17
PROFILE OF TENNESSEE RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

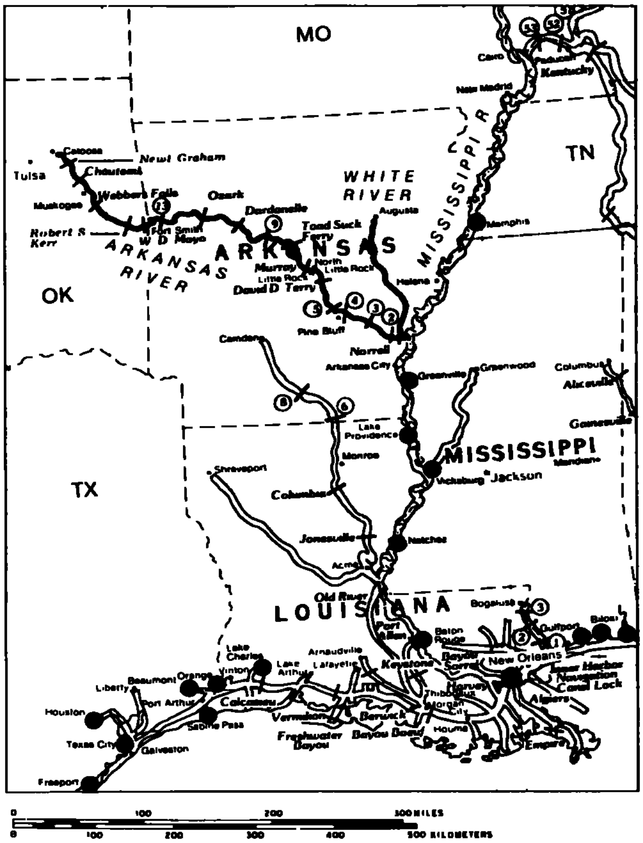


Mixed commodity tow carrying steel, sulphur, tin plate, and sand and gravel.

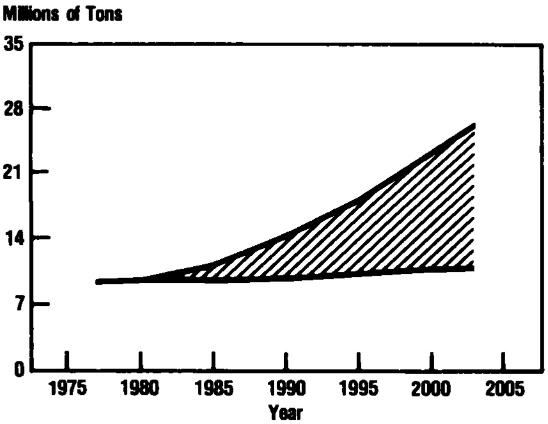


Wilson Lock and Dam near Florence.

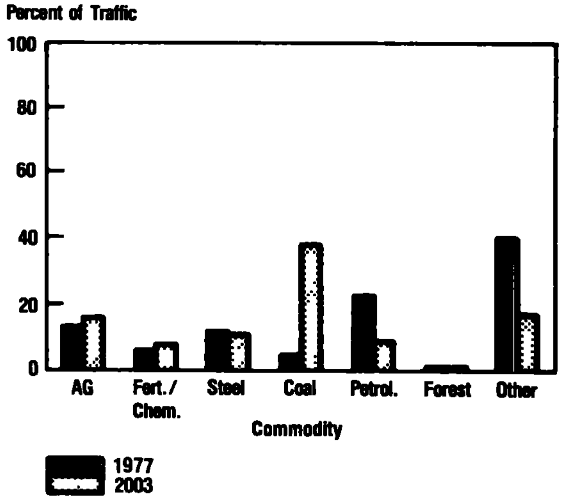
Figure D-18
REACH 9, ARKANSAS RIVER
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note. Sites of locks and dams are shown by a name or number

REACH NUMBER 9
McCLELLAN-KERR ARKANSAS RIVER NAVIGATION SYSTEM

1. *Physical Characteristics.* The project and controlling depth is 9 feet; the controlling width is 250 feet. There is a total lift of 420 feet in the 448 mile distance between the Mississippi River and the head of navigation at Catoosa, Oklahoma provided through 17 locks.

2. *Dredging.* The average annual dredging (1973 to 1977) was 3.3 million cubic yards at an average annual cost of $2.4 million, or $0.73 per cubic yard.

3. *Lock Dimensions and Capacity.*

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity[1] (10^6 tons)
Norrel	110	600	30	1967	25–31
L&D 2	110	600	20	1967	25–31
L&D 3	110	600	20	1968	26–32
L&D 4	110	600	14	1968	26–33
L&D 5	110	600	17	1968	25–31
David T. Terry	110	600	18	1968	25–31
Murray	110	600	18	1969	29–31
Toad Suck	110	600	16	1969	27–31
L&D 9	110	600	20	1969	28–31
Dardanelle	110	600	55	1969	28–31
Ozark	110	600	34	1969	28–31
L&D 13	110	600	20	1969	28–31
W.D. Mayo	110	600	21	1970	27–29
Robert S. Kerr	110	600	48	1970	27–29
Webbers Falls	110	600	30	1970	25–27
Chouteau (Verdigris River)	110	600	21	1970	24–26
Newt Graham (Verdigris R.)	110	600	21	1970	24–26

1. Preliminary screening revealed no congestion potential Therefore, one lock was used to represent the entire system and no future nonstructural efficiency improvements were taken into account Also, operating conditions and practices for 1977 base year were used throughout Calculations using PMS programs indicate lock capacity could be about 1 6 times larger or about 50 million tons per year

4. *Commercial Traffic.* Total traffic is projected to increase from the 1977 level of 9.4 million tons to between 10.8 and 16.5 million tons by 2003. This 16.5 million ton upper limit was further increased in the Miscellaneous scenario to 26.2 million tons through the application of growth rates determined by the Ozark Regional Commission. Projections show an increase in coal from 0.5 million tons in 1977 to a maximum of 10.2 million tons by 2003 under the Miscellaneous scenario, as well as a decrease in petroleum from 2.1 million tons in 1977 to a minimum of 1.1 million tons by 2003.

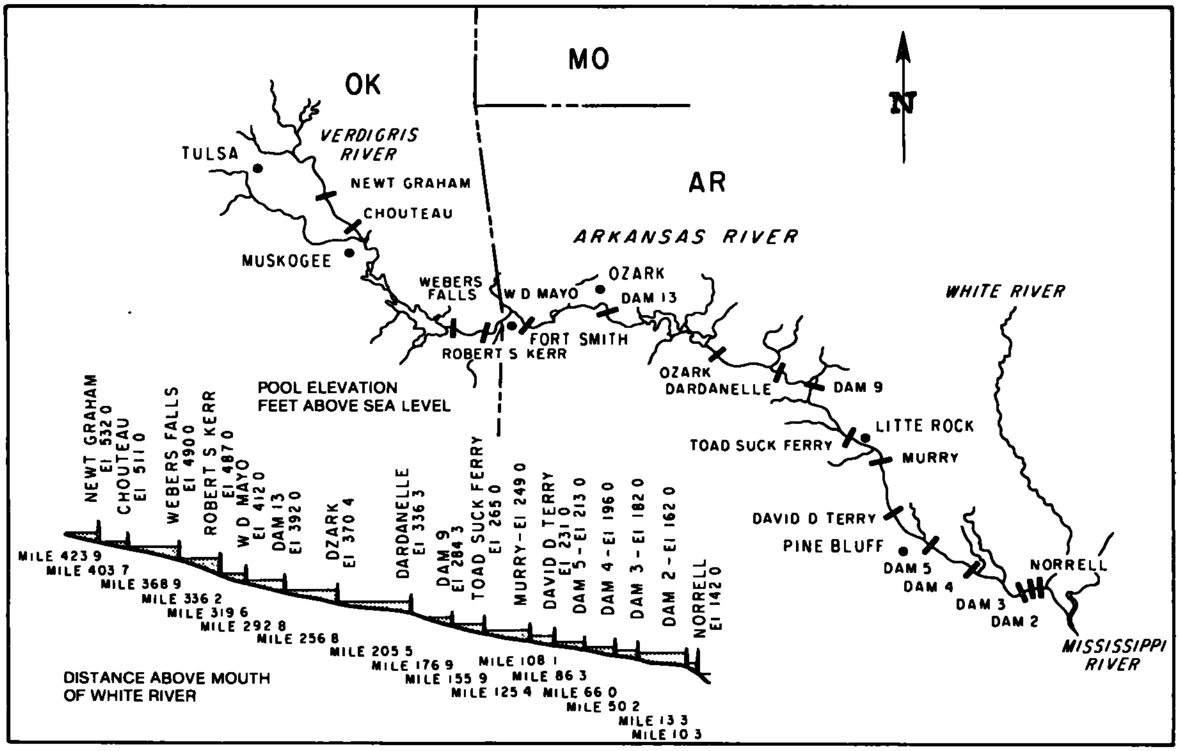
5. *Linkage With Other Reaches.*

	SHIPMENTS			RECEIPTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	9	Intra-Reach	61.1	9	Intra-Reach	59.5
2	4	L. Miss: B.R. to Gulf	21.6	4	L. Miss: B.R. to Gulf	25.1
3	5	Illinois Waterway	3.5	10	Gulf Coast-West	7.5
4	3	L. Miss: Cairo to B.R.	3.4	11	Gulf Coast-East	7.9
5	7	Ohio River System	2.6	7	Ohio River System	1.3
6	1	Upper Mississippi	2.5		L. Miss: Cairo to B.R.	1.2
TOTAL: (Thousands of Tons)			6,636.1			6,816.3

6. *Types of Vessels.* The average tow size is 4 barges, while the maximum tow size is around 9 barges.

7. *Recreational and Other Water Uses.* The uses include navigation, flood protection, hydropower, water supply, recreation, and fish and wildlife. The system is a major producer of hydropower and additional low head installations are anticipated. River and reservoir operations are balanced to support navigation, flood control and power production. State and Federal efforts to increase sports fisheries have increased the popularity of this activity, and now the navigation project supports a large water-based recreation component.

Figure D-19
PROFILE OF ARKANSAS RIVER NAVIGATION POOLS

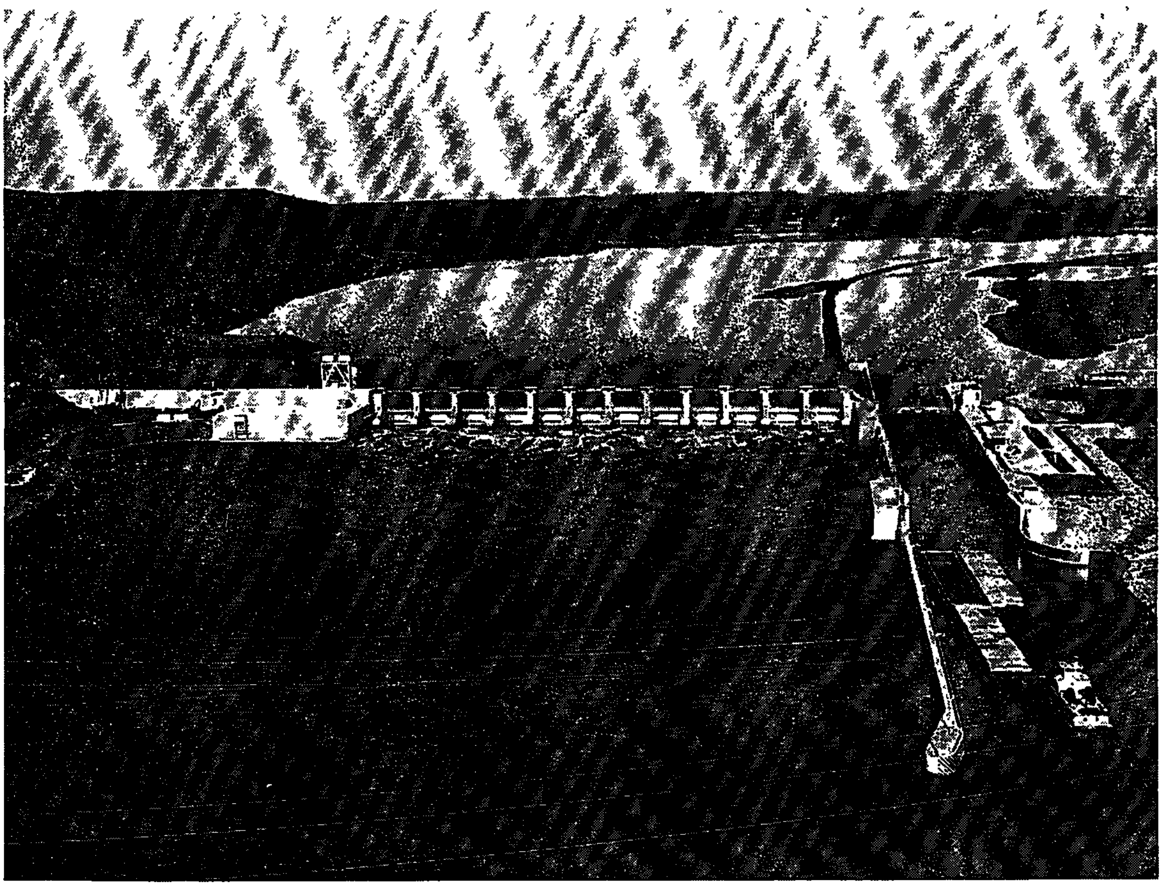


Note. Sites of locks and dams are shown by a name or number.

8. *Environmental Concerns*. Multipurpose project construction has resulted in habitat alterations. Upstream and tributary reaches have high chloride levels, but these are falling. River training and sediment collection by upstream lakes have sharply reduced suspended sediment loads. There is still some turbidity in the river, but it is not a significant environmental concern. Some archeological sites along the river have been disrupted by channel training and dredged material placement, while others have been protected through bank stabilization. Dike fields have helped contribute to the diversity of aquatic life in the river, however aggradation behind dikes may reduce this habitat.

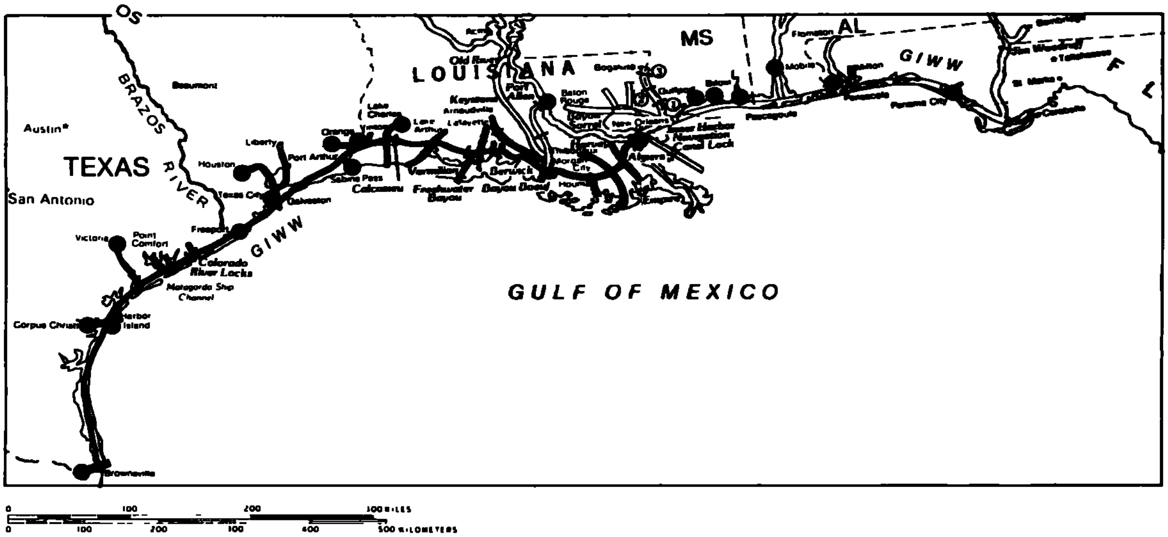
9. *Status of the Waterway*. The 9-foot multipurpose project is complete to Catoosa, Oklahoma, on the Verdigris River. A 5-foot navigable depth is maintained on the White River up to Augusta, Arkansas.

10. *Capability*. High water levels increase navigation problems, but improved operating techniques and better navigation aids have improved the situation. Navigating the bridges at Little Rock can be a problem during such high water stages, but only one of the locks has ever had to be closed due to water levels higher than the design condition. Locks are not projected to become seriously congested or constraining according to the NWS traffic forecasts. Dredging requirements had been about 3.3 million cubic yards annually for the period 1973–1977, but a steady decrease in need for dredging has been in evidence—recent statistics show less than three million cubic yards dredged.

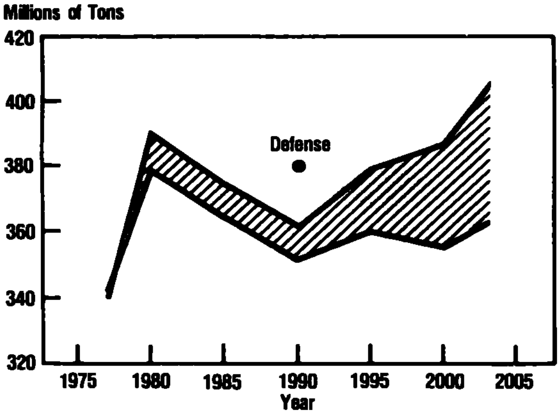


Webbers Falls Lock and Dam.

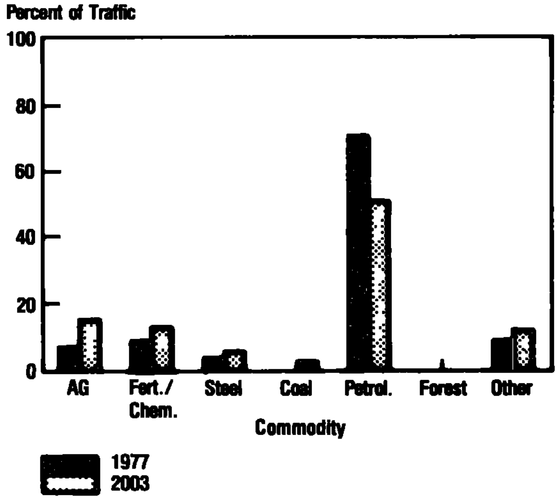
Figure D-20
REACH 10, GULF COAST-WEST
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note: Sites of locks and dams are shown by a name or number

1. *Physical Characteristics*. The project and controlling depth varies from 12 feet for the Gulf Intracoastal Waterway (GIWW)-West to 45 feet in the Corpus Christi Ship Channel; the controlling width is 125 to 1125 feet; and the aggregate length of the principal waterways is 1013 miles (of which 669 is the GIWW-West). This region experiences tide ranges of generally less than 2 feet.

2. *Dredging*. The average annual dredging (1973 to 1977) was 61.0 million cubic yards at an average cost of $26.5 million, or $0.43 per cubic yard.

3. *Lock Dimensions and Capacity*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
Harvey	75	425	20	1934	12
Algiers	75	800	18	1956	35
Bayou Boeuf	75	1156	11	1954	161–248
Vermilion	56	1182	5	1933	72–74
(under construction)	110	1200	5	1982	
Calcasieu	75	1206	4	1950	97–98
Brazos River Floodgates	75	—	—	1954	nc
Colorado River: East Lock	75	1200	5	1954	nc
Colorado River: West Lock	75	1200	5	1954	nc
Keystone (Bayou Teche)	36	160	8	1913	nc
Berwick (Bayou Teche)	45	300	14	1950	nc
Freshwater Bayou	84	600	—	1968	nc
Catfish Point Cont. Struc.	56	—	—	1951	nc

nc = not calculated

4. *Commercial Traffic*. Traffic is projected to fluctuate (see Figure D–20), but eventually increase from 341 million tons in 1977 to between 362.2 and 404.1 million tons by 2003. The major commodity, petroleum, is expected to continue to predominate, though tonnage is projected to decrease from the 1977 level of 240.6 million tons to between 168.7 and 200.0 million tons in 2003. All other commodity groups are projected to increase. Domestic traffic surges by over 50 million tons during the hypothesized defense emergency in 1990.

5. *Linkage With Other Reaches*.

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	10	Intra-Reach	29.7	23	Overseas and Pacific Canada	64.6
2	23	Overseas and Pacific Canada	19.3	10	Intra-Reach	25.7
3	14	Mid Atlantic	13.0	4	L. Miss: B.R. to Gulf	4.4
4	13	South Atlantic	8.5	11	Gulf Coast-East	1.6
5	4	L. Miss: B.R. to Gulf	7.1	12	Mobile River and Trib.	1.4
6	15	North Atlantic	6.4	14	Mid Atlantic	0.6
TOTAL:	(Thousands of Tons)		183,542.0			212,195.2

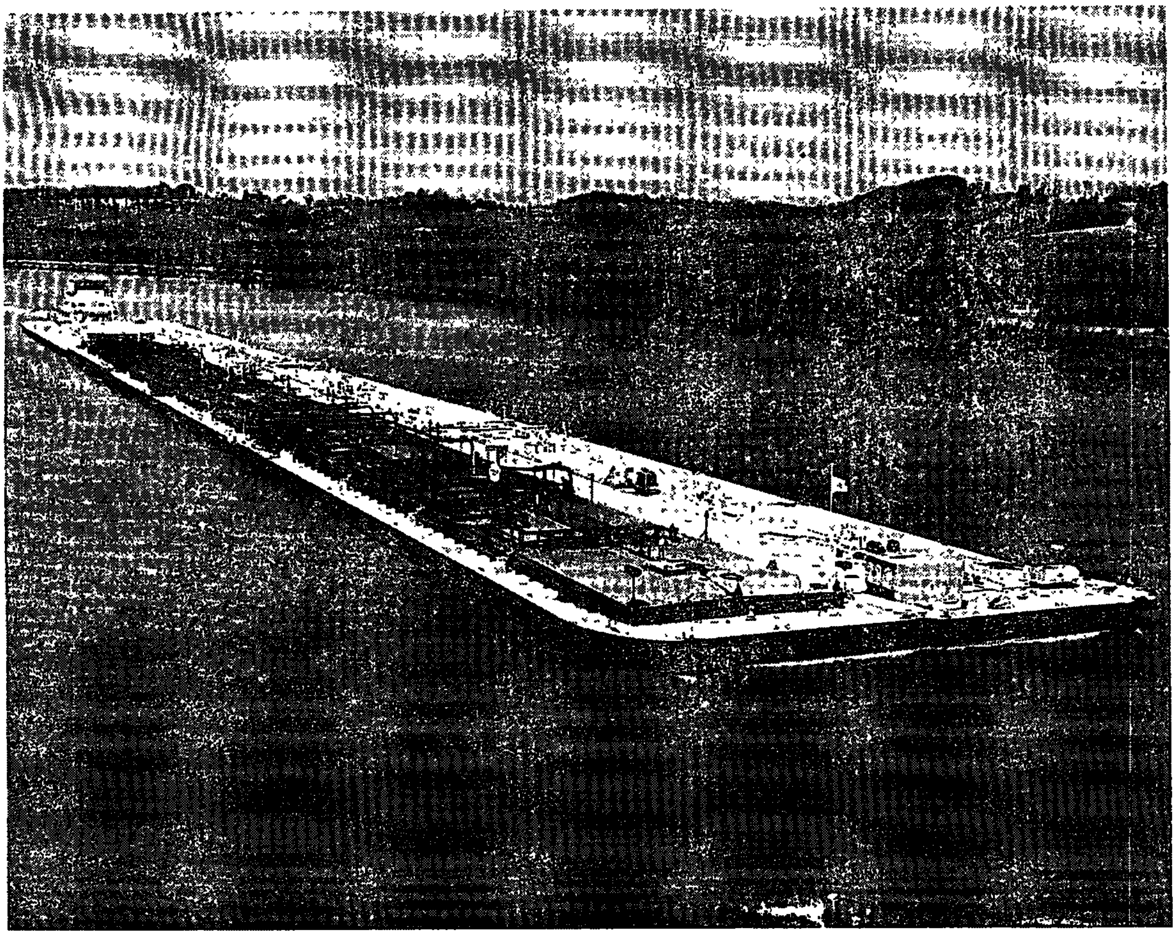
6. *Types of Vessels*. Oceangoing ships as well as barge tows operate in this reach. Maximum tow size on the GIWW-West is generally 5 barges.

7. *Recreational and Other Water Uses*. Uses include navigation, flood protection, and extensive recreational boating.

8. *Environmental Concerns*. Bank erosion occurs in narrow channels of the GIWW. Polluted sediments are found along the industrialized portions of the GIWW. Saltwater intrusion has occurred in the marshlands of Louisiana due to deepened or manmade channels. There are numerous sensitive coastal wetlands and estuaries in Louisiana and Texas. Oil spills are a risk due to the very heavy movement of petroleum in this reach.

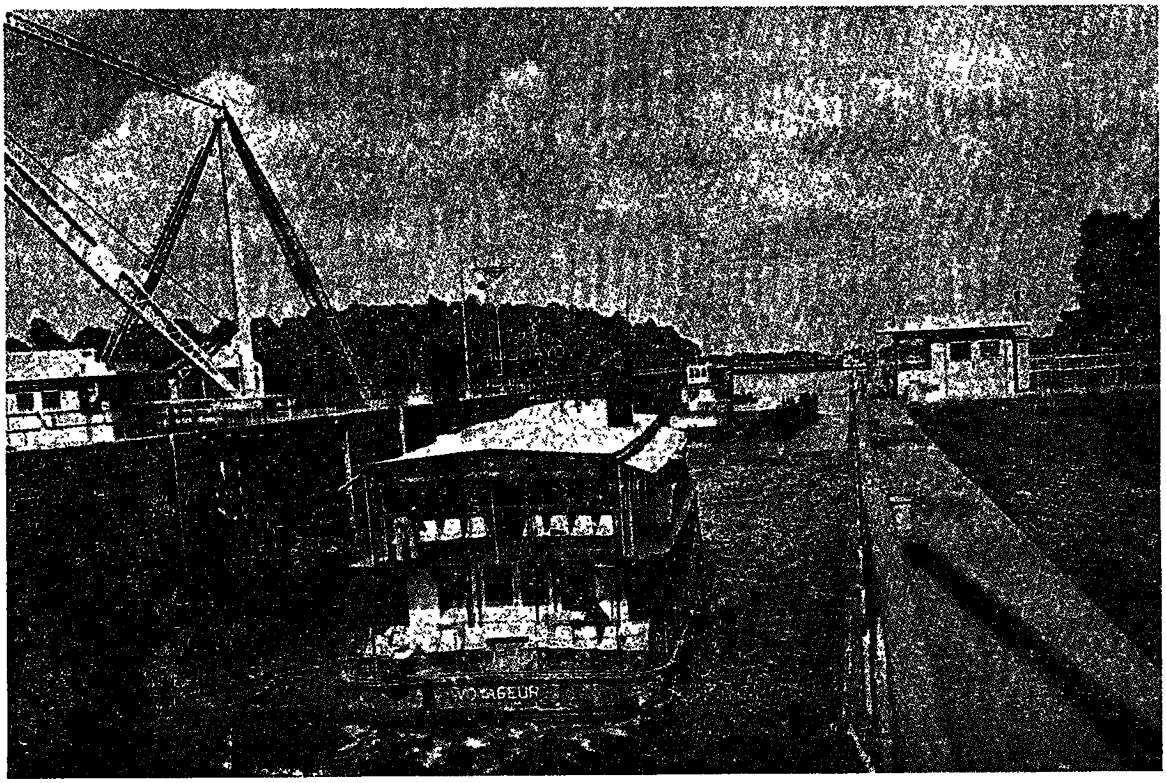
9. *Status of the Waterway*. A replacement lock is currently under construction at Vermilion on the GIWW-West. The port of Galveston has plans underway for channel deepening beyond the existing 40-foot depth.

10. *Capability*. Two GIWW locks, Harvey and Algiers, experience substantial congestion by 2003 under all seven forecasts. Harvey is structually obsolete as well as being congested. As the leading reach in handling petroleum and chemical traffic in the United States, many different structures and congested channels become notable hazards to navigation. Two separate sections on the GIWW-West, plus Port Arthur (the Sabine-Neches Waterway) and the Houston Ship Channel, will have increasingly serious congestion problems. Two locks pose minor safety problems. However, 28 bridges have conditions which pose notable safety problems to navigation. Restrictive bends exist at Baytown on the GIWW. It is anticipated that the past annual dredging volume of 60 million cubic yards will continue.



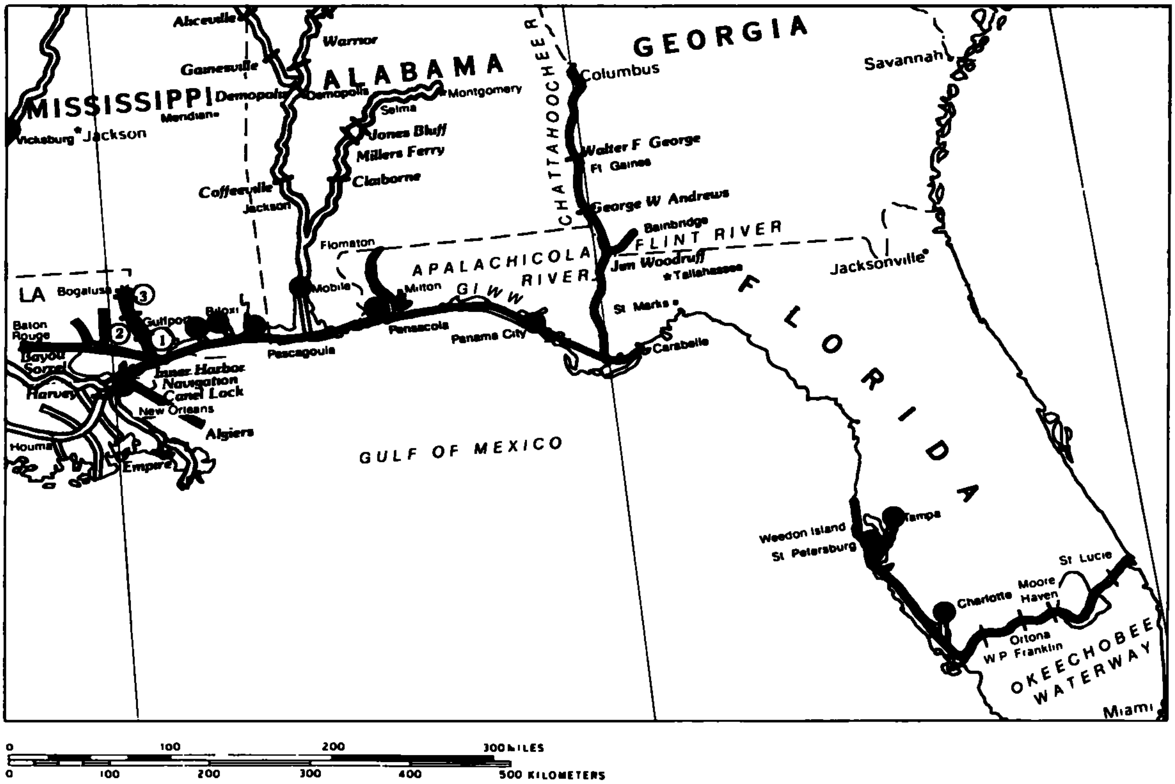
Eight-barge tow of petroleum products.

Harvey Lock

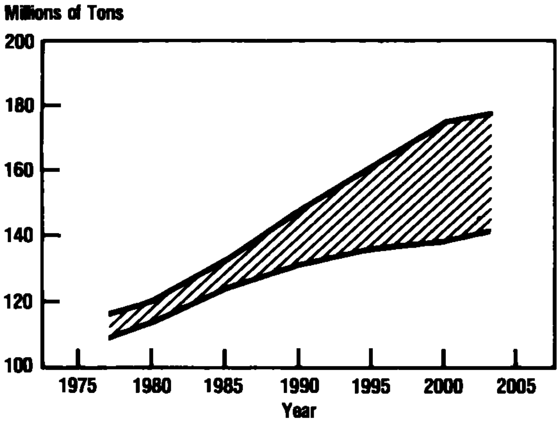


Algiers Lock

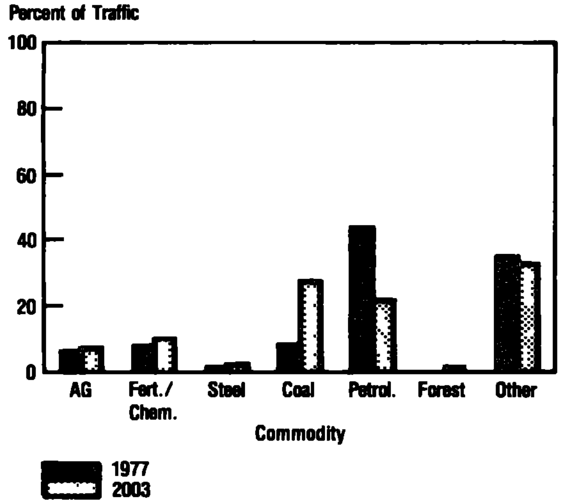
Figure D-21
REACH 11, GULF COAST-EAST
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, Misc. Sensitivity



Note. Sites of locks and dams are shown by a name or number

1. *Physical Characteristics.* The Apalachiola-Chattahoochee-Flint (ACF) river system has a project and controlling depth of 9 feet, and an authorized and controlling width of 100 feet. Total mileage for the navigable portions of the three rivers is 297 miles. The GIWW-East has an authorized and controlling depth of 12 feet and width of 150 feet. Tidal ranges are generally less than 2 feet. Mileage on the GIWW-East between New Orleans, Louisiana and Carrabelle, Florida is approximately 430 miles.

2. *Dredging.* The average annual dredging (1973 to 1977) was 9.7 million cubic yards at an average annual cost of $8.3 million, or $0.86 per cubic yard.

3. *Lock Dimensions and Capacity.*

Lock Name of Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
GIWW-East					
Inner Harbor	75	640	17	1923	31–35
Apalachicola River					
Jim Woodruff	82	450	33	1954	13–15
Chattahoochee River					
George W. Andrews	82	450	88	1962	9
Walter F. George	82	450	25	1963	10
Okeechobee Waterway					
St. Lucie	50	250	13	1941	nc
Port Mayaca	56	400	2	1977	nc
Moore Haven	50	250	2	1953	nc
Ortona	50	250	11	1937	nc
W.P. Franklin	56	400	3	1965	nc

nc = not calculated

4. *Commercial Traffic.* Traffic is projected to steadily increase from about 115.7 million tons in 1977 to between 140.5 and 177.9 million tons in 2003. The major commodity in 1977, petroleum, is projected to decrease from 46.3 to between 30.5 and 36.4 million tons by 2003, while coal could increase from 8.7 in 1977 to between 34.5 and 48.1 million tons by 2003. Other miscellaneous commodities will continue to account for about 34 percent of the tonnage.

5. *Linkage With Other Reaches.*

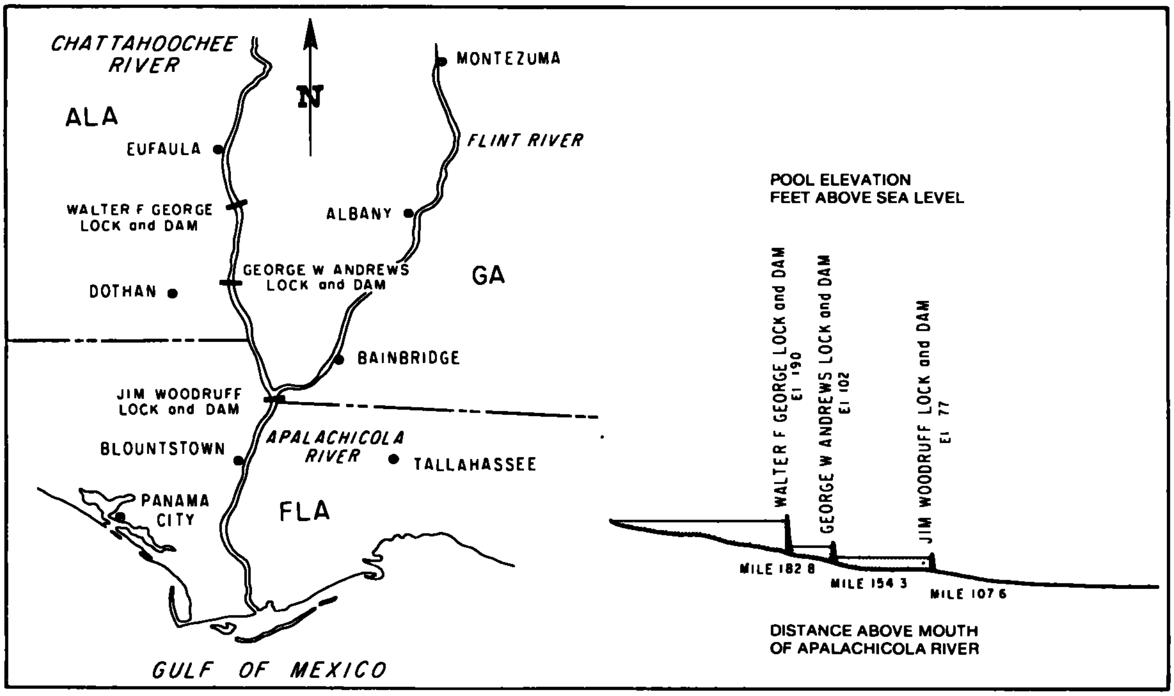
	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	23	Overseas and Pacific Canada	40.7	23	Overseas and Pacific Canada	32.2
2	11	Intra-Reach	21.0	11	Intra-Reach	20.0
3	4	L. Miss: B.R. to Gulf	18.7	10	Gulf Coast-West	18.7
4	10	Gulf Coast-West	6.0	4	L. Miss: B.R. to Gulf	13.4
5	13	South Atlantic	4.3	7	Ohio River System	5.5
6	12	Mobile River & Trib.	3.7	12	Mobile River & Trib.	5.5
TOTAL:	(Thousands of Tons)		54,366.8			56,964.2

6. *Types of Vessels.* Oceangoing vessels as well as barges and tows utilize this reach. Tow size varies from 1 to 5 barges, with a maximum of about 5 on the GIWW. There is heavy recreational navigation along the coast, on the Okeechobee Waterway, and on the navigation pools of the ACF.

7. *Recreational and Other Water Uses.* Uses include navigation, flood protection, general and boating recreation, and hydropower.

8. *Environmental Concerns.* The State of Florida has stringent water quality laws which have halted some dredging projects. Saltwater intrusion into groundwater supplies is a continuing problem, especially in southern Florida.

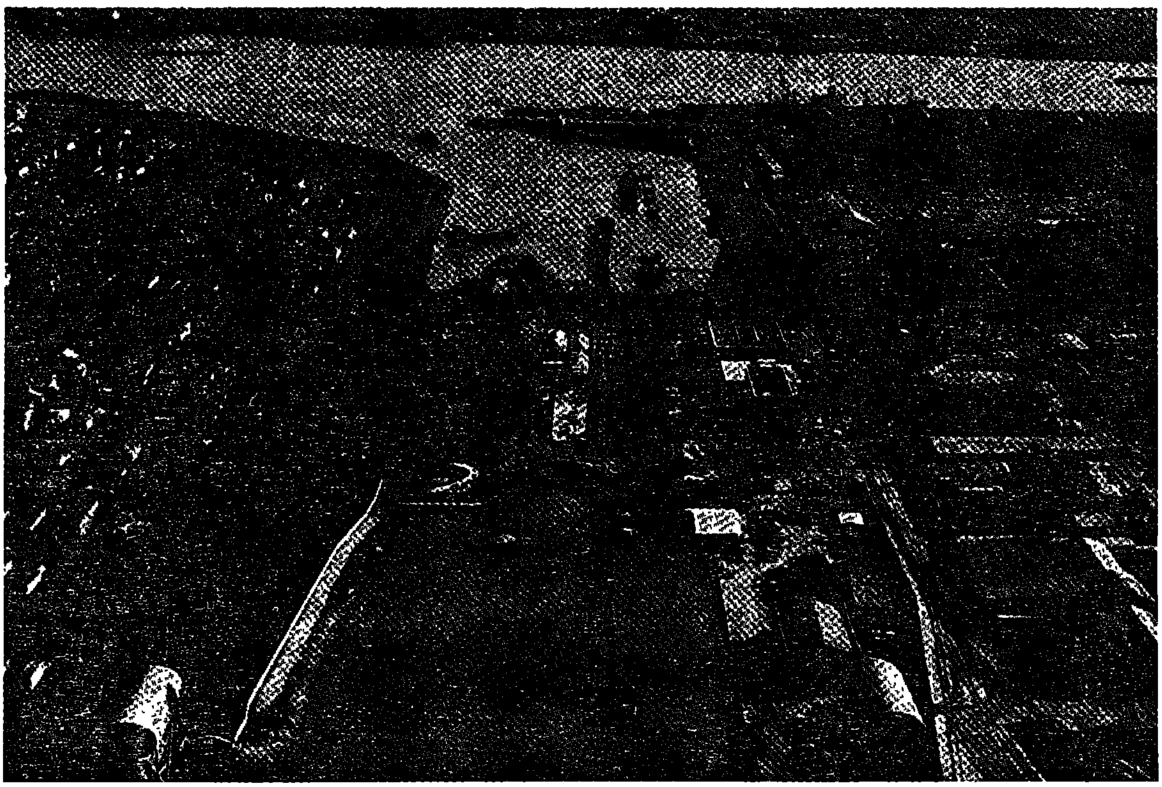
Figure D-22
PROFILE OF CHATTAHOOCHEE RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number

9. *Status of the Waterway*. Studies for modification of the Inner Harbor Canal Lock, which is on the GIWW at New Orleans, are nearing completion. The navigation channel to the Port of Tampa was recently deepened to 41 feet. During dry periods the 9-foot depth on the ACF is not always available.

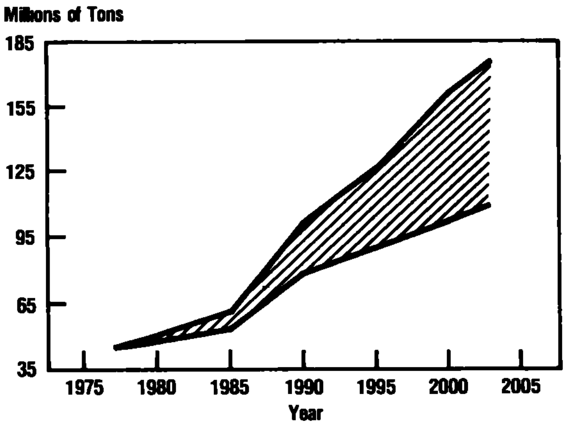
10 *Capability*. The capacity of the GIWW in this reach is restricted by the 31–35 million ton limit at Inner Harbor Canal Lock, which becomes a primary navigation constraint before 1990 under all scenarios. This lock is located in the Port of New Orleans and connects the Mississippi River with the canal and Mississippi River Gulf Outlet. It is a constraint to many waterway industries using this reach, including agriculture, fertilizer, iron and non-metallic ores, petroleum and petroleum products, and chemicals. The complicated Inner Harbor Canal also has four hazardous bridges. This highly congested canal as a whole, as well as the point of intersection of the GIWW with Mobile Bay, are both recognized as hazardous to navigation. Also hazardous, but not highly congested, are Mississippi Sound and the Pascagoula Channel. The Apalachicola-Chattahoochee-Flint system experiences periodic low flows. Dredging is anticipated to continue at the previous annual level of about 10 million cubic yards.



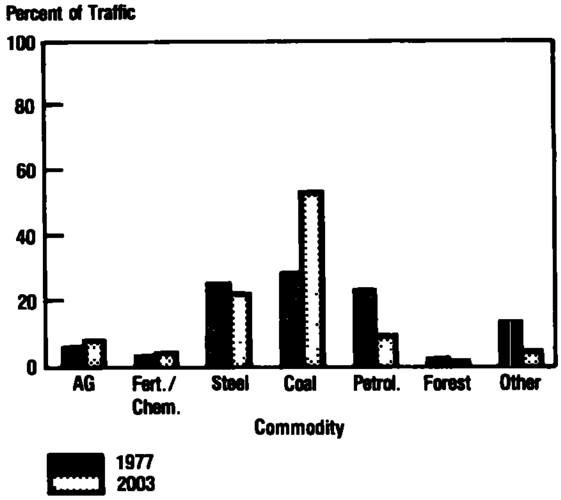
Inner Harbor Lock

Figure D-23
REACH 12, MOBILE RIVER AND TRIBUTARIES
Map and Waterborne Commerce Graphs

Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note. Sites of locks and dams are shown by a name or number.

1. *Physical Characteristics*. The reach consists of the Mobile, Tombigbee, Black Warrior and Alabama rivers. The project and controlling depth is from 9 feet on the inland rivers to 40 feet in Mobile Bay; the controlling width is 150 to 200 feet in rivers to 400 feet in Mobile Bay. The Mobile-Tombigbee-Black Warrior River segment is about 415 miles in length. The stretch of the Tombigbee above Demopolis, which the Tenn-Tom Waterway will join, is currently open for 115 miles, and the Alabama River is navigable for about 315 miles above its junction with the Mobile River.

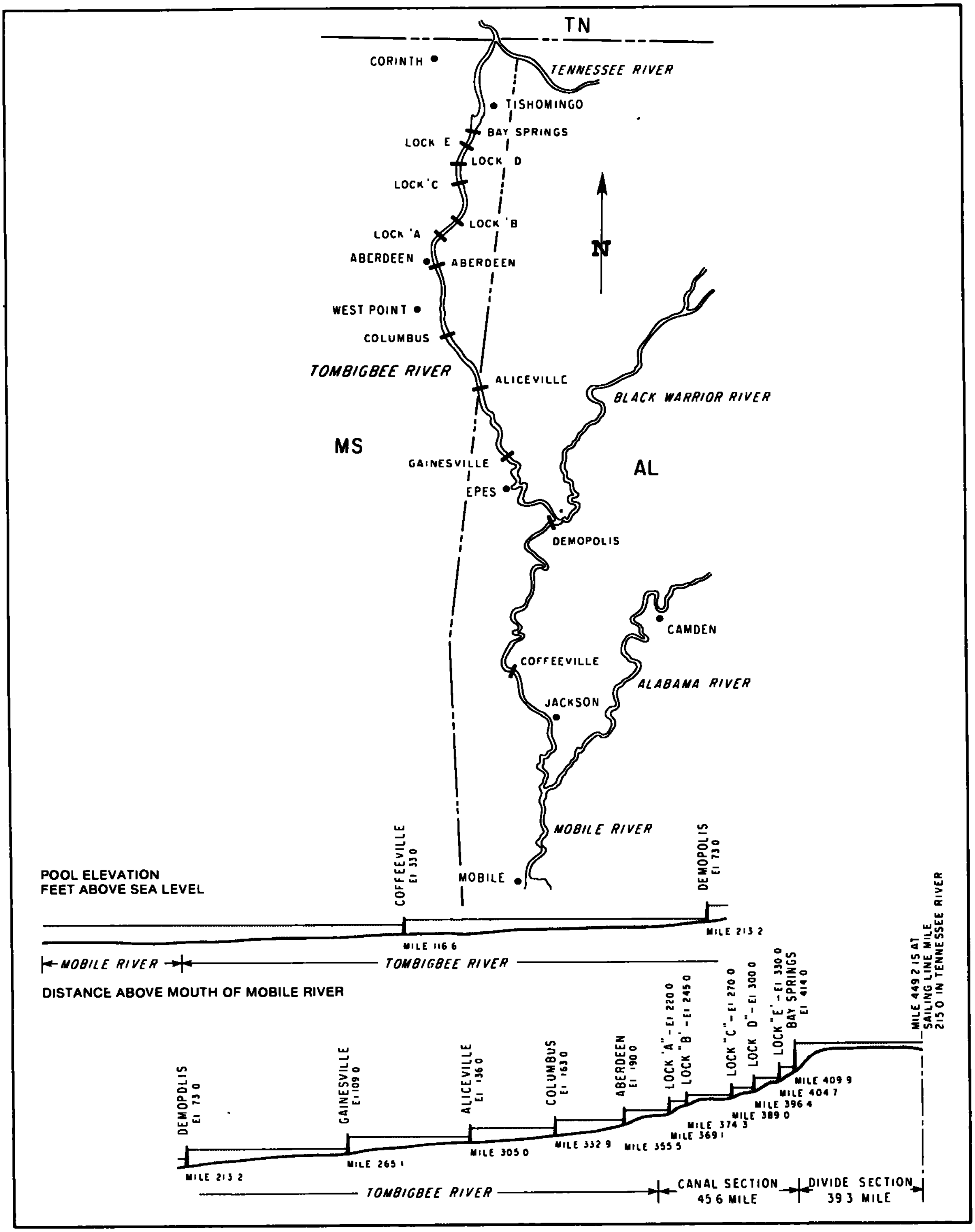
2. *Dredging*. The average annual dredging (1973 to 1977) was 9.8 million cubic yards at an average annual cost of $3.9 million, or $0.40 per cubic yard.

3. *Lock Dimensions and Capacity*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
Black Warrior River					
John Hollis Bankhead	110	600	68	1975	32–39
Holt	110	600	64	1966	31–36
Wm. Bacon Oliver	95	460	28	1939	22–24
Warrior	110	600	22	1957	31–39
Tombigbee River					
Demopolis	110	600	40	1954	45–54
Coffeeville	110	600	34	1960	45–54
Alabama River					
Claiborne	84	600	30	1973	35–39
Millers Ferry	84	600	45	1969	35–41
Jones Bluff	84	600	45	1974	33–35
Tennessee-Tombigbee Waterway					
Gainesville	110	600	36	1978	63–64
Aliceville	110	600	27	1979	63–64
Columbus	110	600	27	1980	63–64
Aberdeen	110	600	27	1986	63–64
A	110	600	30	1986	63–64
B	110	600	25	1986	63–64
C	110	600	25	1986	63–64
D	110	600	30	1986	63–64
E	110	600	30	1986	63–64
Bay Springs	110	600	84	1986	63–64

4. *Commercial Traffic*. Total traffic (domestic plus foreign) is projected to increase from 44.6 million tons in 1977 to between 108.9 and 177.6 million tons in 2003. One of the major commodities in 1977, coal, is expected to predominate in 2003 as it increases from the 1977 level of 12.7 to between 51.4 and 111.0 million tons by 2003, accounting for over 50 percent of the total tonnage at that time under most of the forecasts. All other commodities are projected to increase although relatively modestly, and the balance of commodities is expected to shift as shown in the graph of existing and projected traffic for this reach.

Figure D-24
PROFILE OF TOMBIGBEE RIVER AND WATERWAY NAVIGATION POOLS



Note. Sites of locks and dams are shown by a name or number.

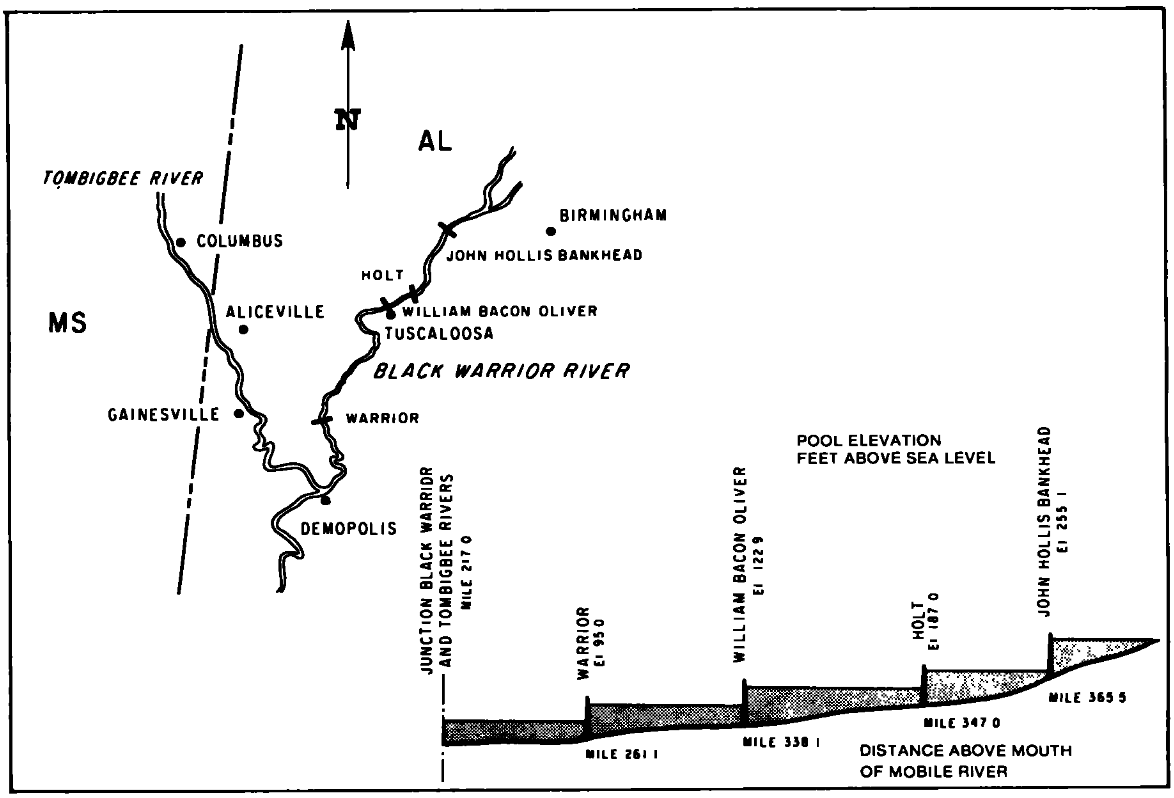
5. *Linkage With Other Reaches.*

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	12	Intra-Reach	48.6	12	Intra-Reach	50.0
2	23	Overseas and Pacific Canada	18.8	23	Overseas and Pacific Canada	28.6
3	11	Gulf Coast-East	10.6	11	Gulf Coast-East	7.0
4	10	Gulf Coast-West	10.1	12	Gulf Coast-West	5.9
5	4	L. Miss: B.R. to Gulf	7.9	4	L. Miss: B.R. to Gulf	3.8
6	3	L. Miss: Cairo to B.R.	1.2	7	Ohio River System	1.4
TOTAL:	(Thousands of Tons)		29,390.6			28,583.4

6. *Types of Vessels.* The current average tow size is 4 barges on the rivers. The maximum tow size is around 6 barges. Ocean vessels call at Mobile Harbor.

7. *Recreational and Other Water Uses.* Uses include navigation, recreation, hydropower, and cooling water for power generating plants.

Figure D-25
PROFILE OF BLACK WARRIOR RIVER NAVIGATION POOLS



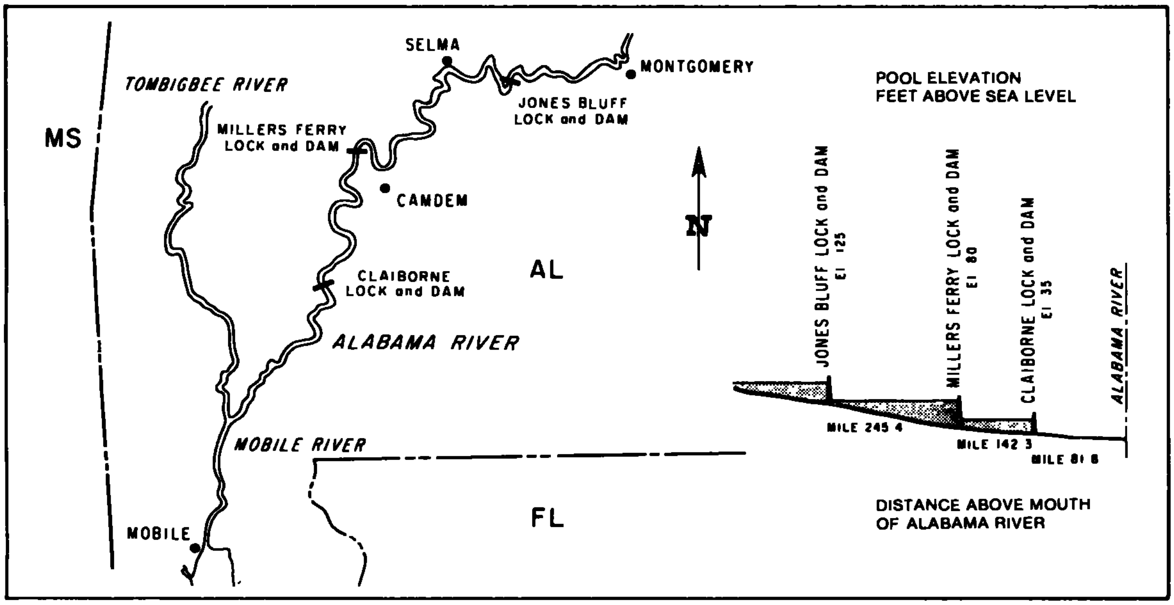
8. *Status of the Waterway.* The project is complete on the Black Warrior and Tombigbee Rivers below Birmingham, and on the Alabama River from just above Montgomery. The Tennessee-Tombigbee project currently under construction is scheduled for completion in 1986. A deepening study was recently completed for the Port of Mobile.

9. *Capability.* On the Black Warrior River, Oliver L&D could constitute a primary constraint by 1990. Warrior and Holt are anticipated to become secondary constraints during the study time frame. On the Tombigbee River, projected secondary constraints include Demopolis and Coffeeville by 2000. Additionally, the narrow channel between Demopolis and Mobile Bay, as well as on the Black Warrior River, limits effective tow sizes to 6 barges. Actions to remedy the channel problems would increase the utilization of most locks and greatly enhance the efficiency of the system. Savings of up to $29 million annually by 2003 could accrue through channel improvements.

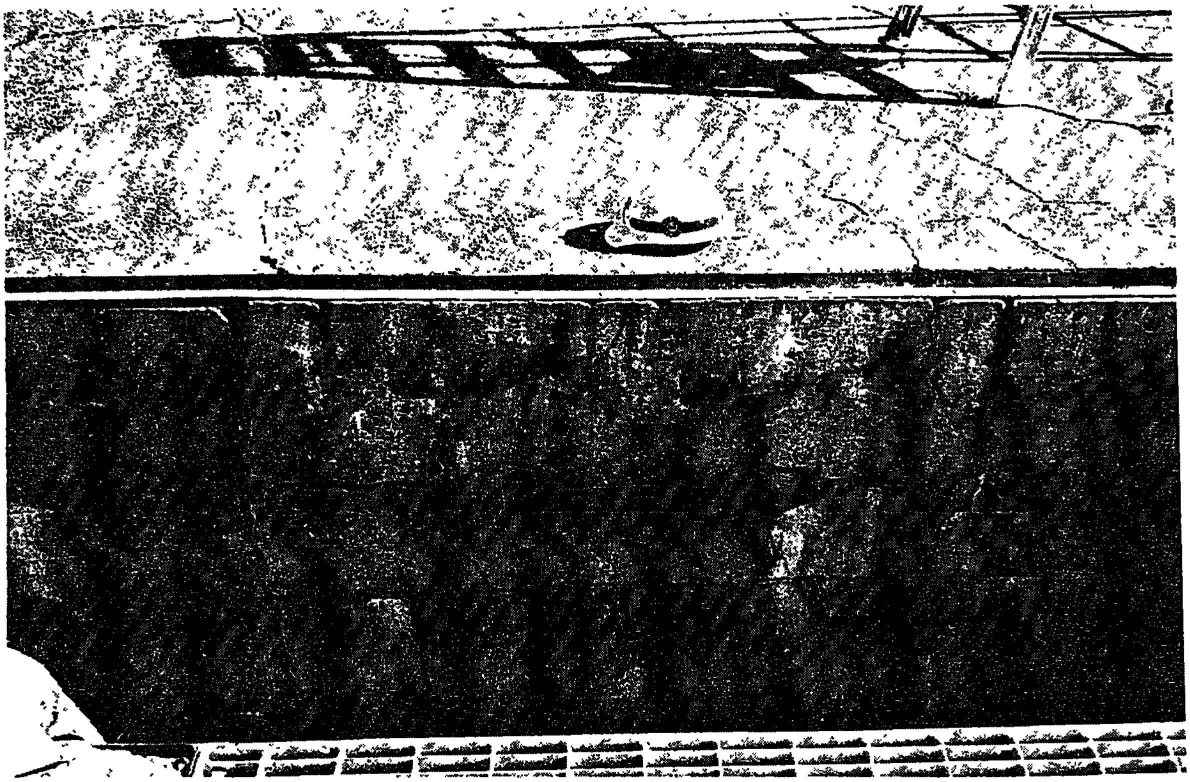
Three channel sites are notably hazardous to navigation due to the configuration. More than 10 different bridges were found to be hazardous to navigation and should be considered for minor safety actions.

The completion of the Tennessee-Tombigbee Waterway will add approximately 1.2 million cubic yards of dredging annually. The 2003 dredging program is therefore expected to be about 9.82 million cubic yards annually.

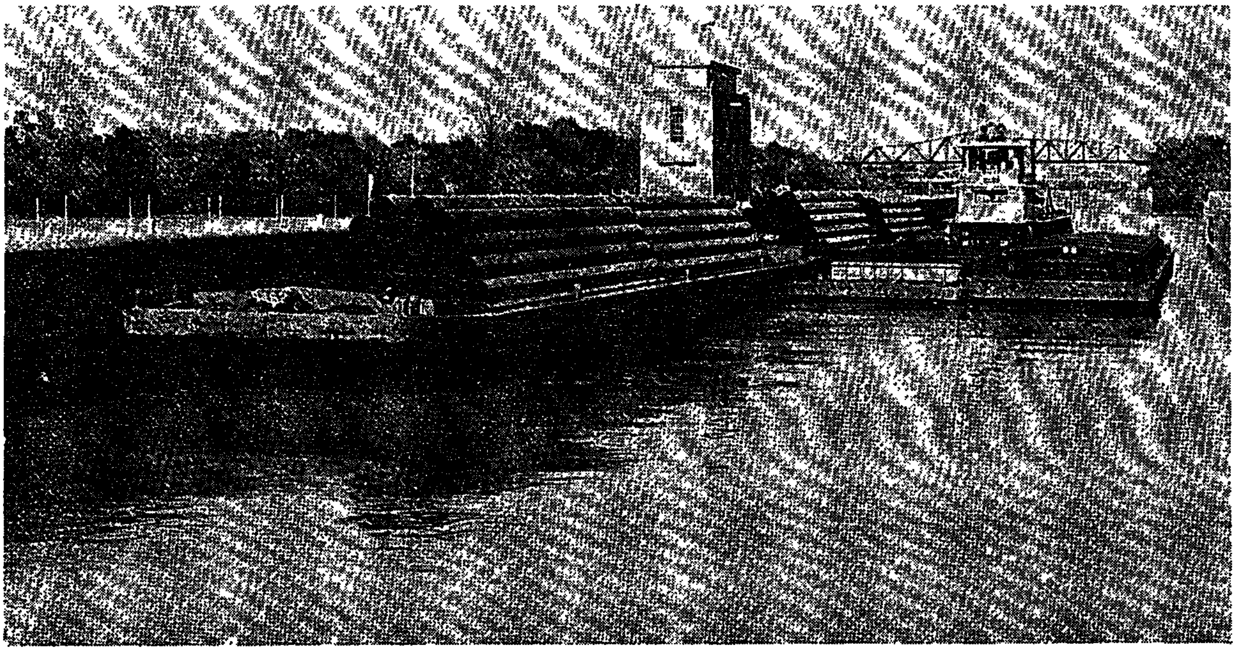
Figure D-26
PROFILE OF ALABAMA RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

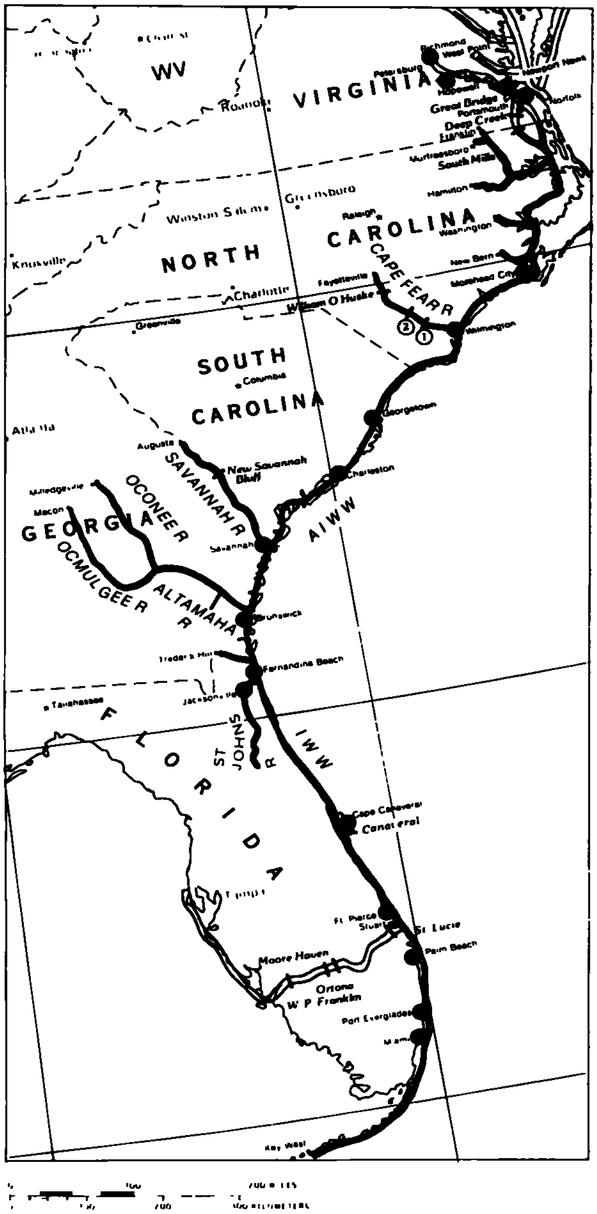


Concrete cracking in lock wall, William Bacon Oliver Lock and Dam, Black Warrior River.

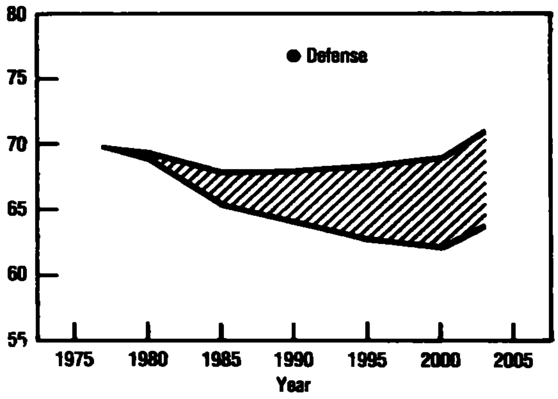


A tow carrying steel products passes through Oliver Lock as it moves down the Black Warrior River.

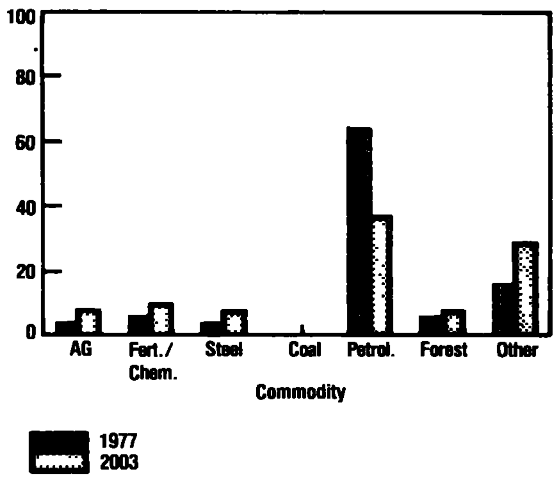
Figure D-27
REACH 13, SOUTH ATLANTIC COAST
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note Sites of locks and dams are shown by a name or number

REACH 13

SOUTH ATLANTIC COAST
(Florida to North Carolina-Virginia Border)

1. *Physical Characteristics*. The Intracoastal Waterway on the Atlantic Coast has a project depth of 7 to 12 feet, but controlling depths from 4 to 12 feet in various segments. The waterway is completed to project dimensions between Norfolk, Virginia and the Florida Keys, a distance of 1170 miles. Unimproved or partially improved stretches extend to Key West, Florida and along the coasts of Virginia, Maryland, Delaware, New Jersey and Long Island. Ocean harbors vary considerably up to a maximum depth (authorized and controlling) of 48 feet. Mean tide at major ports ranges between 5 and 7 feet.

2. *Dredging*. The average annual dredging (1973 to 1977) was 29.5 million cubic yards at an average annual cost of $25.6 million or $0.87 per cubic yard.

3. *Lock Dimensions*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened
Savannah River				
New Savannah Bluff	56	360	15	1936
Cape Fear River				
L&D 1	40	200	11	1934
L&D 2	40	200	9	1917
William O. Huske	40	300	9	1935
AIWW				
South Mills	52	300	12	1941
Canaveral Harbor				
Canaveral	90	600	3	1965

4. *Commercial Traffic*. Total traffic is projected to increase from 69.8 million tons in 1977 to 71.1 million tons in 2003 under three forecasts, or decrease to 63.8 million tons by 2003 under the lowest traffic projection. The major commodity in 1977, petroleum, is expected to remain predominant, although tonnages are expected to decline from 44.9 million tons in 1977 to around 26.4 million tons by 2003. All other commodities are projected to increase modestly, except coal (1977 tonnage was 2,000 tons), which was not projected.

5. *Linkage With Other Waterways.*

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	13	Intra-Reach	45.1	23	Overseas and Pacific Canada	35.6
2	23	Overseas and Pacific Canada	40.9	10	Gulf Coast-West	26.7
3	14	Mid Atlantic	6.5	13	Intra-Reach	16.4
4	22	Caribbean	3.7	14	Mid Atlantic	4.4
5	19	California	0.8	17	Gulf Coast-East	4.0
6	11	Gulf Coast-East	0.6	4	L. Miss: B.R.	3.7
TOTAL:	(Thousands of Tons)		21,081.8			58,190.6

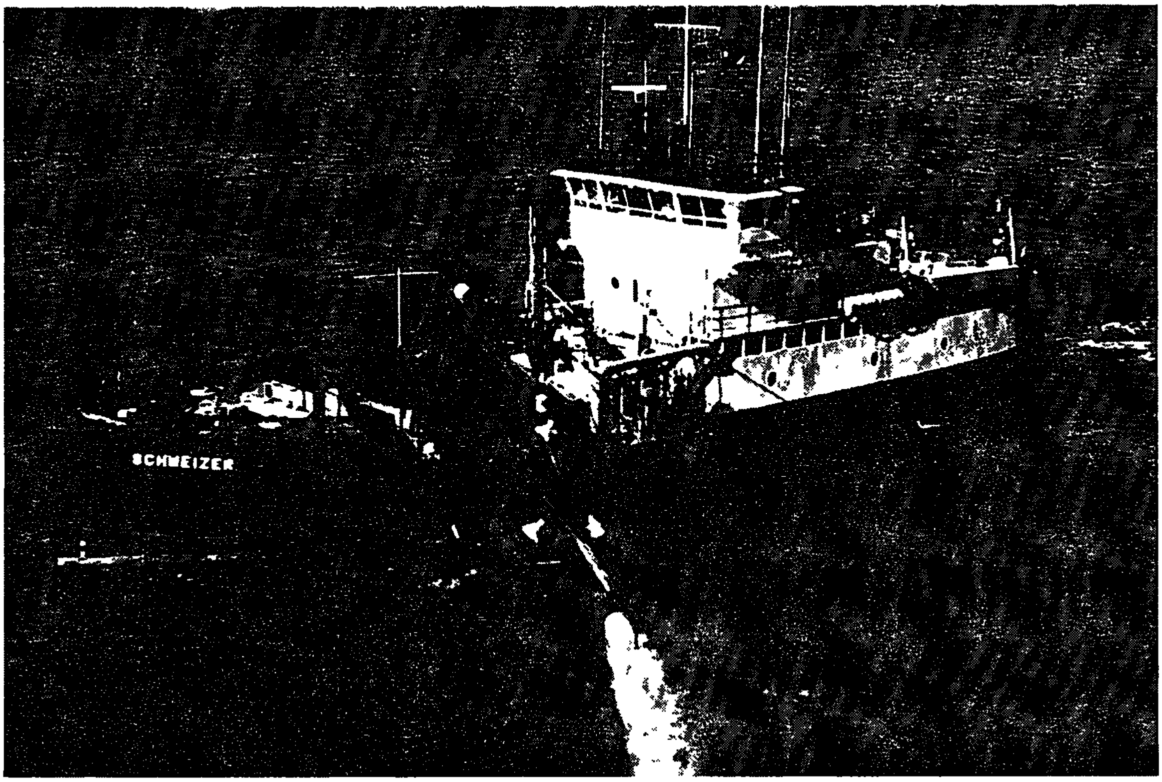
6. *Types of Vessels.* Deep draft navigation is provided in a number of coastal ports, including Jacksonville, Savannah, Charleston, Wilmington, Morehead City and Port Everglades. Shallow draft barges ply the AIWW and the Savannah and Cape Fear Rivers. Naval vessels routinely call at Jacksonville and there is a large submarine base at Kings Bay, Georgia.

7. *Recreational and Other Water Uses.* The authorized and current uses include navigation, hurricane and flood protection, general recreation, extensive recreational boating and national defense.

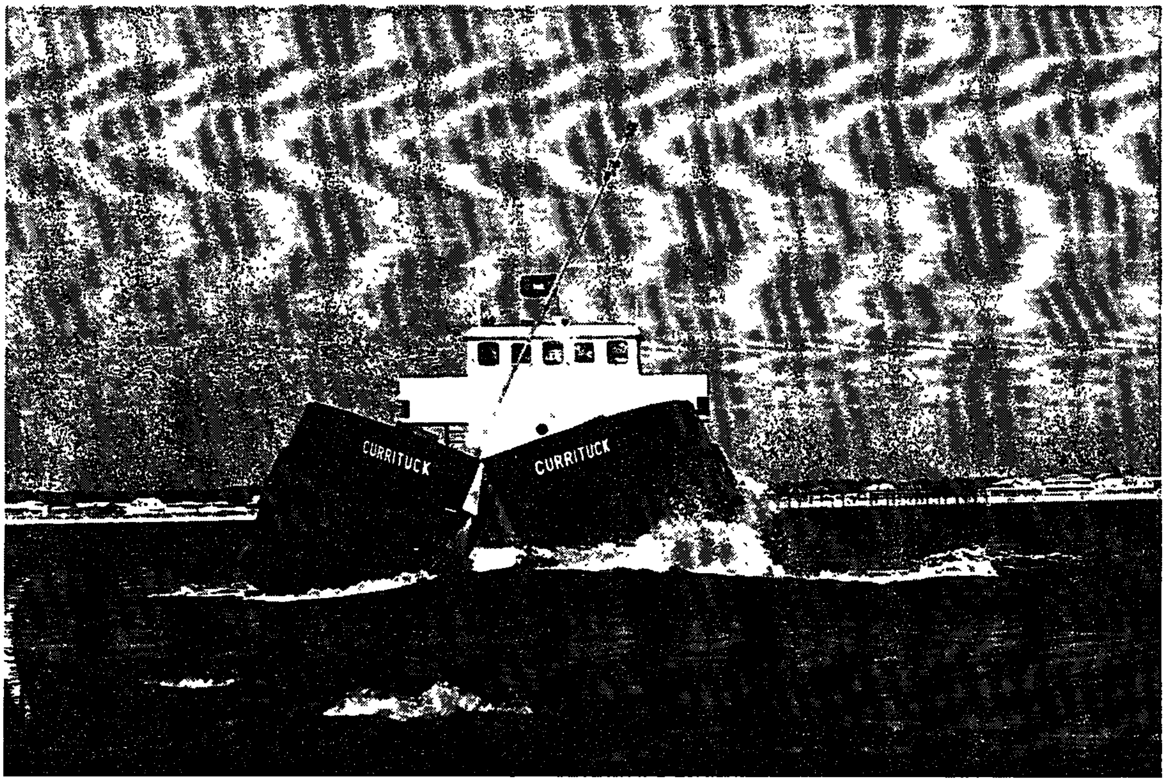
8. *Environmental Concerns.* Vessel wakes produce bank erosion in narrow channels. Dredging may harm sea turtles and other marine life, and disposal of dredged material may impact wetlands.

9. *Status of the Waterway.* The Savannah Harbor Comprehensive Study was presented to the public in 1981. The rediversion of the Cooper River at Charleston is projected to decrease future dredging requirements at Charleston Harbor. The Intracoastal Waterway from Jacksonville to Miami was extended to Cross Bank in the Florida Keys in 1939. The remaining portion of the waterway from Cross Bank to Key West has been placed in an inactive category. The Cross-Florida Barge Canal, connecting the St. John's River with the Gulf of Mexico, was halted by Presidential order in 1971. In 1978, following additional study, the Secretaries of Army and Agriculture forwarded draft legislation for restoration of the Oklawaha River and disposition of other lands and facilities outside the Oklawaha River area.

10. *Capability.* Dredging restrictions exist in Florida. There are several bridge hazards in Jacksonville and Savannah harbors. Dredging needs are not expected to vary significantly by 2003 from the current level of 29 million cubic yards annually.

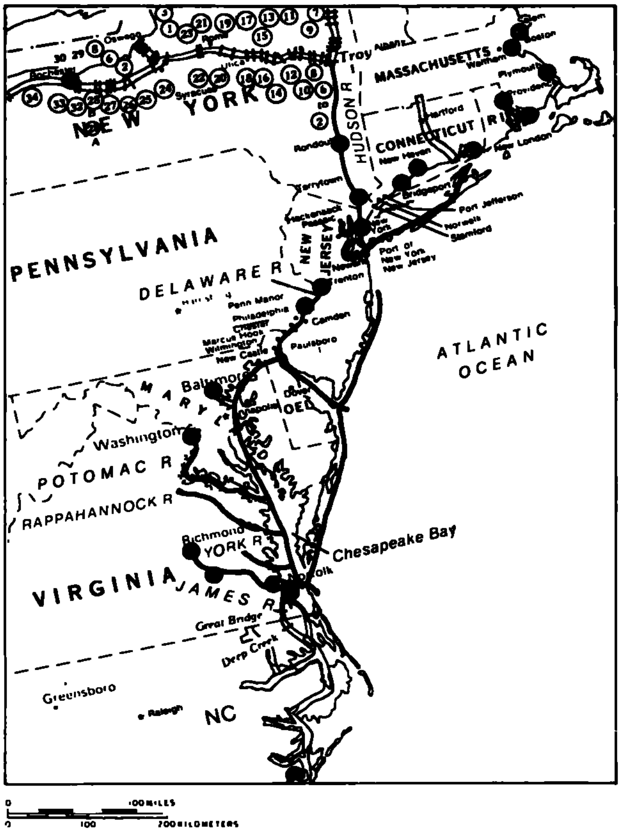


Sidecaster dredge "Schweizer" operating at Oregon Inlet, North Carolina.

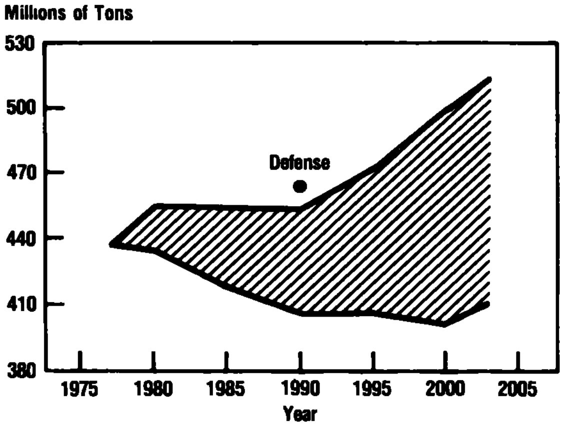


Hopper dredge "Currituck" operating in the South Atlantic.

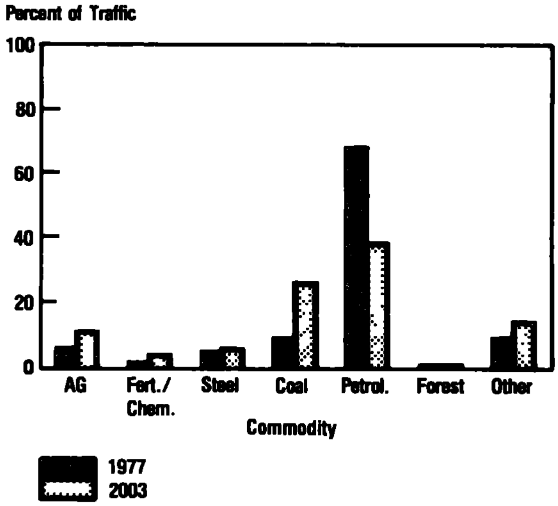
Figure D-28
REACH 14, MIDDLE ATLANTIC COAST
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note. Sites of locks and dams are shown by a name or number

REACH NUMBER 14
MIDDLE ATLANTIC COAST
(North Carolina-Virginia Border to and including Port of New York and the Hudson River to Waterford, New York)

1. *Physical Characteristics*. This reach includes Chesapeake Bay, the Delaware River, the Chesapeake and Delaware Canal, the Hudson River and the Atlantic coastal harbors, all for deep draft navigation with depths up to 45 feet. Mean tidal ranges are lowest in the Chesapeake Bay, around 2 feet, and increase up to around 6 feet at Philadelphia and 7 feet at New York. Unimproved and partially improved stretches of the Atlantic Intracoastal Waterway (AIWW) extend along the Virginia, Maryland, Delaware, New Jersey and Long Island coasts.

2. *Dredging*. The average annual dredging (1973 to 1977) was 16.7 million cubic yards at an average annual cost of $23.8 million or $1.43 per cubic yard.

3. *Lock Dimensions*.

Lock Name	Width (feet)	Length (feet)	Lift (feet)	Year Opened
AIWW				
Great Bridge	75	600	3	1932
Deep Creek	52	300	12	1940
Hudson				
Troy	44	493	17	1917

4. *Commercial Traffic*. Projections for total traffic range from 436.8 million tons in 1977 to a decrease under the low demand forecast to 409.8 million tons by 2003, or to an increase under the High Coal Export scenario to 514.7 million tons by 2003. Petroleum is expected to remain the major commodity through 2003, though tonnage is projected to decrease from 298.6 in 1977 to between 154.9 and 177.6 million tons by 2003. All other commodities are projected to increase somewhat with coal making the most significant increase, from 37.3 in 1977 to 120.3 million tons under the High Demand scenario and 165.7 million tons under the High Coal Export scenario, by 2003. During the assumed defense emergency tested for 1990, domestic traffic flows increased compared to peacetime conditions by over 63 million tons.

5. *Linkage With Other Reaches*.

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	14	Intra-Reach	54.9	23	Overseas and Pacific Canada	48.2
2	23	Overseas and Pacific Canada	26.2	14	Intra-Reach	37.1
3	15	North Atlantic	10.1	10	Gulf Coast-West	6.5
4	13	South Atlantic	1.2	22	Caribbean	4.6
5	22	Caribbean	0.9	4	L. Miss: B.R. to Gulf	2.1
6	16	Great Lakes-St. Lawrence, Canada	0.8	15	North Atlantic	0.5
TOTAL: (Thousands of Tons)			216,744.1			349,892.2

6. *Types of Vessels*. Drafts up to 45 feet are currently being accepted at Norfolk and parts of New York Harbor. Baltimore and Philadelphia have slightly shallower channels.

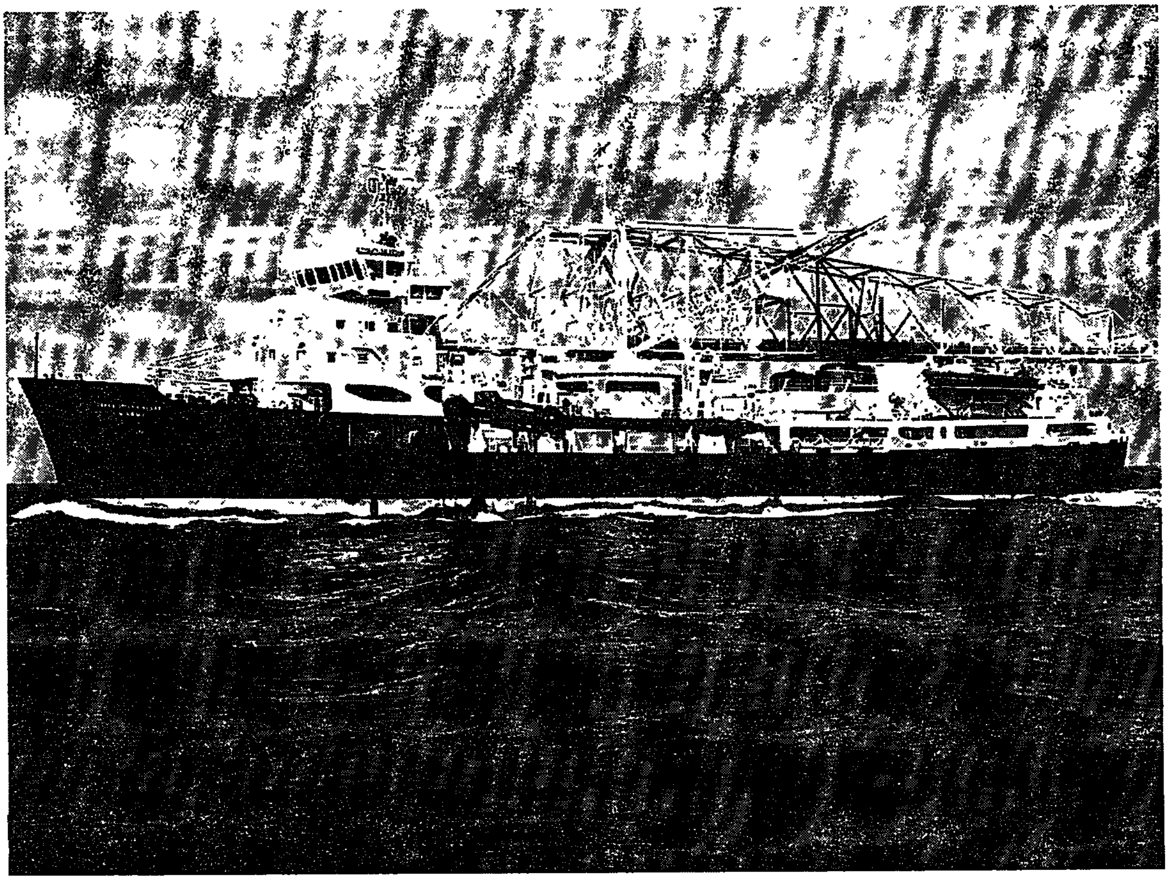
7. *Recreational and Other Water Uses*. Authorized uses within this reach include navigation, flood control, boating, and fish and wildlife enhancement as well as national defense. The recreation resources of the Chesapeake Bay portion of this region are used by a substantially greater number of people than those resources of the Delaware Bay due to pollution and other aesthetically undesirable factors in the latter water area. Both the Chesapeake and Delaware Bay portions of this region are areas of conflicting and competing water uses due to the high population density. Access to both areas by the public for recreation activities is a problem.

8. *Environmental Concerns*. Deepening of Baltimore Harbor could result in some localized disruption to fishery (shellfish) resources. Deepening of the Baltimore Harbor channels will raise the bottom salinity somewhat; however, hydraulic tests have indicated that such increases should not adversely affect the biota. Due to the presence of some pollutants concentrated in sediments, increased dredging activities may lead to environmental degradation. There are numerous dredged material disposal areas in Chesapeake and Delaware bays, some of which are near sensitive areas such as national seashores, extensive wetlands and estuaries, as well as wildlife refuges.

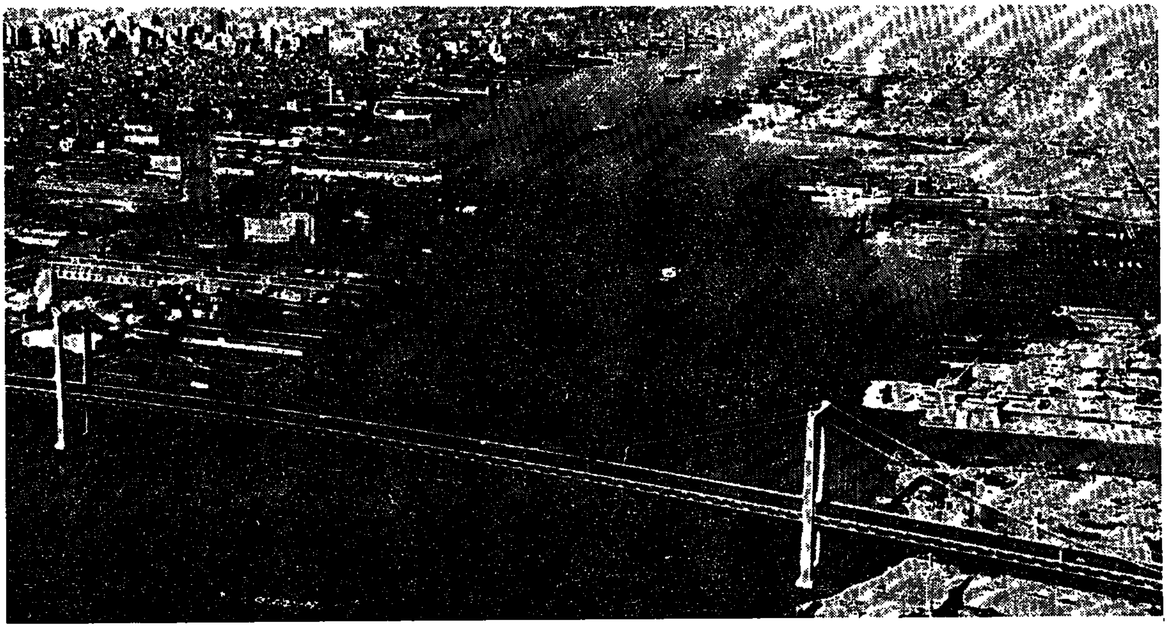
9. *Status of the Waterway*. Plans are underway for deepening Baltimore Harbor channels to 45 feet Environmental considerations on dredge material disposal have delayed implementation, but agreement has recently been reached. The State of Maryland has awarded contracts and approved funding for the construction of the disposal area. Dredging of the Chesapeake and Delaware Canal to a 35-foot navigable depth was recently completed.

10. *Capability*. Storage and loading facilities in the Baltimore and Hampton Road areas were stressed in handling large volumes of coal passing through those ports in 1980 and 1981. Deepening one or more coal ports in this established coal exporting reach would yield immediate returns by enhancing the U.S. competitive position in international coal trade. This reach is expected to move about 60 percent of the nation's coal exports by 2003, while ranking third in petroleum imports and grain exports. Planning and construction of terminal handling facilities are underway in the Mid Atlantic ports to significantly add to coal exporting capacity and ease the congestion experienced in 1980 and 1981. Naturally deep areas such as the Lower Delaware Bay could conceivably handle a fairly significant percentage of the anticipated growth in coal exports. Hazardous transport conditions are forecast for the Southern and Eastern branches of the Elizabeth River, Virginia, due to the large volume of coal projected to utilize these waterways. Improved vessel traffic monitoring and control may be warranted in this area. Bridges in the vicinity of the Elizabeth River, Virginia, as well as on the Delaware River near Palmyra, New Jersey and on Newark Bay near Bayonne, New Jersey, all pose notable safety problems for water transport and are possible sites for improved aids to navigation.

Dredging is expected to continue around 17 million cubic yards annually, but this could vary if harbor deepening actions are undertaken in one or more Mid Atlantic ports.

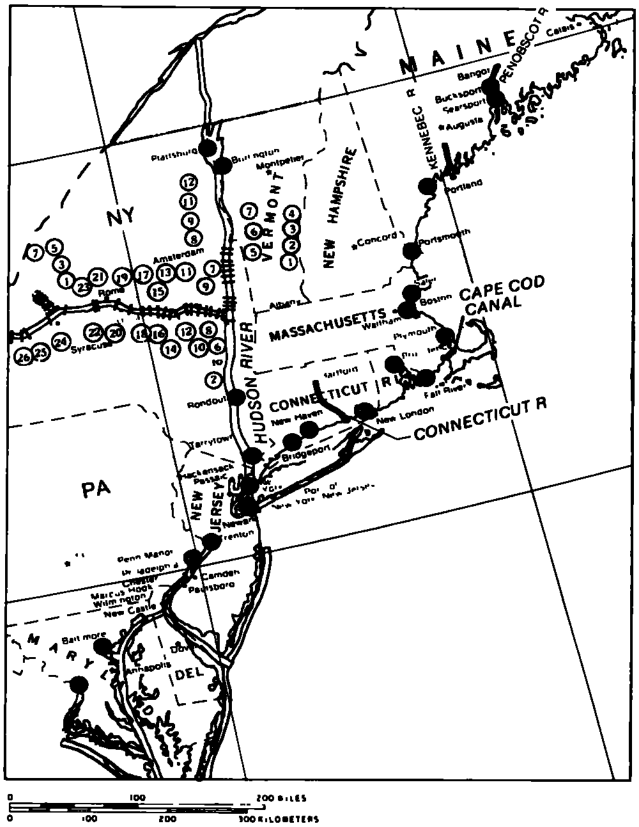


Dredge "McFarland", medium-sized hopper dredge, serving the East Coast.

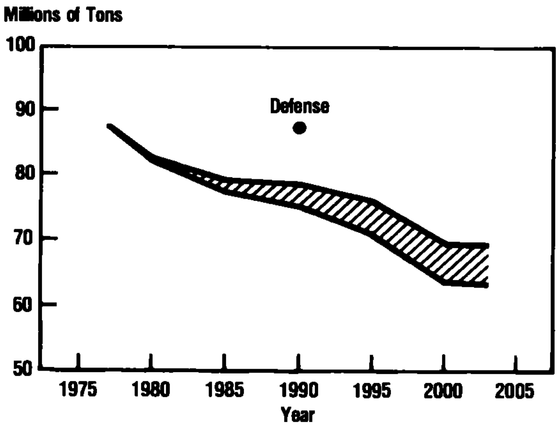


Philadelphia Harbor

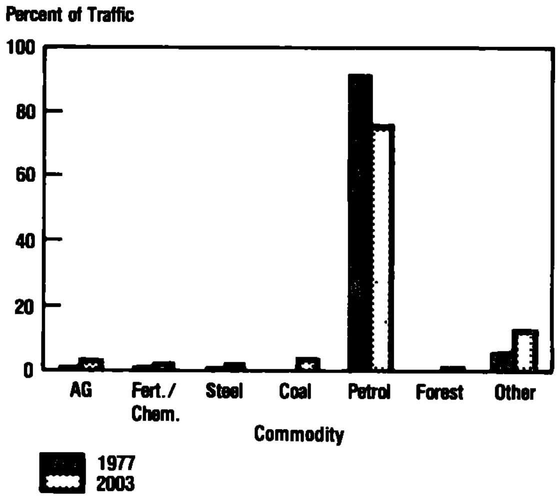
Figure D-29
REACH 15, NORTH ATLANTIC COAST
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note. Sites of locks and dams are shown by a name or number.

REACH NUMBER 15
NORTH ATLANTIC COAST
(Connecticut to Maine-New Brunswick Border

1. *Physical Characteristics*. Waterway depths vary from 15 feet authorized (about 12.5 feet controlling) for the Connecticut River to 32 feet (authorized and controlling) for the Cape Cod Canal. Principal harbor depths range from 28 feet to 45 feet. Relatively high tide ranges exist on the North Atlantic Coast. The mean tidal range at Boston, for example, is 9.5 feet.

2. *Dredging*. The average annual dredging (1973 to 1977) was 0.8 million cubic yards at an average annual cost of $2.5 million or $3.05 per cubic yard.

3. *Commercial Traffic*. Projections show a gradual decline in total traffic from 87.4 million tons to between 63 and 68.9 million tons in 2003. Petroleum, the major commodity, is expected to remain predominant in 2003, although tonnage is projected to decrease from 79.6 to between 46 7 and 51.6 million tons. All other commodities are expected to increase slightly, but the distribution of the total tonnage is expected to remain about the same as shown in the graph for this reach. The defense emergency assumptions tested under the Defense scenario resulted in a 10 percent traffic surge for the period ending in 1990.

4. *Linkage With Other Reaches*.

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	15	Intra-Reach	72.2	23	Overseas and Pacific Canada	40.3
2	14	Mid Atlantic	15.7	14	Mid Atlantic	25.9
3	23	Overseas and Pacific Canada	11.6	10	Gulf Coast-West	14.0
4	4	L. Miss: B.R. to Gulf	0.2	15	Intra-Reach	9.6
5	13	South Atlantic	0.1	22	Caribbean	6.0
6	10	Gulf Coast-West	0.1	4	L. Miss: B.R. to Gulf	3.6
TOTAL: (Thousands of Tons)			11,221.1			84,269.1

5. *Types of Vessels*. Oceangoing vessels (tankers) dominate the shipping in this reach with some shallow draft commerce on the Connecticut River.

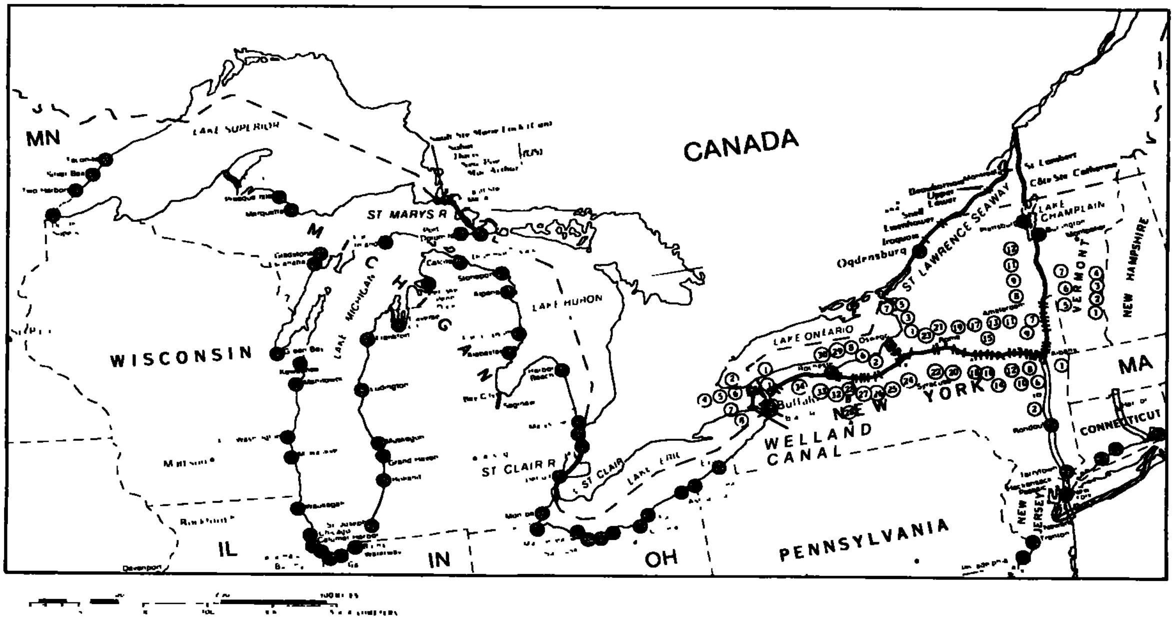
6. *Recreational and Other Uses*. In addition to the authorized uses of the North Atlantic water for navigation, flood control, water supply and general recreation and boating, other uses include hydropower and fish and wildlife. At present there appears to be no major conflict between recreational and commercial uses of waterways in this section of the country, although increasing recreational use of the Cape Cod Canal and adjacent waterways could eventually create problems. The North Atlantic Coast area is also the site of an active fishing industry as well as a region of moderate naval vessel traffic. The strategic New London Submarine Base is located on the Thames River in Connecticut.

7. *Environmental Concerns*. Many of the water quality problems in this area are related to the discharge of municipal and industrial effluents, not directly to navigation.

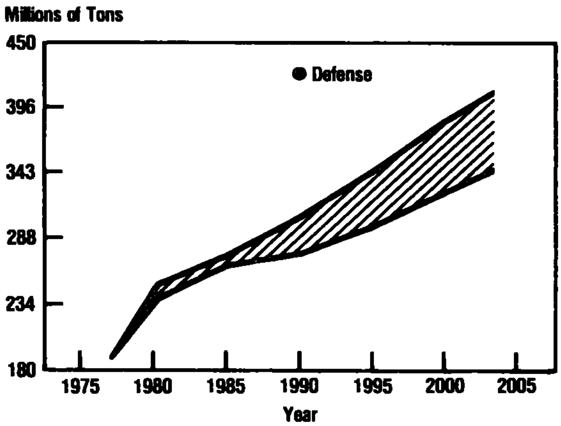
8. *Capability*. Navigation safety problems have been noted at two bridges at New Haven, Connecticut, two bridges near Boston Harbor, Massachusetts, and one located at Portland Harbor, Maine. Improved aids to navigation near these obstacles may warrant further study. Total dredging requirements are expected to remain about 0.8 million cubic yards annually.

Figure D-30

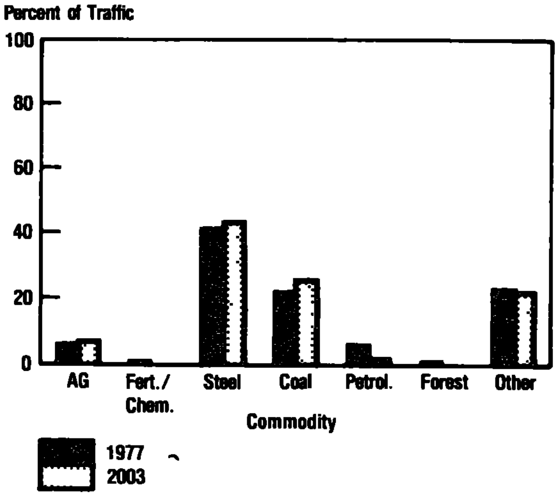
REACH 16, GREAT LAKES/ST. LAWRENCE SEAWAY/NY STATE WATERWAYS
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note Sites of locks and dams are shown by a name or number

REACH NUMBER 16
GREAT LAKES SYSTEM
(Lakes Superior, Huron, Michigan, Erie and Ontario, Connecting Channels, St. Lawrence Seaway and New York State Waterways)

1. *Physical Characteristics.* The Great Lakes-St. Lawrence Seaway System (linking directly with the Atlantic Ocean) has a controlling depth of 27 feet with authorized depths of 27 feet or slightly greater to provide safety. Some low traffic volume harbors and channels have depths slightly less than 27 feet. The Great Lakes-St. Lawrence Seaway System has a navigation connection with the Mississippi River system via Lake Michigan and the Illinois Waterway. The Great Lakes are closed to shipping for about 3 months each winter due to ice conditions, except for shipping intra- or inter-lake as conditions permit. The New York State Barge Canal links Lake Ontario with the Hudson River. The barge canal, owned and operated by the State of New York, has depths of 12 to 14 feet and a navigation season from early May to early December. It consists of the Erie, Oswego and Champlain Canals.

2. *Dredging.* The average annual dredging (1973 to 1977) was 8.9 million cubic yards at an average annual cost of $30.7 million or $3.44 per cubic yard.

3. *Lock Dimensions and Capacity.*

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
St. Lawrence River					
St. Lambert	80	766	16	1959	75–100
Cote Ste. Catherine	80	766	34	1959	75–100
Lower Beauharnois	80	766	40	1959	75–100
Upper Beauharnois	80	766	38	1959	75–100
Snell	80	766	49	1959	75–100
Eisenhower	80	766	42	1959	75–100
Iroquois	80	766	6	1959	75–100
Welland Canal					
L&D 1	80	766	46	1932	65–85
L&D 2	80	766	46	1932	65–85
L&D 3	80	766	46	1932	65–85
L&D 4	80	766	46	1932	131–171
L&D 5	80	766	46	1932	131–171
L&D 6	80	766	46	1932	131–171
L&D 7	80	766	46	1932	65–83
L&D 8	80	1148	3	1932	65–85
St. Mary's River					
New Poe	110	1200	22	1969	115–137
MacArthur	80	800	22	1943	
Davis	80	1350	22	1914	
Sabin	80	1350	22	1919	
Black Rock Channel, Buffalo, NY					
Black Rock Lock	68	625	5	1914	nc

nc = not calculated

4. *Commercial Traffic.* Projections show total tonnage to increase from about 190 million tons to between 345.2 and 411.3 million tons in 2003. Major commodities in 1977 will remain major ones is 2003 and include steel, industry raw materials (especially iron ore), coal, grains, and miscellaneous commodities. All commodity groups are projected to increase except petroleum which will decrease slightly. The Great Lakes, more than any other reach, will be affected by a defense emergency which requires substantial industrial mobilization. The Defense scenario test period ending in 1990 resulted in a net increase in all traffic of 119 million tons.

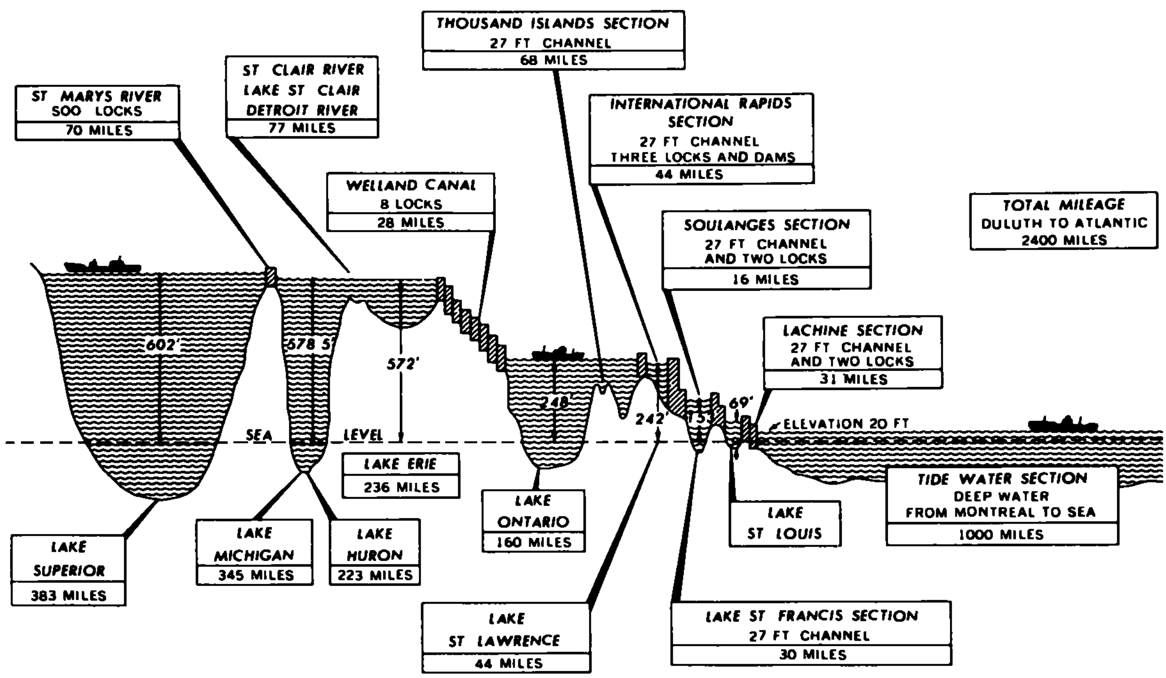
5. *Linkage With Other Reaches.*

	SHIPMENTS AND EXPORTS (U S.)			RECEIPTS AND IMPORTS (U.S.)		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent' of Total
1	16	Intra-Reach	70.8	16	Intra-Reach	74.1
2	24	Great Lakes and St. Lawrence Canada	18.3	24	Great Lakes and St. Lawrence Canada	17 4
3	23	Overseas and Pacific Canada	5.2	23	Overseas and Pacific Canada	4.0
4	5	Illinois Waterway	5.2	5	Illinois Waterway	2.7
5	2	Lower Upper Mississippi	0.1	14	Mid Atlantic	1.2
6	10	Gulf Coast-West	0.1	4	L. Miss: B.R. to Gulf	0.2
TOTAL: (Thousands of Tons)			143,354.3			136,915.1

6. *Types of Vessels.* Both oceangoing vessels and specially designed "lakers" operate on the Great Lakes, but are restricted to 26-foot maximum draft in the connecting channels, locks and most harbors.

7. *Recreational and Other Water Uses.* In addition to the authorized uses for navigation, general recreation, fish and wildlife, and hydropower, other present uses of this waterway system include water supply, water quality, and waste heat dissipation (cooling water) Highest density recreation in this section occurs along the south shores of the Great Lakes where public recreation areas often compete with private development for shoreline access. There are no apparent land use conflicts along the New York State Waterways or the St. Lawrence Seaway.

Figure D-31
PROFILE OF THE GREAT LAKES AND ST. LAWRENCE SEAWAY

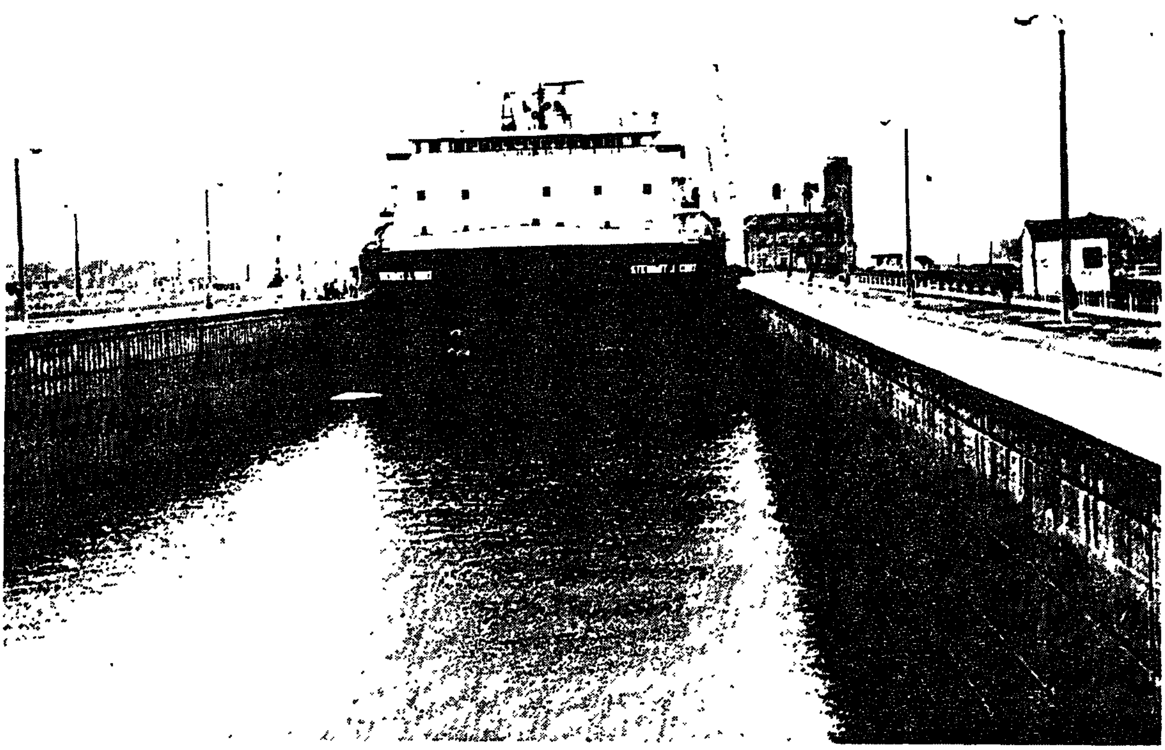


Source Great Lakes Basin Framework Study, Great Lakes Basin Commission, 1975

8. *Environmental Concerns*. Overall water quality has improved during the past decade. However, the presence of industrial pollution, especially taconite by-products, continue to pose water quality problems. Since Lake Erie is the shallowest water body in the region, it is the most susceptible to pollution and related water quality deterioration.

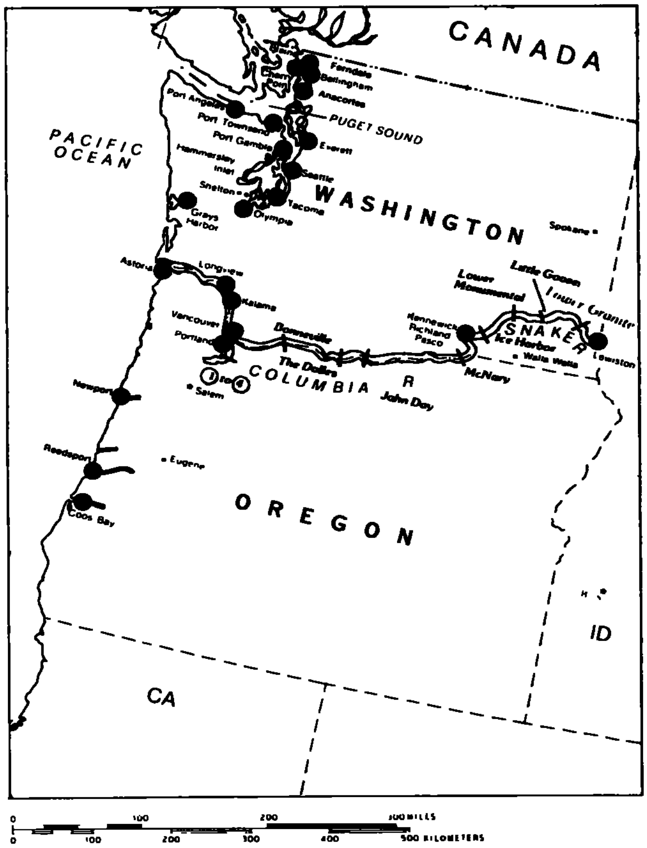
9. *Status of the Waterway*. The 27-foot depth system is basically complete. Land acquisition has been completed for expansion for the Welland Canal (Canadian).

10. *Capability*. The locks at the Welland Canal are projected to exceed their capacity of 65–85 million tons by 1990. The Sault Ste. Marie Locks capacity of 115–137 million tons is exceeded under the Defense scenario in 1990. Under the other scenarios this lock is congested by 2003. Both the St. Mary's River and the Seaway can present hazardous navigation conditions due to heavy traffic, adverse weather and other factors. Thirty-four bridges and one channel section present notable minor navigation safety problems, principally in major harbors. These areas include Buffalo, Cleveland, Toledo, Detroit, Chicago, and Duluth/Superior harbors. Total dredging on the Great Lakes-St. Lawrence Seaway and New York State Waterways is expected to continue to be around 8.9 million cubic yards annually. Dredging on the New York State Waterways is financed by the State of New York and averages 1.93 million cubic yards annually.

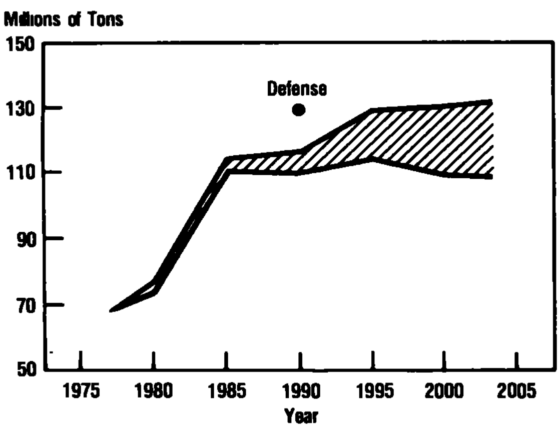


A 1,000 foot self-unloader transits the new Poe Lock at Sault Ste. Marie with only 2½ foot clearance on either side.

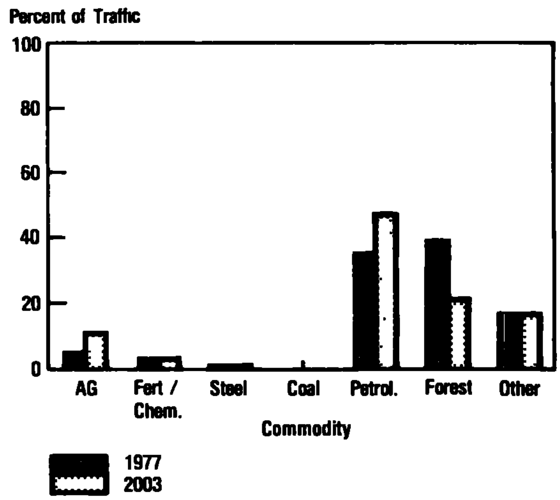
Figure D-32
REACH 17, WASHINGTON/OREGON COAST
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note Sites of locks and dams are shown by a name or number.

REACH NUMBER 17
WASHINGTON-OREGON COAST

1. *Physical Characteristics.* Most harbors in this reach have depths from 28 to greater than 40 feet. Naturally deep water in Puget Sound enhances navigation to Seattle, Tacoma and other ports in this area. Controlling widths range from 50 to over 200 feet. The mean tide range at Seattle is 7.6 feet.

2. *Dredging.* The average annual dredging (1973 to 1977) was 6.8 million cubic yards at an average annual cost of $5.7 million, or $0.85 per cubic yard.

3. *Lock Dimensions.*

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened
Lake Washington Ship Canal				
Hiram M. Chittenden Lock	80	760	26	1916
	28	123	26	

4. *Commercial Traffic.* Total traffic is projected to increase by 1985 to between 111 and 115 million tons from the 1977 level of 68.4 million tons, and then level off with a tendency toward increasing by 2003 to 132.9 million tons under the High Coal Export scenario, or decreasing to 109.4 million tons under the low use projection. Major commodities—petroleum and forest products—are expected to remain so. Petroleum, though, is projected to increase from 24 to between 48 3 and 57.6 million tons due to increased handling of Alaskan crude, while forest products are projected to decrease from 26.6 to 24.9 million tons. This reach experiences a surge in domestic traffic of 19 million tons under the conditions of the Defense scenario in 1990.

5. *Linkage With Other Reaches.*

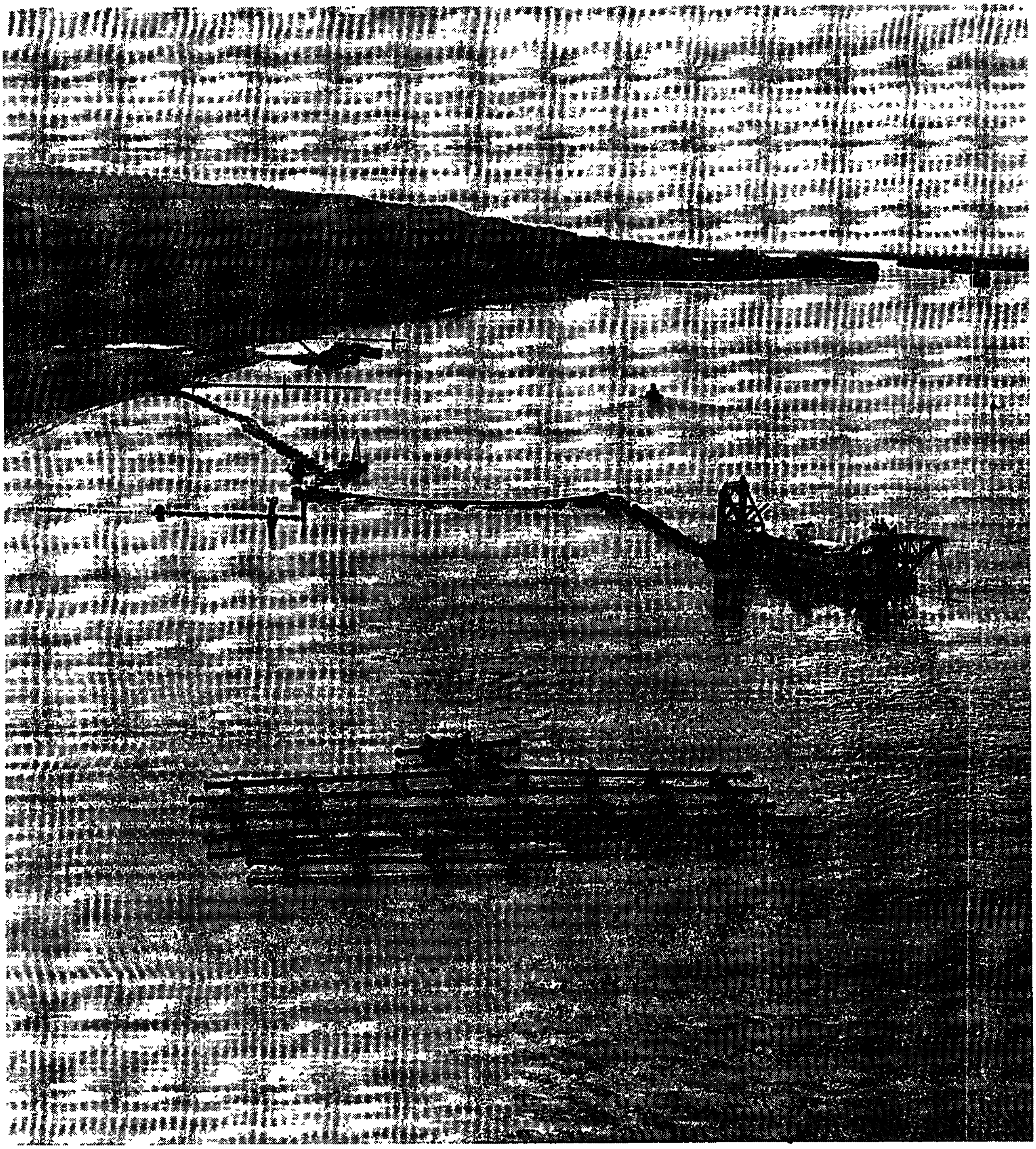
	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	23	Overseas and Pacific Canada	44.4	23	Overseas and Pacific Canada	44.5
2	17	Intra-Reach	42.5	17	Intra-Reach	38.4
3	19	California	6.6	20	Alaska	9.0
4	20	Alaska	4.6	19	California	7.0
5	18	Columbia-Snake	0.9	18	Columbia-Snake	0.7
6	21	Hawaii	0.7	21	Hawaii	0.4
TOTAL: (Thousands of Tons)			40,660.0			45,010.6

6. *Types of Vessels.* Oceangoing vessels are the major commercial transport vessels. Fishing craft and pleasure craft also share this reach extensively.

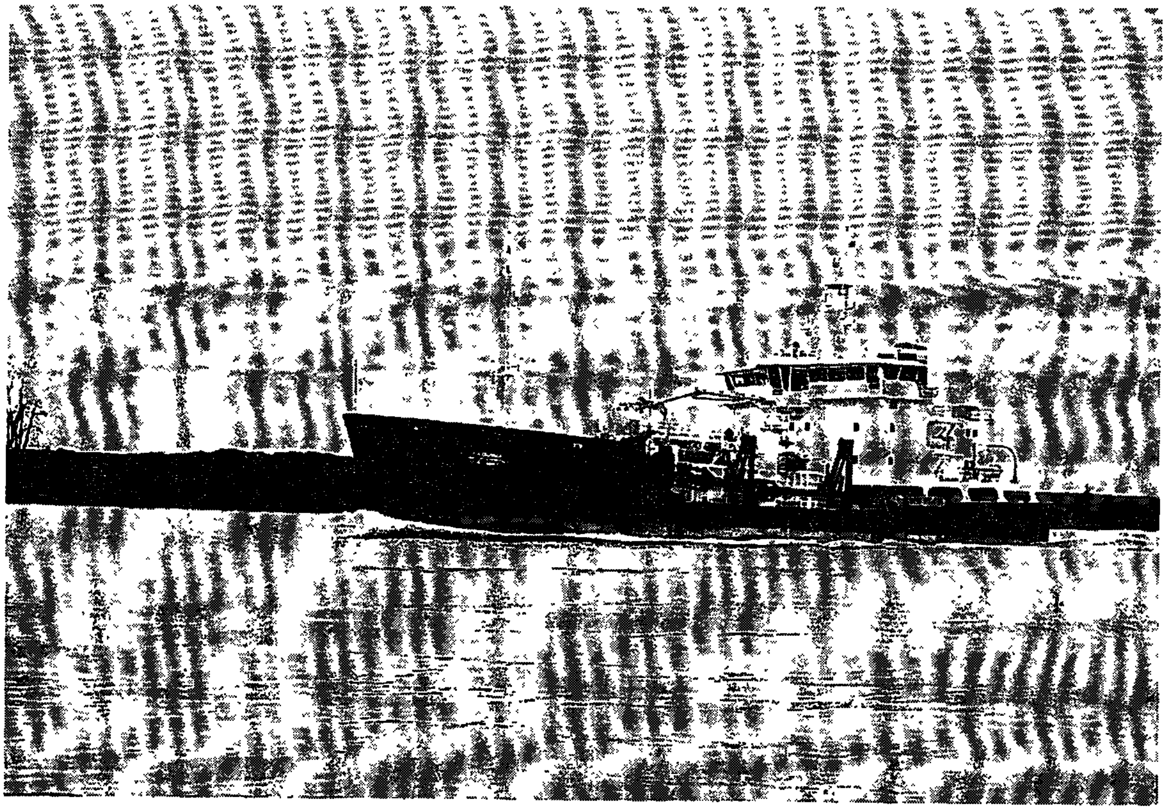
7. *Recreational and Other Water Uses.* Authorized as well as present uses of this section include navigation, general recreation and boating. High density recreation activities occur in the Puget Sound area and to a lesser extent along the coasts of Oregon and Washington. Recreation uses along Puget Sound are often in competition with private land development. Uses of the waterways for defense include passage and docking of "Trident" submarines.

8. *Environmental Concerns.* Environmentally sensitive factors in the management of the water resources of this area include anadromous fish and protected marine mammals. Along the Oregon and Washington coasts and in the Puget Sound area, high sedimentation can occur due to upstream logging practices. In 1980 substantial increases in channel sedimentation occurred due to the eruption of Mount St. Helens in Washington.

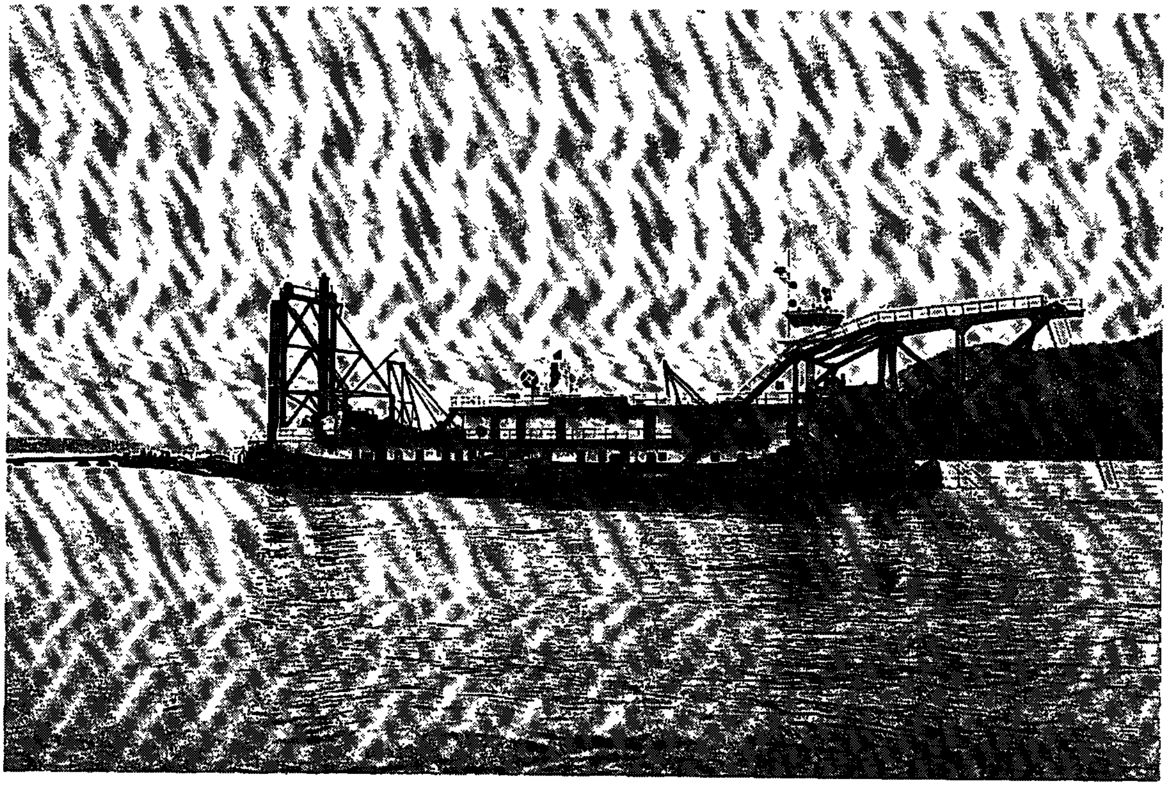
9. *Capability.* With the recent increase of Alaskan oil imports, there has been a corresponding increase in hazardous navigation conditions. Several bridges, including three in the Tacoma area and three in the Seattle region, are also notable navigation safety problems. Dredging in the reach should continue at about 6 to 7 million cubic yards annually.



Pipeline dredge "Oregon."

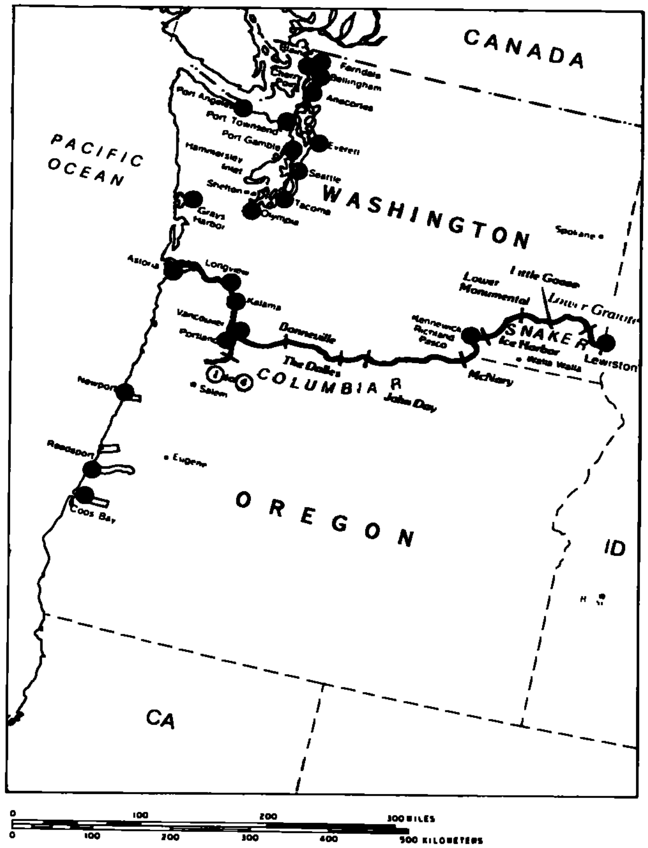


Small class hopper dredge "Yaquina" specially built for Oregon's shallow draft ports.

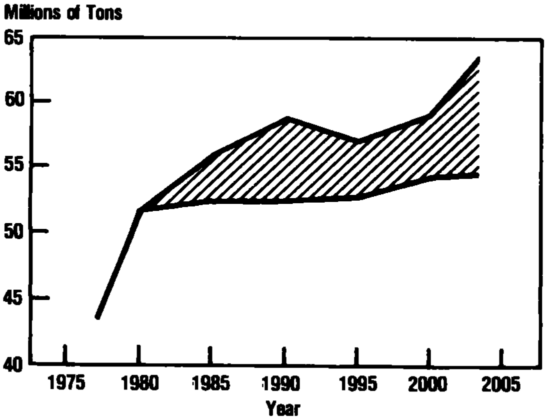


Port of Portland dredge "Oregon."

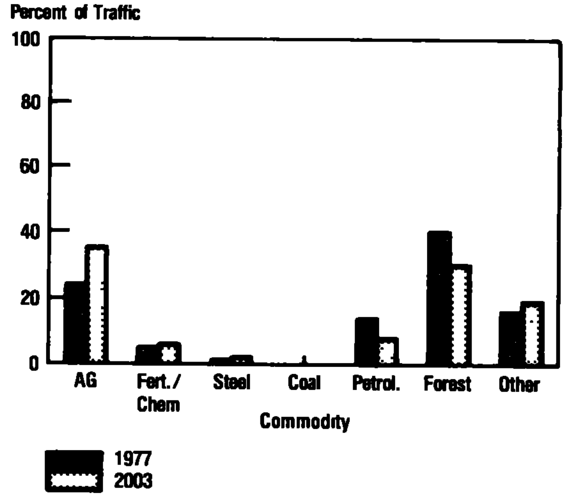
Figure D-33
REACH 18, COLUMBIA-SNAKE WATERWAY/WILLAMETTE RIVER
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, Misc. Sensitivity



Note: Sites of locks and dams are shown by a name or number

1. *Physical Characteristics*. Authorized and controlling widths for the Upper Columbia-Snake are 250 feet; for the Lower Columbia, they range from 250-600 feet; for the Willamette, they are 150 feet. Depths similarly vary from 14 feet in the Upper Columbia-Snake to a range of about 11 to 40 feet in the Lower Columbia, and 3 to 8 feet in the Willamette. Total length of the reach is 465 miles with a total lift of 700 feet accomplished by means of 8 Columbia-Snake locks. The mean tide ranges from 6.7 feet at Astoria to 1.8 feet at Portland.

2. *Dredging*. The average annual dredging (1973 to 1977) was 13.3 million cubic yards at an average annual cost of $5.6 million or $0.42 per cubic yard.

3. *Lock Dimensions and Capacity*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened	Capacity (10^6 tons)
Columbia-Snake Waterway					
Lower Granite	86	675	100	1975	32–33
Little Goose	86	675	98	1970	32–33
Lower Monumental	86	675	100	1969	32–33
Ice Harbor	86	675	100	1962	32–33
McNary	86	675	75	1953	32–33
John Day	86	675	105	1968	32–33
The Dalles	86	675	85	1957	12
Bonneville	76	500	59	1938	
Williamette River					
Lock No. 1	37	175	23	1873	nc
Lock No. 2	37	175	9	1873	nc
Lock No. 3	37	175	11	1873	nc
Lock No. 4	37	175	8	1873	nc
Guard Lock	40	210	—	1873	nc

nc = not calculated

4. *Commercial Traffic*. Total traffic is projected to increase from 43.5 million tons in 1977 to between 54.6 and 63.7 million tons in 2003. All commodities except petroleum are projected to experience a gain in tonnage, though the balance of commodities is projected to shift to agriculture in accounting for the greatest share of traffic, followed closely by forest products. Recent development of coal export facilities indicates a potential for coal exports.

5. *Linkage With Other Reaches*.

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach			Origin Reach		
Rank	No.	Description	Percent of Total	No.	Description	Percent of Total
1	18	Intra-Reach	61.3	18	Intra-Reach	72.2
2	23	Overseas and Pacific Canada	36.4	23	Overseas and Pacific Canada	13.5
3	19	California	0.7	19	California	11.0
4	21	Hawaii	0.6	17	Washington-Oregon	1.2
5	20	Alaska	0.1	19	California	1.0
6	13	South Atlantic	0.1	10	Gulf Coast-West	0.6
TOTAL: (Thousands of Tons)			35,227.8			29,893.5

6. *Types of Vessels.* Deep draft navigation for oceangoing vessels extends upstream to Portland. Average shallow draft tow size on the entire waterway is 3 barges, with a maximum tow size of 5 barges.

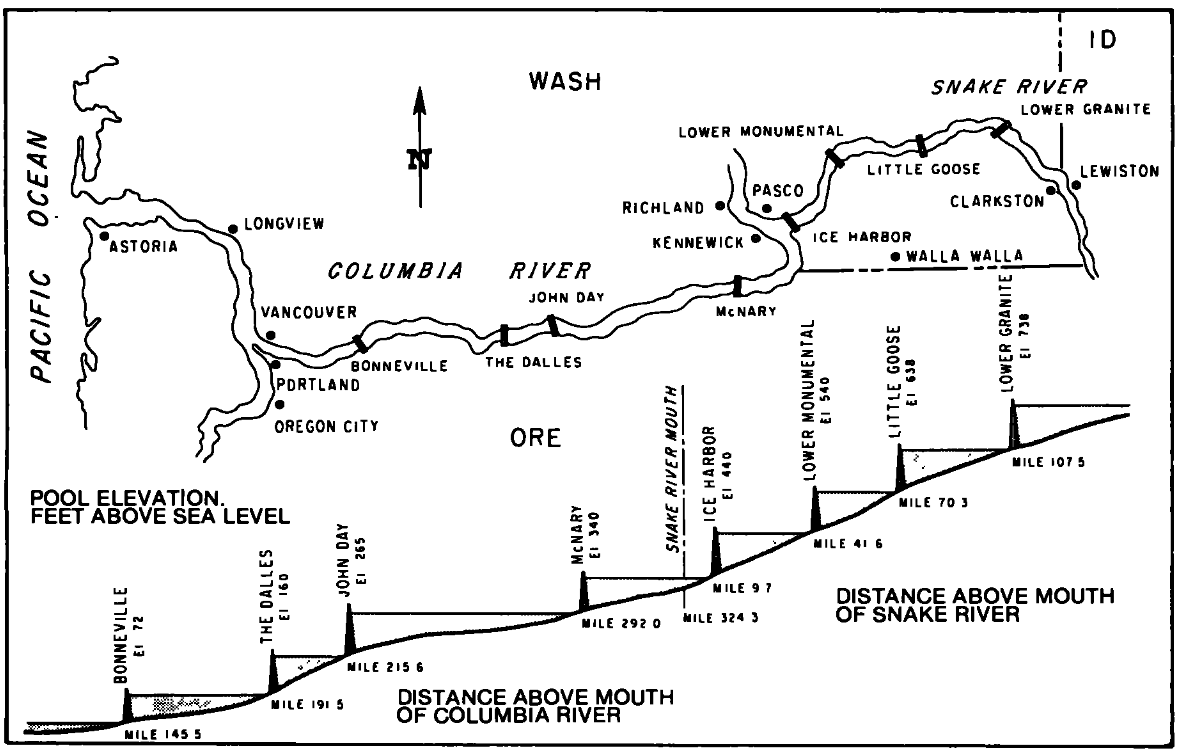
7. *Recreational and Other Water Uses.* Authorized and present uses of Columbia/Snake and Willamette waterways include navigation, flood control, general recreation, irrigation and hydropower. All three major river basins are areas of high recreational activity, especially during summer months. Time delays and conflicts often result during these same months at the Bonneville Lock due to the simultaneous demand for usage of the lock by both recreational and commercial craft.

8. *Environmental Concerns.* The operation of numerous hydropower facilities in the main stem of the Columbia River is more significant than navigation with respect to the environment. Hydropower facilities can result periodically in disruption to fishery and other aquatic habitats.

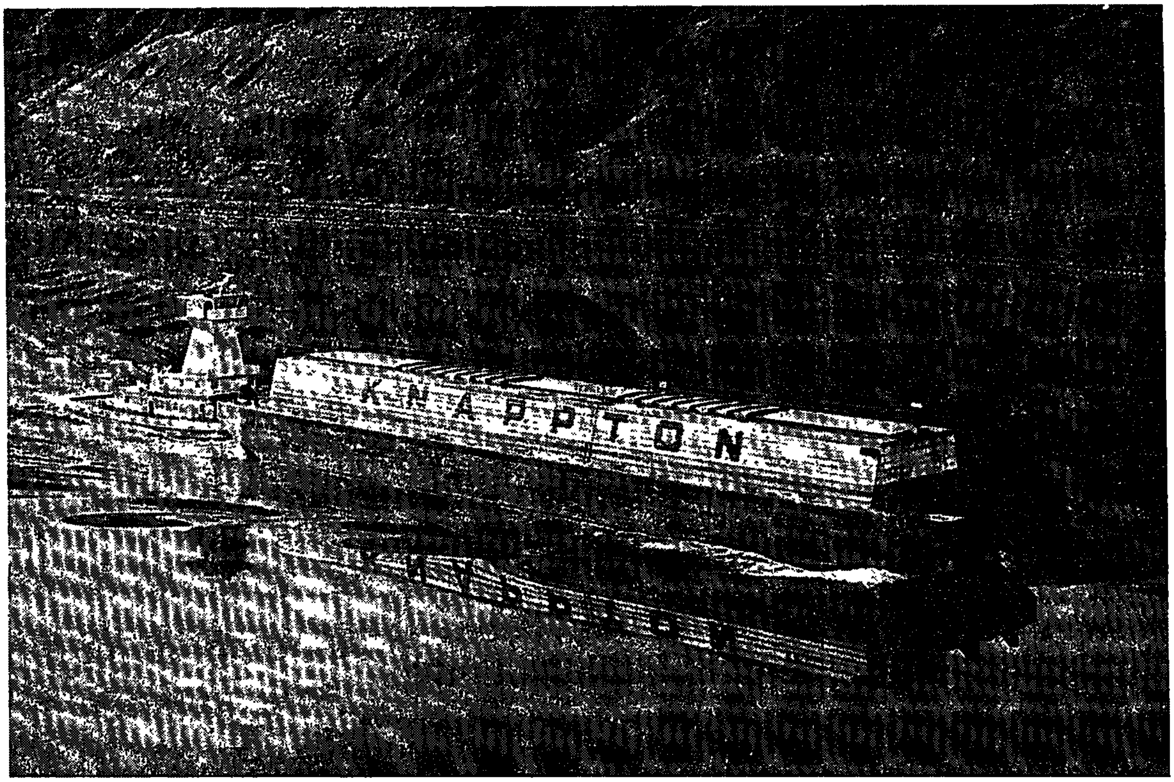
9. *Status of the Waterway.* A report recommending a larger navigation lock for Bonneville Dam was approved in 1978 by the Board of Engineers for Rivers and Harbors. The report recommends that the new lock be 86 feet wide and 675 feet long, the same dimensions as the seven other navigation locks upstream. Technical studies are being undertaken concerning various navigation operations around the hazardous Columbia River bar. Full navigation dimensions have been restored on the Lower Columbia in the aftermath of the eruption of Mount St. Helens.

10. *Capability.* The principal projected source of congestion is Bonneville Lock, opened in 1938, which is also a navigation hazard from the point of view of safety. Hazardous navigation conditions on the Snake River from mile 0 to 9 require tow breakup. A bridge at Vancouver, Washington was also identified as a navigation safety problem. In addition, if one scenario of this study is realized, it is expected that the Bonneville Lock capacity will be exceeded by 1990. Tidal fluctuations combined with high wave actions at the mouth of the Columbia River pose the risk of grounding for deep draft vessels. High traffic densities and the mixture of deep and shallow draft vessels present a safety problem on the Columbia River below Portland.

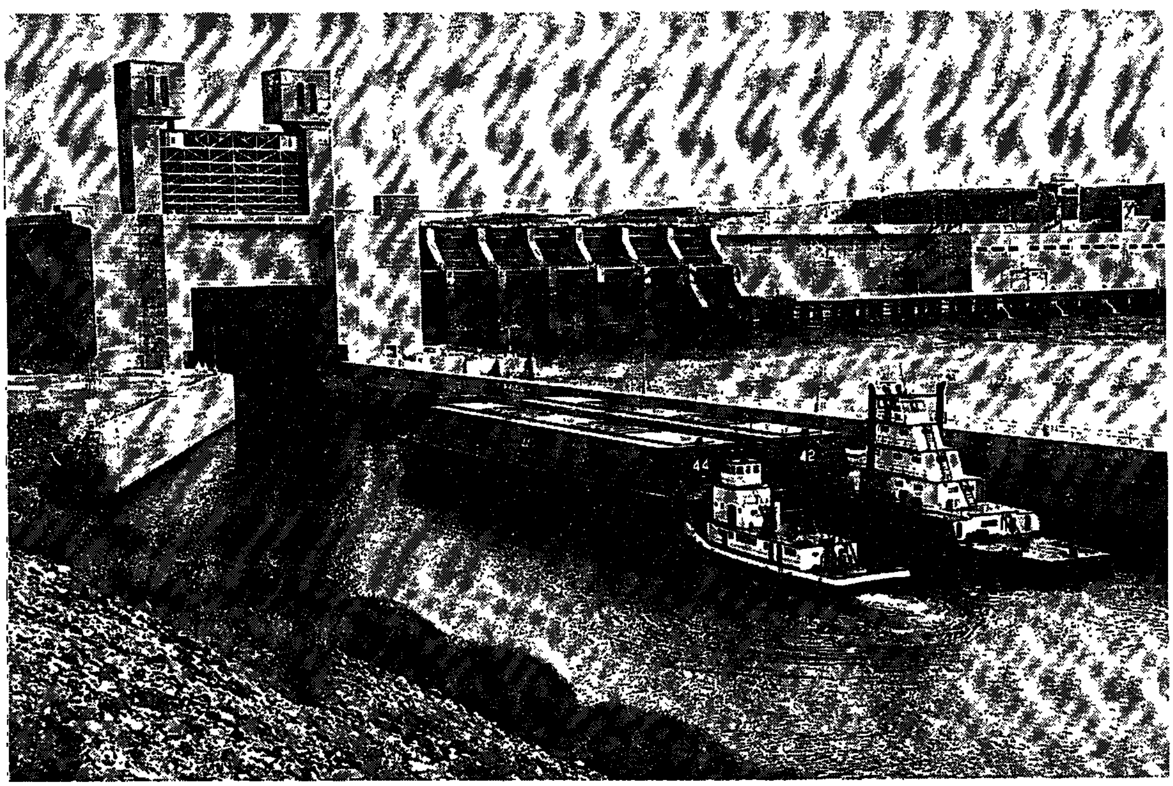
Figure D-34
PROFILE OF COLUMBIA-SNAKE WATERWAY NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

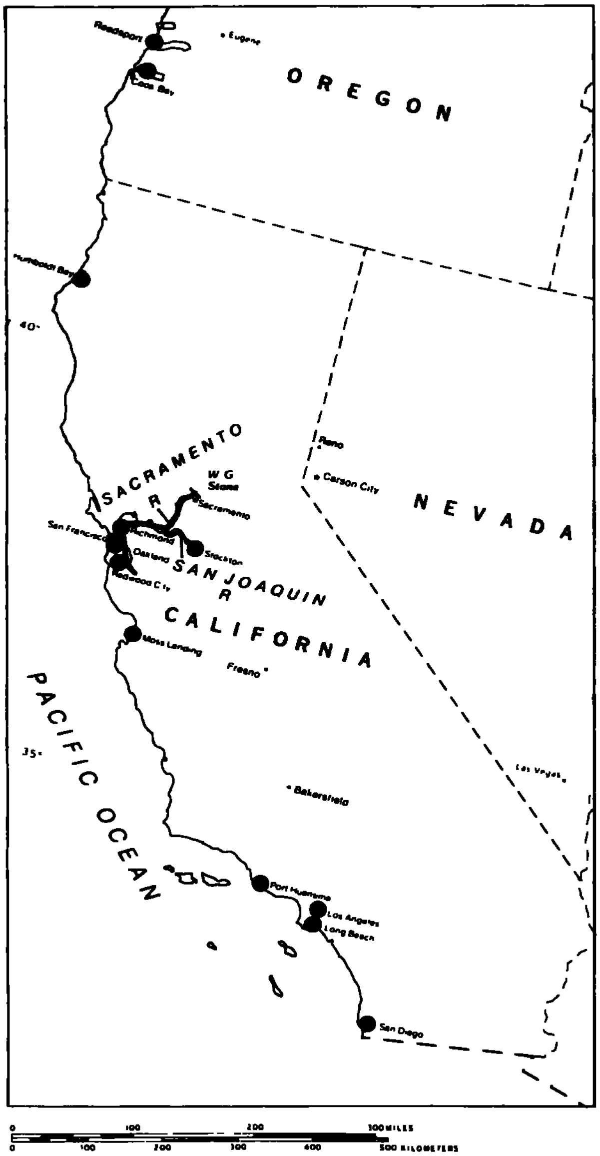


Barges using the Columbia-Snake Waterway are specially designed for the unique locks found on this system.

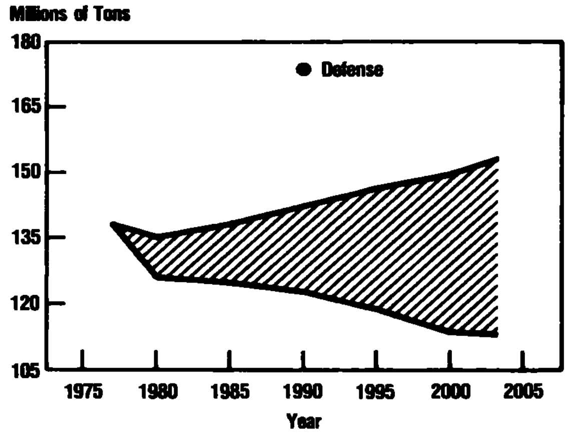


Ice Harbor Lock and Dam on the Snake River.

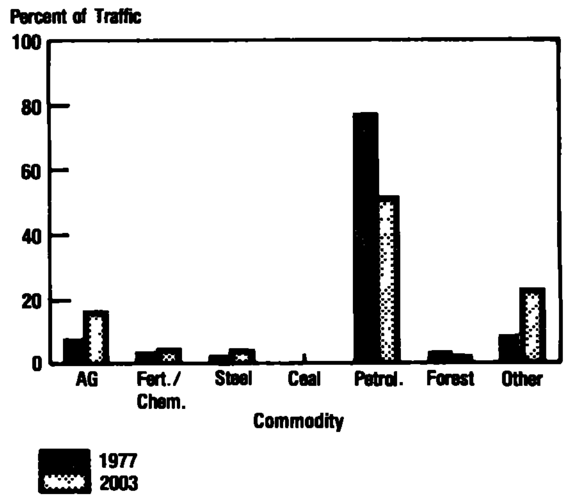
Figure D-35
REACH 19, CALIFORNIA COAST
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



Note Sites of locks and dams are shown by a name or number

REACH NUMBER 19
CALIFORNIA COAST
(California-Oregon Border to Mexican Border)

1. *Physical Characteristics*. The majority of ports in this reach have depths greater than 28 feet; the deepest are San Francisco and Los Angeles at 45 feet and Long Beach at 55 feet. The Sacramento and San Joaquin Rivers have depths between 28 and 34 feet. Controlling widths vary throughout the reach, the largest width ranging from 300–5,000 feet occurring in the San Francisco Bay area. The mean tide range on the coast of California is about 4 feet.

2. *Dredging*. The average annual dredging (1973 to 1977) was 16.53 million cubic yards at an average annual cost of $23.5 million or $1.42 per cubic yard.

3. *Lock Dimensions*.

Lock Name or Number	Width (feet)	Length (feet)	Lift (feet)	Year Opened
Sacramento River				
W.G. Stone Lock	86	600	4	1961

4. *Commercial Traffic*. Future total traffic is projected to increase modestly from 138.3 million tons in 1977 to 153.4 million tons under the highest forecast, or decrease to 113.3 million tons under the lowest forecast, by 2003. Petroleum will remain the dominant commodity, though tonnage is projected to decrease from 106.5 to between 42.3 and 72.6 million tons. All other commodities are expected to increase slightly except forest products. The potential for increased coal movements has already begun to be realized. At the ports of Los Angeles/Long Beach, 1981 export coal traffic was 3.5 million tons, up from a previous high of .7 million tons in 1980. The Defense scenario assumptions showed a 36 million ton surge if a defense emergency ended in 1990.

5. *Linkage With Other Reaches*.

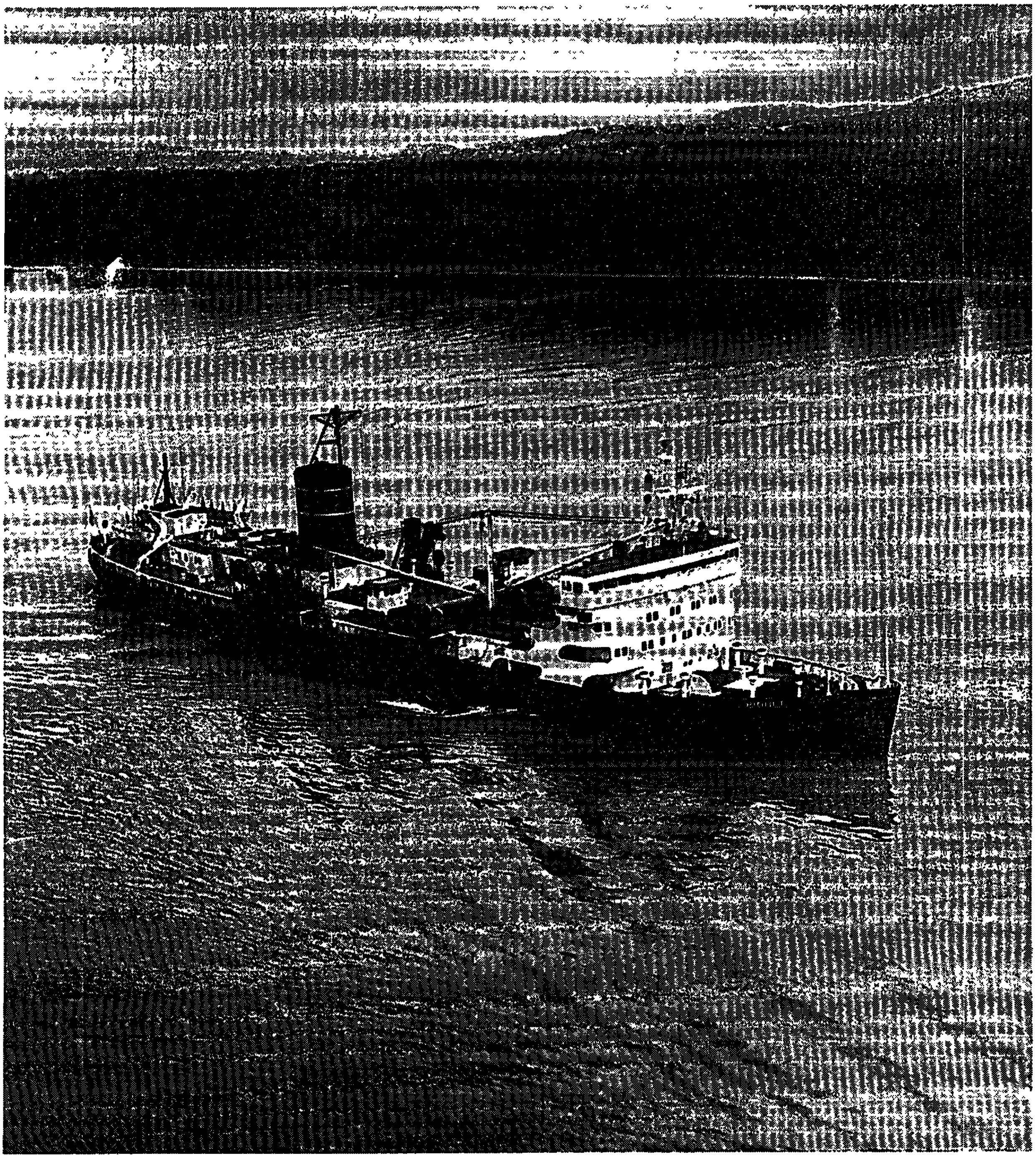
	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	19	Intra-Reach	53.0	23	Overseas and Pacific Canada	54.4
2	23	Overseas and Pacific Canada	27.0	19	Intra-Reach	28.4
3	18	Columbia-Snake	5.6	20	Alaska	10.5
4	21	Hawaii	5.5	17	Washington-Oregon	2.4
5	17	Washington-Oregon	5.3	21	Hawaii	2.3
6	20	Alaska	1.4	4	L. Miss: B.R. to Gulf	0.3
TOTAL: (Thousands of Tons)			59,217.9			110,636.2

6. *Types of Vessels*. Deep draft oceangoing vessels as well as towboats with barges operate in various sections of the Sacramento and San Joaquin Rivers. Large oceangoing vessels call at ports on San Francisco Bay, including Oakland, Richmond and San Francisco. The ports of Los Angeles and Long Beach have excellent deepwater facilities. Fishing vessels as well as pleasure craft all share this reach.

7. *Recreational and Other Uses*. Improvements in the reach were authorized for navigation, flood protection, recreational boating and national defense. Present uses include all these in addition to general recreation, fish and wildlife, aesthetic and environmental purposes. The number and diversity of users have led to congestion on the waterway and competition for space for landside facilities.

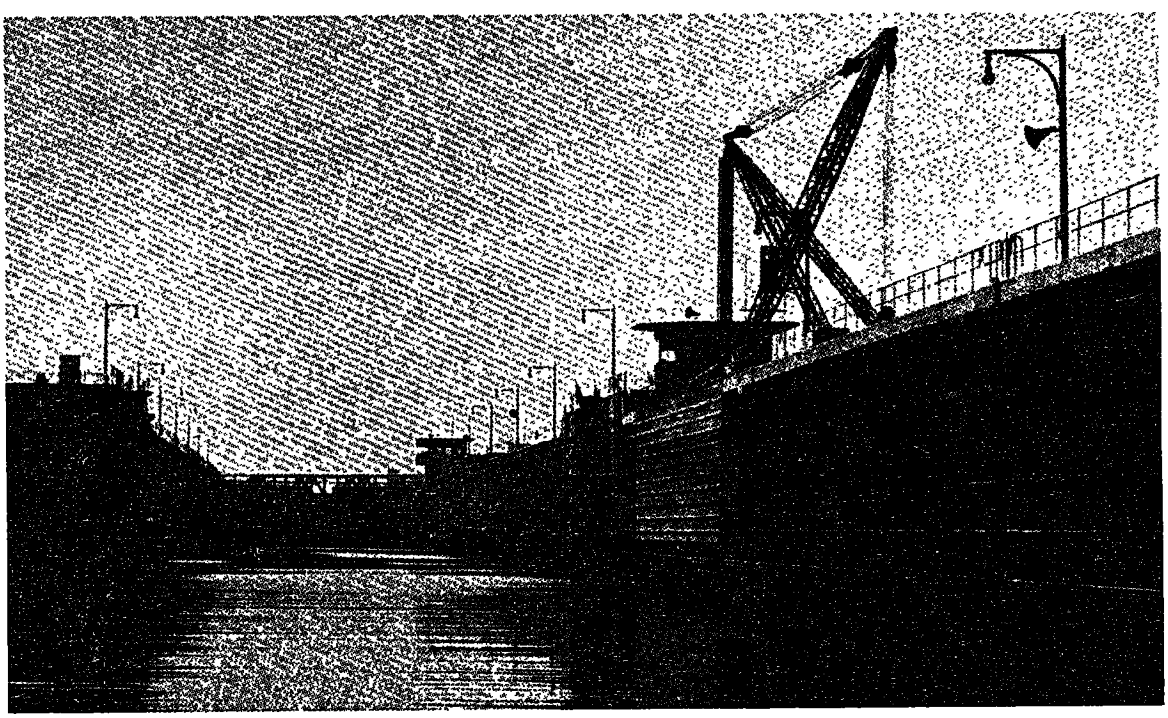
8. *Environmental Concerns*. Potential problems with saltwater intrusion, particularly in San Francisco Bay, require that any plans for alterations to the waterways consider this issue. The propensity toward earthquakes within this reach might also be taken into consideration when navigation improvements are planned.

9. *Capability*. Both San Francisco and the Los Angeles-Long Beach areas have high densities of waterborne traffic which contribute to potentially hazardous navigation. The Dumbarton Point bridges in the San Francisco Bay area are minor navigation safety problems. Dredging is expected to continue to average about 16 million cubic yards annually.



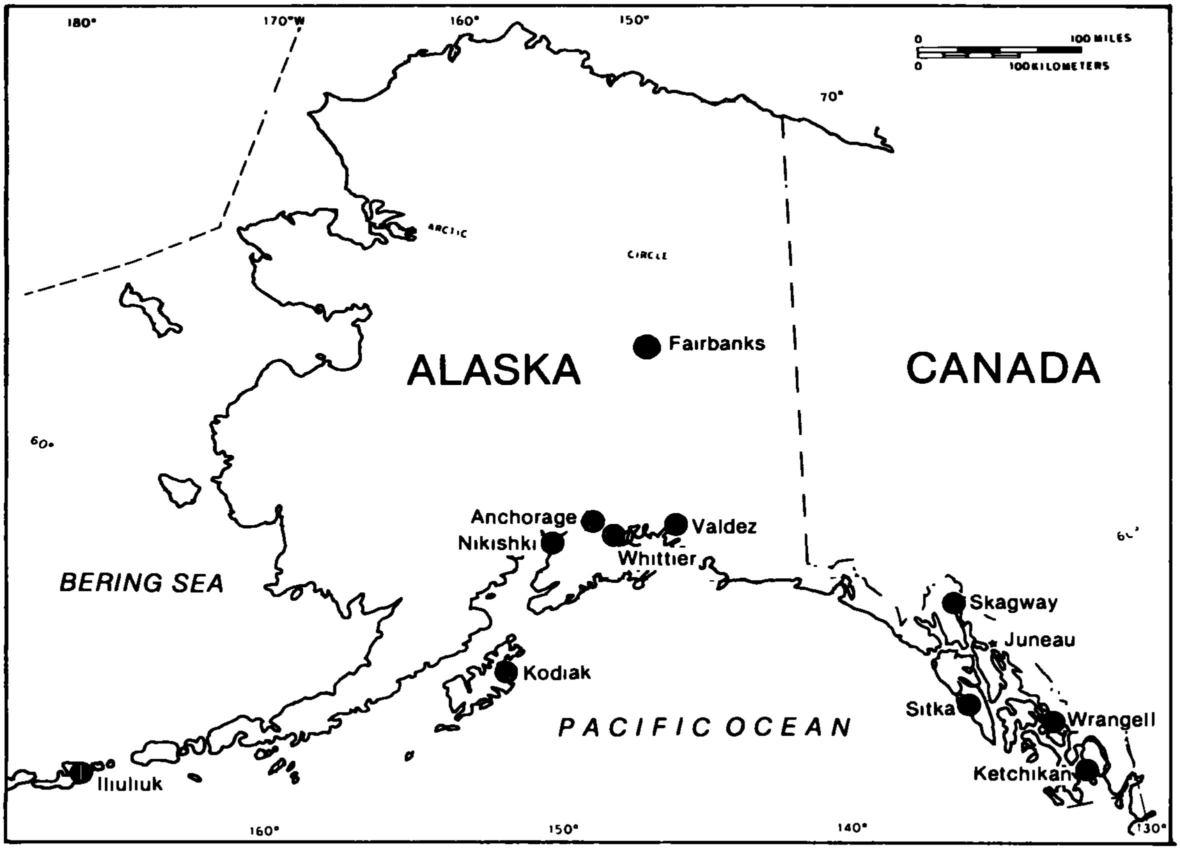
Corps hopper dredge "Biddle" operates on the West Coast.

Containerization has become increasingly important in the ocean trade, as seen at this terminal at Oakland Harbor, California.

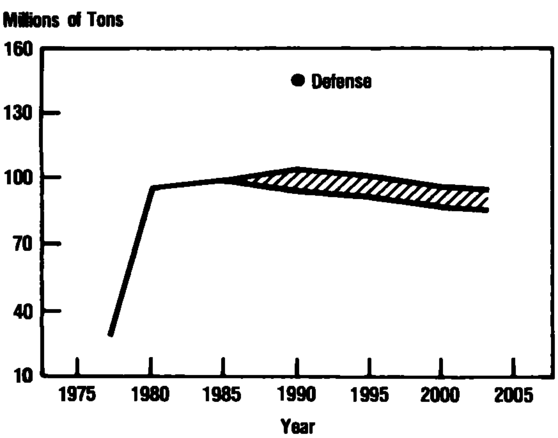


William G. Stone Lock - the only navigation lock in California and the connecting link between deep draft navigation at the Port of Sacramento and shallow draft navigation in the Sacramento River.

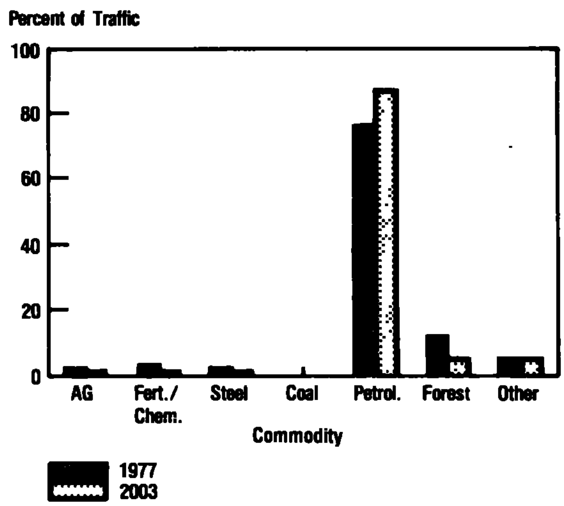
Figure D-36
REACH 20, ALASKA
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



REACH NUMBER 20
ALASKA

1. *Physical Characteristics*. The majority of Alaskan ports have depths greater than 35 feet, and four (Ketchikan, Valdez, Whittier and Nikishki) have depths greater than 40 feet. The mean tide ranges are about 13 feet, though Juneau observes some tidal ranges in excess of 20 feet. Rugged coastlines, fog, and ice are common features within this reach.

2. *Dredging*. The average annual dredging (1973 to 1977) was .09 million cubic yards at an average annual cost of $0.297 million, or $3.18 per cubic yard.

3. *Commercial Traffic*. Projected traffic indicates an increase from 28.8 million tons in 1977 to a peak between 99.3 and 104.7 million tons between 1985 and 1990, then a slight decline to between 86.2 and 95.4 million tons by 2003. The outstanding commodity between 1977 and 2003 is petroleum, which is projected to increase significantly from 21.9 million tons in 1977 to between 75.1 and 84.6 million tons by 2003. All other commodities except fertilizer/chemicals and coal show a modest increase. During the hypothesized defense emergency ending in 1990, the Alaska reach was forecast to carry an additional 52 million tons.

4. *Linkages With Other Reaches*.

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	19	California	47.4	20	Intra-Reach	43.9
2	23	Overseas and Pacific Canada	20.5	17	Washington-Oregon	24.1
3	17	Washington-Oregon	16.5	23	Overseas and Pacific Canada	21.0
4	20	Intra-Reach	13.8	19	California	10.6
5	18	Columbia-Snake	1.2	18	Columbia-Snake	0.4
6	4	L. Miss: B.R. to Gulf	0.4	—	—	0
TOTAL: (Thousands of Tons)			24,509.3			7,695.4

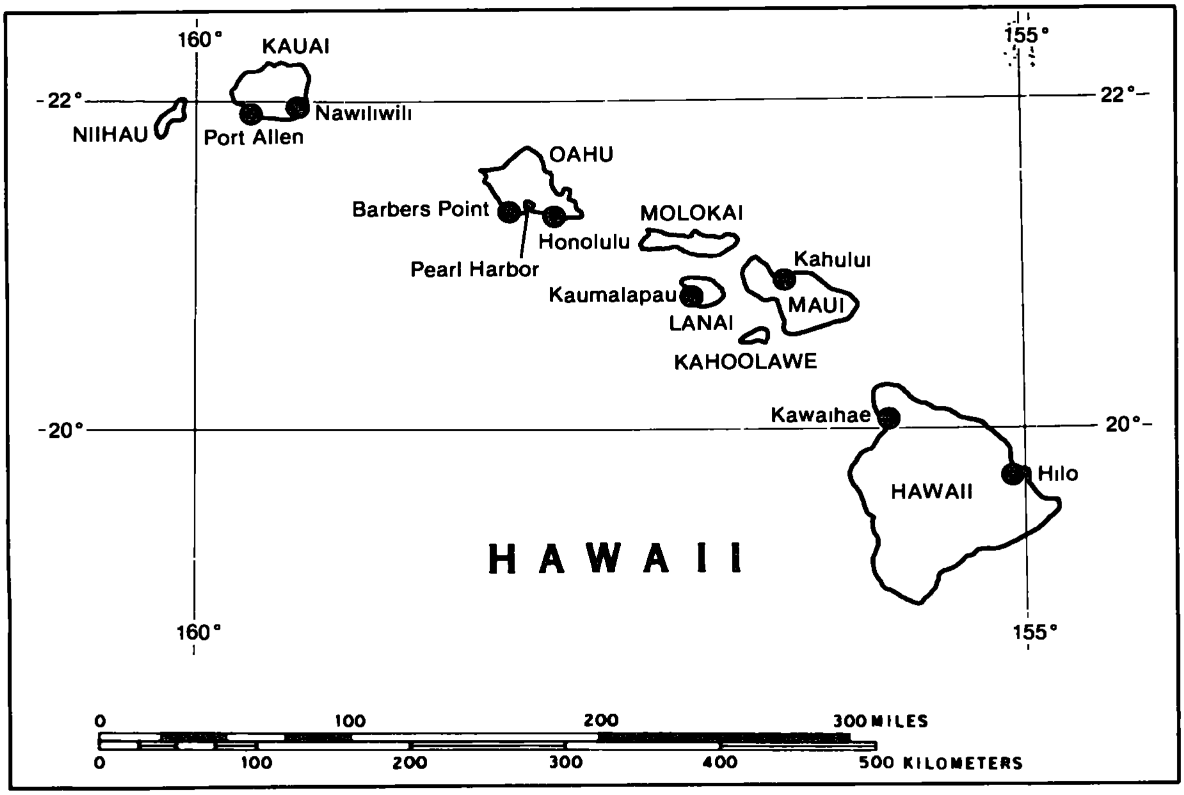
5. *Types of Vessels*. Oceangoing vessels including tankers, commercial fishing craft, passenger ferries and pleasure boats are among the vessels that utilize this reach.

6. *Recreational and Other Water Uses*. Improvements in the reach were authorized for navigation, recreational boating, national defense and other purposes. All these functions are presently utilized.

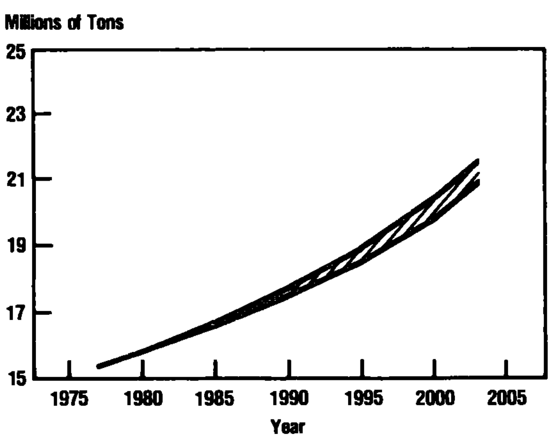
7. *Environmental Concerns*. The potential for cargo spills, including petroleum spills, is high because of frequently hazardous navigation conditions caused by shoals, islands, rough weather and other features associated with the rugged shorelines within the reach.

8. *Capability*. The South Alaska coast with its ice and fog conditions and large volumes of petroleum traffic, is a particularly hazardous stretch of channel. Dredging in this reach is expected to continue around the average annual volume of 0.09 million cubic yards.

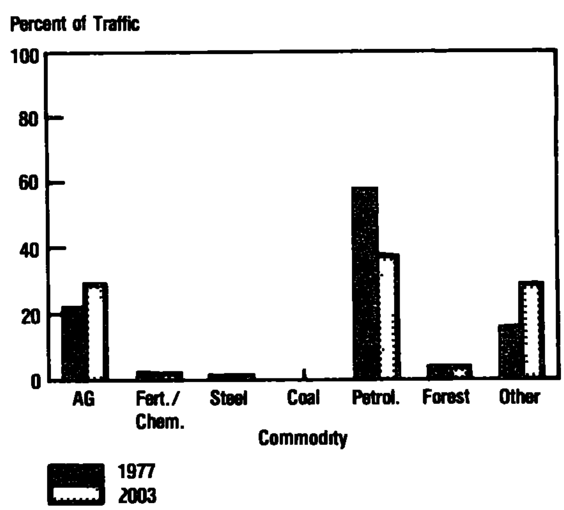
Figure D-37
REACH 21, HAWAII AND PACIFIC TERRITORIES
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



REACH NUMBER 21
HAWAII

1. *Physical Characteristics*. The majority of Hawaii's ports have depths greater than 28 feet. Over half have depths greater than 35 feet. Nawiliwili, on Kauai, is the deepest at greater than 40 feet. The mean tidal ranges are from 1 to 2 feet.

2. *Dredging*. The average annual dredging (1973 to 1977) was 0.15 million cubic yards at an average annual cost of $0.2 million or $1.36 per cubic yard.

3. *Commercial Traffic*. Future traffic is projected to increase from 15.3 million tons in 1977 to between 20.9 and 21.5 million tons in 2003. Petroleum is projected to remain the major commodity, though tonnage could decline from 8.7 to 7.9 million tons between 1977 and 2003. All other commodities are forecast to increase in tonnage. If power plants on Oahu convert to coal-fired generators, coal consumption could increase significantly over the study time period.

4. *Linkages With Other Reaches*.

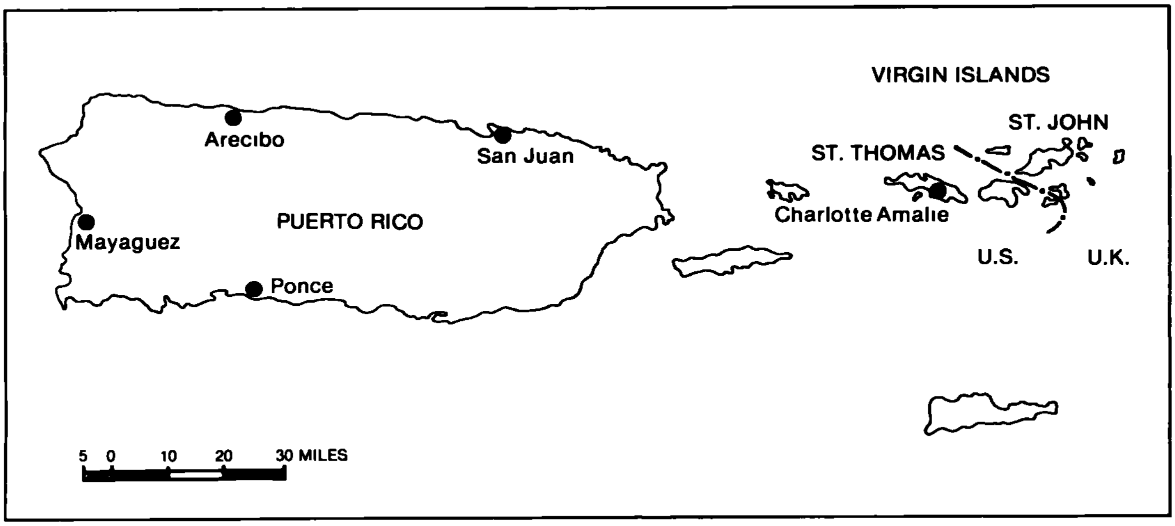
	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	19	California	46.5	23	Overseas and Pacific Canada	48.8
2	21	Inter-Reach	43.6	19	California	26.7
3	17	Washington-Oregon	3.0	21	Intra-Reach	19.9
4	5	Overseas and Pacific Canada	2.6	17	Washington-Oregon	2.3
5	4	L. Miss: B.R.	2.5	18	Columbia-Snake	1.8
6	18	Columbia-Snake	1.4	14	Mid Atlantic	0.5
TOTAL: (Thousands of Tons)			5,556.3			12,153.8

5. *Types of Vessels*. Deep draft oceangoing vessels and pleasure craft are principal users of this reach.

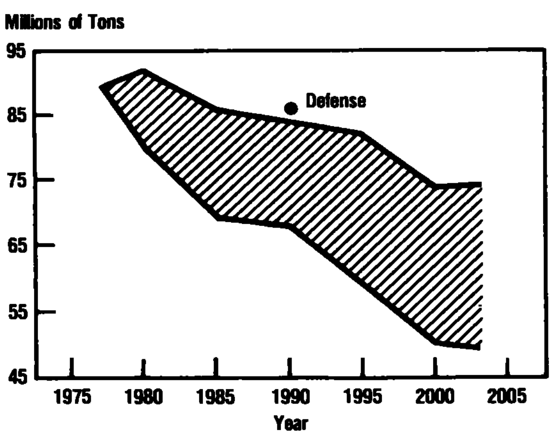
6. *Recreational and Other Water Uses*. Improvements in the reach were authorized for navigation, the principal present use. Military vessels and recreation craft are concentrated in this area, particularly around Oahu.

7. *Capability*. No significant congestion problems due to maritime traffic are expected in the study time frame. Dredging is anticipated to remain at about the same level throughout the period.

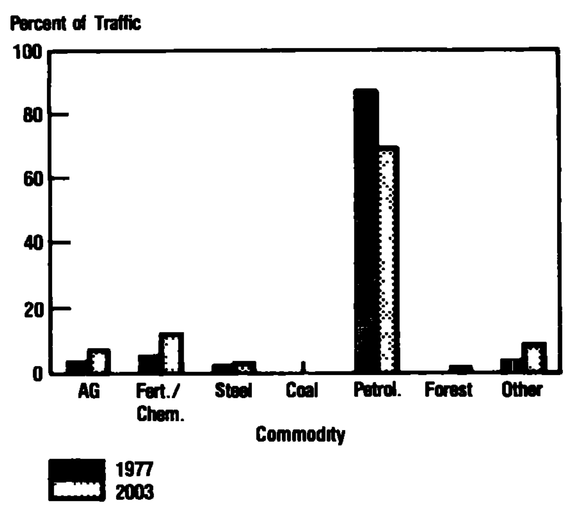
Figure D-38
REACH 22, U.S. CARIBBEAN
Map and Waterborne Commerce Graphs



Highest and Lowest Projections of Total Commercial Traffic



Existing and Projected Traffic, High Use



REACH NUMBER 22
CARIBBEAN
(Including Puerto Rico and Virgin Islands)

1. *Physical Characteristics*. The majority of commercial ports within this reach have depths greater than 28 feet. These include San Juan and Ponce Harbors, Puerto Rico and St. Thomas Harbor, U.S. Virgin Islands.

2. *Dredging*. The average annual dredging (1973 to 1977) was 0.21 million cubic yards at an average annaul cost of $0.29 million, or $1.41 per cubic yard.

3. *Commercial Traffic*. Projections show an overall decline from 89.8 million tons in 1977 to between 49.4 and 74.5 million tons in 2003, depending on the forecast. The decline is due to the projected decrease in tonnage of the major commodity, petroleum, from 77.8 to between 27.3 and 51.5 million tons. All other commodities are projected to experience slight gains in tonnage.

4. *Linkage With Other Reaches*.

	SHIPMENTS AND EXPORTS			RECEIPTS AND IMPORTS		
	Destination Reach		Percent	Origin Reach		Percent
Rank	No.	Description	of Total	No.	Description	of Total
1	14	Mid Atlantic	47.1	23	Overseas and Pacific Canada	86.7
2	13	South Atlantic	15.4	22	Intra-Reach	6.2
3	15	North Atlantic	15.0	14	Mid Atlantic	3.1
4	22	Intra-Reach	10.9	13	South Atlantic	1.3
5	23	Overseas and Pacific Canada	4.3	10	Gulf Coast-West	0.7
6	10	Gulf Coast-West	3.3	11	Gulf Coast-East	0.0
TOTAL: (Thousands of Tons)			33,868.0			59,575.7

5. *Types of Vessels*. Oceangoing vessels are the major commercial transporters. Pleasure craft also share the reach. Luxury oceanliners and cruise ships frequently call at San Juan and St. Thomas.

6. *Recreational and Other Water Uses*. Improvements are authorized for navigation, but present uses also include recreational boating, general recreation, fish and wildlife, and environmental purposes.

7. *Environmental Concerns*. Poor land use practices contribute to high sedimentation rates in Puerto Rican harbors, threatening mangrove swamps, offshore coral reefs, and otherwide superb aquatic habitat conditions. The Virgin Islands National Park is among the world's premier diving areas.

8. *Status*. In 1982, the Board of Engineers for Rivers and Harbors approved deepening of San Juan Harbor from 35 to 40 feet.

9. *Capability*. Due to declining petroleum traffic, no problems are anticipated in accommodating projected traffic. Dredging is expected to remain at the present average annual volume of 0.21 million cubic yards.

APPENDIX E

SAFETY PROBLEMS AND POTENTIAL SOLUTIONS

Appendix E

SAFETY PROBLEMS AND POTENTIAL SOLUTIONS

The following is a listing of safety problem sites. They are identified by NWS reach and segment, mile point, and type of solution along with a brief notation of the type of hazard to navigation.

Several types of problems are included in the listing:

(1) Site-specific channel problems identified will involve placement of additional aids to navigation at locations which are hazardous due to physical channel characteristics and/or heavy vessel traffic. (See Table E–1)

(2) Major channel congestion at locations where existing or forecast traffic levels may warrant actions such as improved monitoring and control of vessel movements, are identified. Only areas of additional need are cited. (See Table E–2)

(3) Bridge safety problems fall into two categories: major structural and minor structural. Major structural needs involve solutions such as the alteration, replacement or removal of specific bridges deemed to be hazardous to navigation. Minor structural solutions at bridges involve the placement of navigational aids and minor protective measures. (See Table E–3)

(4) Lock safety problems involve solutions to reduce hazardous navigation conditions in the vicinity of a given lock. Hazards at locks can include heavy traffic, terminals, bends, dangerous currents and shoals, as well as the lock configurations. (See Table E–4)

Table E–1
CHANNEL SAFETY PROBLEMS

NWS Reach/ Segment	Site	Hazard
L. Miss: Cairo to B.R.		
Upper Lower Miss	Vicksburg, MS MI 428–445	Bends, groundings, congestion
	Greenville, MS MI 531	Sharp bends
L. Miss: B.R. to Gulf		
Miss. River. B.R.-New Orleans	Donaldsonville, LA MI 165–175	Sharp reversing bends, terminals
	MI 210–225	Sharp reversing bends, terminals
Miss River New Orleans to Gulf	Belle Chasse, LA MI 75–85	Bends, terminals, congestion
Ohio River System		
Lower Ohio-One	Paducah, KY MI 932–943	Tennessee River intersection, terminals, hazardous approach to L&D 52
	Fort Massac Bar	Channel configuration, traffic
Gulf Coast-West		
Houston Ship Channel	MI 0–49	Shoaling, heavy traffic, restrictive bends at Baytown
Gulf Coast-East		
GIWW East-One	Mississippi Sound, Pascagoula Channel	Shoaling
Mobile River and Tribs.		
Black Warrior-Mobile Harbor	MI 217	Sharp turn to enter Black Warrior River
	MI 385	Sharp bends at junction of Locust and Mulberry Forks
	Locust Fork	Sharp bends, shoaling
Great Lakes System		
Lake Ontario and St Lawrence Seaway	Johnstown, ON	Channel above Galop Island subject to shoaling

Table E–2

MAJOR CHANNEL CONGESTION PROBLEMS

NWS Reach/ Segment	Location	Problem Description	Possible Number of New VTS Centers
L. Miss: B.R. to Gulf			
Miss. River B.R.-New Orleans	MI 109–235 (entire segment)	Heavy traffic, mixture of deep and shallow draft vessels	1
Miss. River New Orleans-Gulf	MI 0–109 (entire segment)	Heavy traffic, mixture of deep and shallow draft vessels	1
B.R.-Morgan City Bypass	MI 0–64 (entire segment)	Heavy traffic	1
Illinois Waterway	Marseilles, IL MI 244–247	Constricted channel at Marseilles Lock and Canal	1
Ohio River System			
Upper Ohio	Pittsburgh, PA to Stratton, OH MI 0–54	Congested traffic	2
	Point Pleasant, WV MI 254–270	Fleeting areas and terminals, intersection of Ohio and Kanawha rivers	2
Middle Ohio	Huntington, WV Ashland, KY, Ironton, OH MI 304–328	Fleeting area and terminals, intersection with Big Sandy River, bridges	1
Lower Ohio-Three	Louisville, KY MI 597–607	Fleeting areas and terminals, entrance to Louisville and Portland Canal	1
	Newburgh, IN MI 774–785	Island and terminals on upper approach to Newburgh L&D, intersection with Green River	1
Monongahela River	Pittsburgh, PA MI 0–11	Numerous terminals, 13 bridges	1
Tennessee River			
Upper Tennessee	Decatur, AL MI 301–306	Terminals, bridges	1
	Chattanooga, TN MI 462–471	Terminals, bridges, bends, shoals	1
Gulf Coast-West			
GIWW West-One	Morgan City to Lake Charles, LA MI 85–241	Heavy traffic, numerous intersecting channels, hazardous cargo	2
Gulf West-Two	Port Arthur, TX MI 276–289	Terminals, heavy traffic intersections, hazardous cargo	1
Gulf Coast-East			
GIWW East-One	New Orleans, LA	Terminals, congestion, Inner Harbor Navigation Canal	1
GIWW East-Two	Mobile Bay, AL	Intersection with Mobile Channel	1
South Atlantic Coast			
Florida/Georgia Coast	Jacksonville Harbor	Intersection with AIWW, bends, heavy traffic, recreation vessels	1
	Savannah Harbor	Traffic, recreation, bridges	1
Middle Atlantic Coast			
Chesapeake and Delaware Bays	Elizabeth River: South and East Branches	Numerous terminals, bends, congested traffic	2
Great Lakes System			
Lake Ontario and St. Lawrence Seaway	Massena, NY	Channel configuration, traffic	1
Lake Huron	St. Mary's River	Heavy traffic, constricted channel in stretches, currents, ice	1
Washington/Oregon Coast			
Puget Sound	Seattle Harbor	Heavy traffic, terminals, hazardous cargo	1
Columbia-Snake Waterway			
Lower Columbia River	MI 0–145	Heavy traffic, shoalings, bends	1
California Coast			
San Francisco Bay	Golden Gate, Bay Area	Heavy traffic, irregular currents	1
Central/South California Coast	Los Angeles/ Long Beach Harbor	Heavy traffic in harbor channels	1
Alaska			
South Alaska Coast	Entire coast	Severe weather, difficult harbor approaches, icing	1

Table E-3
BRIDGE SAFETY PROBLEMS

NWS Reach/ Segment	Bridge Location	Type of Solution
Upper Miss.	Hannibal, MO MI 310	Minor Structural
	Keokuk, IA MI 360–365	Minor Structural
	Ft. Madison, IA MI 384	Alteration
	Burlington, IA MI 403–405	Alteration
	Sabula, IA MI 535	Minor Structural
	Dubuque, IA MI 578–583	Minor Structural
	La Crosse, WI MI 723	Minor Structural
	Winona, MN MI 723	Removal
Lower Upper Miss		
Middle Miss	Thebes, IL MI 44	3 Minor Structural
	St. Louis, MO MI 172–184	2 Minor Structural
Lower Miss Cairo to B.R.		
Lower Middle Miss.	Memphis, TN MI 735–755	4 Minor Structural
Upper Lower Miss.	Natchez, MS MI 361–365	Minor Structural
	Vicksburg, MS MI 428–445	Minor Structural
	Greenville, MS MI 531	Minor Structural
Lower Miss: B R. to Gulf		
B R. to New Orleans	Baton Rouge, LA MI 225–235	2 Minor Structural
New Orleans to Gulf	New Orleans, LA MI 85–109	2 Minor Structural
B.R.-Morgan City Bypass	Morgan City, LA MI 0–3	Minor Structural
Illinois Waterway		
	Dresden Island, IL MI 270	Minor Structural
	Joliet, IL MI 286–289	6 Minor Structural
	Pekin, IL MI 150–155	2 Replacements
	Peoria, IL MI 160–165	2 Removals 3 Minor Structural
	Hennepin, IL MI 214	Removal
	Ottawa, IL MI 239–240	2 Minor Structural
Ohio River System		
Upper Ohio	Bellaire, OH MI 95	Minor Structural
	Parkersburg, WV MI 184	Minor Structural
Middle Ohio	Cincinnati, OH MI 460–485	3 Minor Structural
Lower Ohio-Three	Louisville, KY MI 597–607	Removal
Green River	Spottsville, KY MI 9	Minor Structural
	Livermore, KY MI 71	Minor Structural
	Smallhous, KY MI 80	Minor Structural
Cumberland River	Clarksville, TN MI 126	Alteration
	Bordeaux, TN MI 185	Minor Structural
	Nashville, TN MI 189–190	Minor Structural

Table E-3
BRIDGE SAFETY PROBLEMS
(Continued)

NWS Reach/ Segment	Bridge Location	Type of Solution
	MI 173	Minor Structural
	MI 202	Minor Structural
	Eutaw, AL MI 265–267	2 Minor Structural
	MI 413	Minor Structural
	MI 416	Minor Structural
	Mobile Harbor	2 Minor Structural
South Atlantic Coast		
Florida/Georgia Coast	Jacksonville Harbor	3 Minor Structural
Middle Atlantic Coast		
Chesapeake & Delaware Bays	Elizabeth River-Southern Branch Chesapeake, VA MI 2–3	3 Minor Structural
	Gilmerton, VA MI 5	Minor Structural
	Delaware River Palmyra, NJ	Minor Structural
New Jersey/New York Coasts	Newark Bay Bayonne, NJ	2 Minor Structural
North Atlantic Coast		
Upper Atlantic Coast	New Haven, CT	2 Minor Structural
	Boston Harbor, MA	2 Minor Structural
	Portland Harbor, ME	Minor Structural
Great Lakes System		
Lake Erie	Buffalo River, NY	3 Minor Structural
	Cleveland Harbor, OH	7 Minor Structural
	Toledo Harbor, OH	6 Minor Structural
Lake Huron	Rouge River, MI	5 Minor Structural
Lake Michigan	Calumet River, IL	8 Minor Structural
Lake Superior	Duluth/Superior Harbor, MN and WI	5 Minor Structural
Washington-Oregon Coast		
Puget Sound	Seattle Harbor, WA	3 Minor Structural
	Tacoma Harbor, WA	2 Minor Structural Removal
Columbia-Snake Waterway		
Lower Columbia River	Vancouver, WA MI 106	Minor Structural
California Coast		
San Francisco Bay	Dumbarton Point, CA	2 Minor Structural
Tennessee River		
Upper Tennessee	Bridgeport, AL MI 414	Alteration
	Chattanooga, TN MI 462–471	Minor Structural
Lower Tennessee	MI 66	Minor Structural
	MI 78	Removal
Gulf Coast-West		
GIWW West-One	(Algiers Route) MI 0–7	3 Minor Structural
	(Harvey Canal) MI 0–6	Minor Structural
	Larose, LA MI 35	2 Minor Structural
	Bourg, LA MI 40–50	Minor Structural
	Houma, LA MI 55–60	2 Alterations 2 Minor Structural
	Cypremort, LA MI 135	Minor Structural
	Grand Lake, LA MI 231	Minor Structural
	Barataria, LA (Barataria Waterway) MI 1	Alteration

Table E–3
BRIDGE SAFETY PROBLEMS
(Continued)

NWS Reach/ Segment	Bridge Location	Type of Solution
GIWW West-Two	Ellender, LA MI 244	2 Minor Structural
	Galveston, TX MI 353–358	3 Minor Structural
	Freeport, TX MI 393–405	Minor Structural
	Caney Creek, TX MI 418	Minor Structural
	Matagorda, TX MI 440–442	Minor Structural
	Aransas Pass, TX MI 533	Minor Structural
	Lake Charles, LA (Calcasieu River) MI 36	Minor Structural
Gulf Coast-East		
GIWW East-One	Freeport Harbor, TX	2 Minor Structural
	New Orleans, LA MI 6–8	Minor Structural
	New Orleans, LA (Inner Harbor Navigation Canal) MI 7–10	4 Minor Structural
Mobile River and Tribs		
Black Warrior-Mobile Harbor	MI 13	Minor Structural
	Nanafalia, AL MI 165	Minor Structural

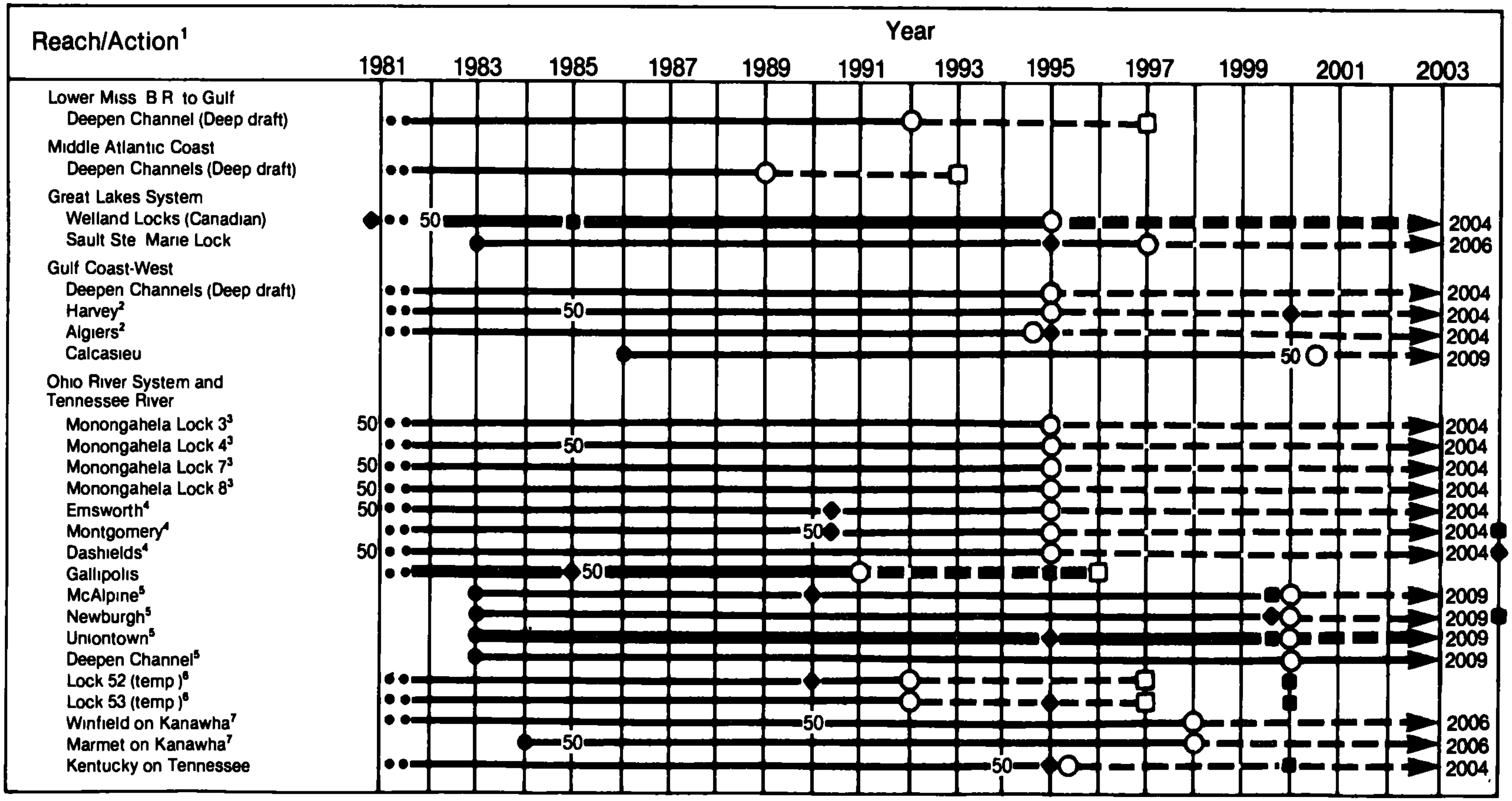
Table E–4
LOCK AND DAM SAFETY PROBLEMS

NWS Reach/ Segment	Lock and Dam	Location
Upper Miss.	Lock and Dam 24	Clarksville, MO MI 273
Illinois Waterway	Butterfly Dam	Lockport, IL MI 290
Ohio River System		
Upper Ohio	Emsworth	Emsworth, PA MI 975
	Dashields	Glenwillard, PA MI 968
	Montgomery	Industry, PA MI 949
Middle Ohio	New Cumberland	Stratton, OH MI 927
	Gallipolis	Hogsett, WV MI 702
	Greenup	Greenup, KY MI 640
Lower Ohio-One	Markland	Markland, IN MI 450
	Newburgh	Newburgh, IN
Gulf Coast-West		
GIWW West-Two	Brazos River Floodgates	Freeport, TX MI 404
	Colorado River Locks	Matagorda, TX MI 445
Columbia-Snake Waterway		
Upper Columbia-Snake Waterway	Bonneville	Bonneville, OR MI 145

APPENDIX F

SCHEDULE FOR NAVIGATION ACTIONS UNDER EXISTING PROCESS

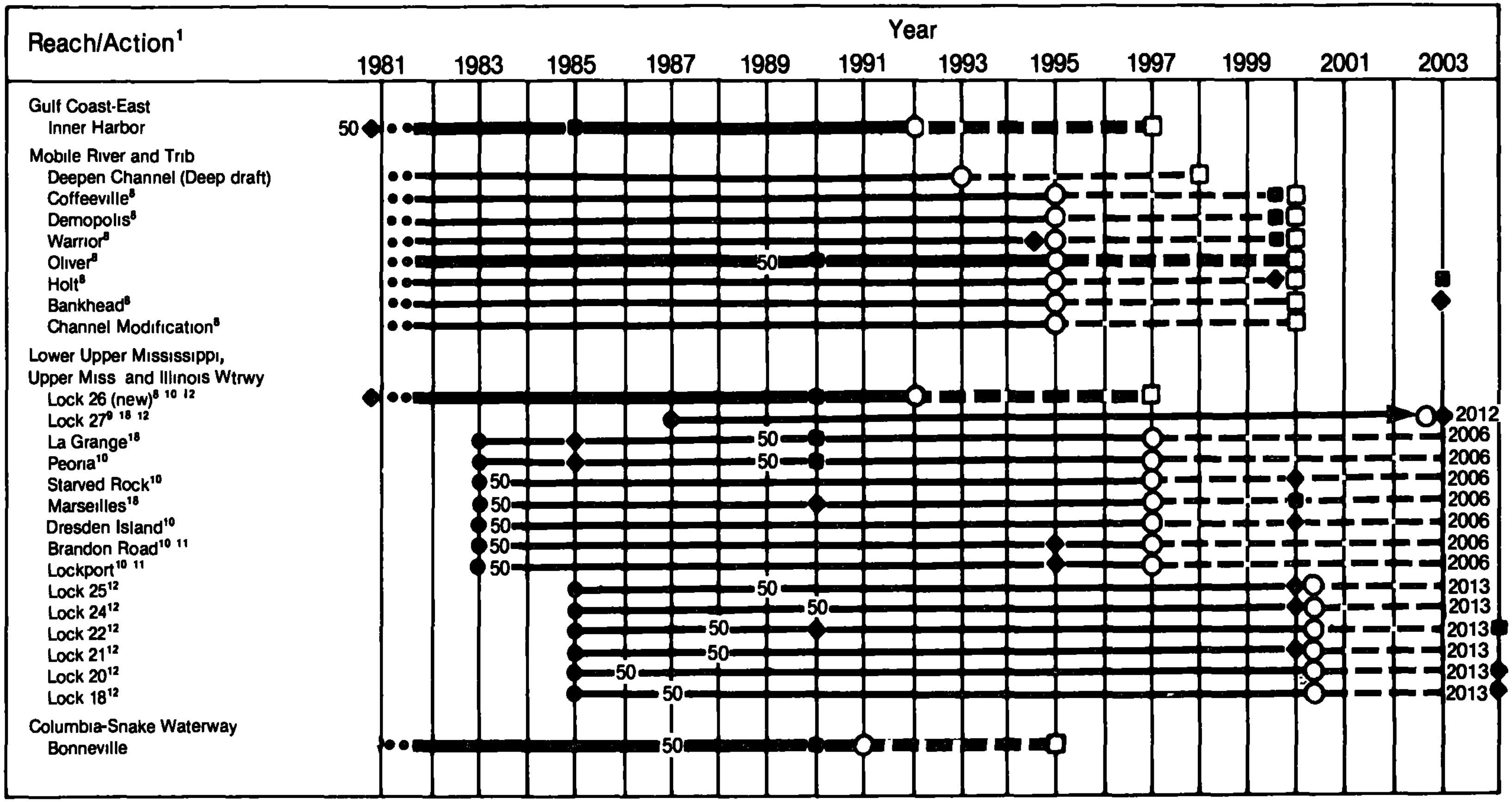
Figure F-1
SCHEDULE FOR NAVIGATION ACTIONS UNDER EXISTING PROCESS



1. Reaches are ordered by volume of traffic in 2003.
2. through 12. Locks with the same numeral are in close proximity and/or highly interactive within a reach, and therefore suggest a need for a coordinated study design and construction program. The sequence and schedule displayed here reflects these close interrelationships and initiates all actions within this group or subgroup based upon the earliest needs.

Legend:
- ◆ Earliest Date Congested
- ■ Earliest Date Constraining
- •• Planning Process Underway
- ● Initiate Planning
- ○ Possible Completion (Median)
- □ Possible Completion (Mean)
- 50 Date Lock Exceeds 50 Years
- ▬ Median Time
- – – Mean Time
- ▬ Primary Constraint (Median Time)
- ■ ■ Primary Constraint (Mean Time)

Figure F-1 (Continued)
SCHEDULE FOR NAVIGATION ACTIONS UNDER EXISTING PROCESS



1. Reaches are ordered by volume of traffic in 2003.

2. through 12. Locks with the same numeral are in close proximity and/or highly interactive within a reach, and therefore suggest need for a coordinated study design and construction program. The sequence and schedule displayed here reflects these close interrelationships and initiates all actions within this group or subgroup based upon the earliest needs.

Legend:
- ◆ Earliest Date Congested
- ■ Earliest Date Constraining
- •• Planning Process Underway
- ● Initiate Planning
- ○ Possible Completion (Median)
- □ Possible Completion (Mean)
- 50 Date Lock Exceeds 50 Years
- ── Median Time
- ‒ ‒ Mean Time
- ▬ Primary Constraint (Median Time)
- ■ ■ Primary Constraint (Mean Time)

APPENDIX G

WATERWAYS SYSTEM AND COMMODITY MAPS

(Separately Bound)

APPENDIX H

PUBLICATIONS AND SUPPORTING DOCUMENTS OF THE NATIONAL WATERWAYS STUDY

Appendix H

PUBLICATIONS AND SUPPORTING DOCUMENTS OF THE NATIONAL WATERWAYS STUDY

The National Waterways Study is the product of extensive research efforts on the part of the Institute for Water Resources, the Corps divisions and districts, the NWS prime contractor and his two subcontractors, and numerous smaller contract efforts. A variety of publications during the course of the study have helped to consolidate these research efforts by documenting methodology, technical findings and conclusions, and evaluation efforts.

Study highlights, including numerous public involvement activities, were publicized in a series of NWS Information Bulletins. An historical series examines the early growth and development of U.S. ports and waterways with an emphasis on the changing Federal role over time. The NWS *Waterway System and Commodity Movement Maps* portray data and information about the physical characteristics of U.S. waterways and the type and volume of traffic utilizing them. These maps are supplemented by the report *Trends in Waterborne Commerce of the United States. 1947–1979,* which highlights recent changes in the flow and mix of traffic as well as a brief description of each of the maps. Research efforts of the prime contractor are also detailed in 11 reports which provide an overview of his technical findings and evaluation criteria.

These and other NWS publications are included in the following annotated listing.

NWS Planning Documents

NWS Plan of Study, March 1978: The National Waterways Plan of Study defined the congressionally mandated objectives of the project. The study scope as well as management organization and stages of implementation were detailed. The Plan of Study stated and refined NWS goals and how these were to be achieved. It also provided the organizational basis for seeking contractural support on the technical research phase of the project. (Out of print)

NWS Workplan and Abridged Workplan, July 1979: The National Waterways Study Workplan provided a schedule of activities and estimates of personnel and financial requirements for each study element. The document explained the tasks of the NWS prime contractor, A. T. Kearney, Inc. and two subcontractors, Data Resources, Inc. and Louis Berger and Associates. Study phases, and the activities performed under each, were identified and highlighted. Technical research and evaluation efforts, as well as a considerable program for public involvement, were detailed. An *Abridged Workplan* was published as well in order to provide a condensed version for public distribution. (Out of print)

NWS Map Series and Trends in Waterborne Commerce

One of the first tasks of the National Waterways Study was to gather data and information to describe the existing navigation network. The results of this effort were used to develop a series of maps depicting the navigation system and principal commodity movements. An accompanying document discussed the maps as well as highlights of waterborne commerce from 1947 to 1979. The first 19 maps became available in 1979, the 20th in spring 1980, and 21–24 in 1982. (Available with final report or separately from the Institute for Water Resources (IWR).)

NWS Waterways System and Commodity Movement Maps: This series of 24 maps was prepared especially for the National Waterways Study. One national and four regional maps highlight the existing waterway system by controlling navigable depths and identify principal ports and 1976 tonnages. The other 19 maps depict movements by water of principal bulk commodities, and, in some instances, movements by alternate modes such as rail and pipeline. In addition to total waterborne flows, individual commodities depicted include coal, grain, petroleum and petroleum products, metallic ores, chemicals, and iron and steel.

Trends in Waterborne Commerce of the United States, 1947–1979: This pamphlet, designed to accompany the NWS map set, discusses waterborne commerce in terms of total flows and movements of individual commodities. Major trends since 1947 are highlighted, including the significant growth of commerce on the inland system. Each of the *Waterway System and Commodity Movement Maps* is briefly discussed.

NWS Contractor Technical Research, Evaluation and Conclusions

The NWS prime contractor, A. T. Kearney, Inc., and that firms's two subcontractors, Data Resources, Inc. and Louis Berger and Associates, prepared a series of reports on the results of their technical research, as well as an evaluation of the present navigation system, strategies for waterway actions, and contractor conclusions. The eight technical volumes were initially submitted in draft form in the spring of 1980. An intensive review effort by the Corps followed. Revised final reports were then submitted in the spring of 1981. The draft technical reports received wide distribution within the Corps of Engineers. Copies were also provided on request to other state and other Federal agencies, trade organizations, and the waterways industry, among many other interest groups. The two contractor evaluation reports on the present navigation system and strategies for action, as well as the final report and conclusions, were submitted in draft form in the spring of 1981. Final versions were all received by the following December. All 11 final contractor reports are available from the National Technical Information Service in Springfield, Virginia.

Traffic Forecasting Methodology: This volume briefly describes principal waterborne commodities and projections of traffic through 2003. The assumptions and contractor forecasting techniques used are explained in detail. The tables of projections presented in this document are preliminary unconstrained forecasts of waterborne commerce. Modified forecasts reflecting assumptions about future conditions—scenarios—are presented as an appendix to a later document entitled *Evaluation of the Present Navigation System.* (Available through National Technical Information Service (NTIS).)

Commercial Water Transportation Users: This report identifies the principal industries utilizing commercial waterways. Areas of production and consumption are highlighted for principal waterborne commodities. Industry-wide trends or changes that can be expected to influence the future use of water transportation are identified. Three key industries—coal, agriculture and petroleum—are expected to dominate changes in water transportation use through the turn of the century. (Available through NTIS.)

Overview of the Transportation Industry: The focus of this report is a review of the water transportation carriers and ports and terminal industries. The report provides a profile of the transportation industry and reviews the outlook, problems, and impacts that other surface modes are likely to have on the waterways industry. (Available through NTIS.)

Review of National Defense, Emergency and Safety Issues Affecting the Waterways: One mandate of the National Waterways Study was to address, ". . . the existing system and its capabilities for meeting the national needs, including emergency and defense requirements." This document focuses on national defense roles of the waterways system historically, currently, and as envisioned for future contingents. Also, waterborne transportation requirements during non-defense emergencies are discussed. Finally, waterway system safety problems and issues are highlighted. (Available through NTIS.)

Analysis of Navigation Relationships to Other Water Uses: This report summarized multipurpose uses of the waterways and related national water resource policy. Five types of relationships between navigation and other water uses are analyzed for areas of conflict and compatibility. These include: (1) water availability; (2) reservoir management and instream flow; (3) saltwater intrusion; (4) recreation activities; and (5) beneficial effects of navigation projects. (Available through NTIS.)

Waterways Science and Technology: This document examines state-of-the-art aspects of navigation structures, methods of increasing the capacity of existing locks, channel design standards, dredging and river training technology, and methods of season extension. Existing techniques and possible future trends are outlined. (Available through NTIS.)

Engineering Analysis of Waterways Systems: Four major areas of waterways maintenance and operation are examined in this report: Lock capacity; channel maintenance; channel conditions for fleet operations; and waterway reliability. Lock capacities are estimated using representative locks on principal waterways. Different hydrologic conditions are discussed for major types of waterways. (Available through NTIS.)

Evaluation of the Present Navigation System: This report draws upon the technical research conducted for other elements of NWS in order to evaluate the capability of the present waterways system to handle current and projected waterborne commodity flows. The evaluation is based on four scenarios and three sensitivity analyses of projected demand for waterborne traffic. A separately bound appendix documents the projections by commodity and by individual waterway system reaches. (Available through NTIS.)

Evaluation of Alternative Future Strategies for Action: The water transportation needs determined in the *Evaluation of the Present Navigation System* are analyzed using four alternative strategies. The strategies are formulated to represent distinct policy and top management options available to Congress and the Corps for meeting water transportation needs. The relative merits or disadvantages of each strategy is presented in terms of the degree to which anticipated water transportation needs are met by each. (Available through NTIS.)

Analysis of Environmental Aspects of Waterways Navigation: This report presents an overview of the various environmental issues associated with navigation and with waterway development. A more detailed appendix addresses dredging and dredge material disposal on a segment by segment basis. In addition to dredging, other issues discussed include dam construction and dam-related phenomena such as flow allocation and alteration of the aquatic environment, as well as general navigation impacts, such as spills. (Available through NTIS.)

Findings and Conclusions (from Contractor Study Effort): This report presents the major findings of the technical research performed by the study contractor, summarizes conclusions drawn from that research, and presents evaluations of four alternative strategies for future management of the waterways.

Public Involvement Publications of NWS

National Waterways Study Public Involvement Program: This separately bound document was prepared in order to present the extensive activities aimed at incorporating public review and comment in NWS. Highlights include general public meetings, presentations to trade organizations and in other special interest forums, miscellaneous publications related to the public involvement effort, and a variety of other coordination efforts aimed at ensuring a broad public review of NWS findings and conclusions. (Available through IWR.)

NWS Information Bulletins: A series of bulletins were prepared and distributed at intervals throughout the study. The bulletins summarized findings to date, announced upcoming events such as public meetings or workshops, and highlighted the results of other public involvement actitivites. NWS bulletins, now out of print, were published in:

October 1978	March 1980
March 1979	August 1980
September 1979	June 1981
November 1979	

Public Meeting Materials: Pamphlets produced by the study contractor were distributed at several NWS public meetings and on request. Two particularly detailed short reports were provided at the important milestone meetings dealing with the evaluation of the present navigation system and evaluation of alternative strategies for action. For the public meeting on the NWS Draft Final Report, a summary of highlights from the report was prepared for release to the general public. Copies of speeches and presentations given at the meeting were also provided. These materials are out of print.

Evaluation of the Present Navigation System: This short report summarized preliminary findings for this phase of the contractor effort. The document was distributed at a public meeting on this topic in September 1980.

Evaluation of Alternative Strategies for Action: This report takes the findings of the previous publication a step further by highlighting contractor strategies for meeting waterway system problems identified in prior evaluation efforts. This document was distributed at the public meeting on this topic in November 1980.

National Waterways Study Team's Draft Final Report (Summary Document): This document condensed the highlights of the Corp's Draft Final Report on the National Waterways Study. It was distributed for the public meeting on the Draft Final Report in July 1981, and upon request.

NWS Speeches by BG Forrest Gay, III and Arlene Dietz: Copies of the speeches given at the July 1981 public meeting by the study director, BG Gay, III and the study manager, Mrs. Dietz, were distributed with the Summary Document. The speeches served to clarify and expand upon certain points among the conclusions in the Summary Document.

NWS Fact Sheets: Three short Fact Sheets were printed for the study which served as interim summaries of principal findings and preliminary conclusions. The first was printed in October 1980, the second the following April, and the third in June 1982. Fact Sheets were distributed to the public on request. Each documented study findings, including: an evaluation of the existing waterway system; principal growth waterways and commodities; analysis of congested locks; and changes in linehaul costs. The April version elaborated on the NWS evaluation of waterway system capability and strategy development. The June 1982 material covered the principle study findings and conclusions.

NWS Waterway History Series

The U.S. Waterways and Ports—A Chronology: Part One, 1541–1871: This paper is a chronological account of waterways development and use, which depicts the history of waterway and port improvements in the European colonies and in North America, and in the early years of the United States. Exploration, technological advances, and policy decisions on state and Federal levels are addressed in this paper, as well as detailed coverage of major events pertaining to the era of canal construction and development in the United States. (Available from Government Printing Office (GPO).)

History of the Commercial Waterways and Ports of the United States, Volume 1: From Settlement to Completion of the Erie Canal: A narrative history of the U.S. waterways system, this paper focuses on the exploration and settlement of the coastal ports and inland waterways. A close look is taken at the planning processes which established the present waterways system. The development of an effective public works program for the advancement of the waterways system is examined in light of private, state and Federal participation. Special attention is paid to the planning, construction and use of the Erie Canal. (Available through GPO.)

Other NWS Historical Navigation Papers: The following reports have been prepared under special contract for the National Waterways Study. Each discusses an aspect of historical navigation in the United States, and an effort has been made to address the development of different principal river systems and coastal areas on an individual basis. (Available through GPO.)

- *Western Tributaries of the Mississippi,* by D. Clayton Brown.
- *The Evolution of Vessels Engaged in the Waterborne Commerce of the United States,* by Rovert Taggert.
- *History of Great Lakes Navigation,* by John W. Larson.
- *History of the Gulf Intracoastal Waterway,* by Lynn M. Alperin.
- *History of Navigation and Navigation Improvements on the Pacific Coast,* by Anthony Turhollow, Benjamin F. Gilbert and K. Jack Bauer.
- *A History of Transportation on the Upper Mississippi and Illinois Rivers,* by Roald Tweet.
- *A History of the Waterways of the Atlantic Coast of the United States.* by Aubrey Parkman.
- *A History of Navigation on the Lower Mississippi River.* by Floyd M. Clay.
- *A History of Navigation in the Ohio River Basin,* by Michael Robinson.

NWS Roundtable Papers and Proceedings

This publication contains papers and presentations given at the National Waterways Roundtable, held in Norfolk, Virginia, in April 1980. This meeting brought together a wide range of professional opinion, and it was a meeting of minds between engineer-historians interested in the past and engineer-planners interested in the future of the national waterways system. The Roundtable was designed to include participants from academia, the transportation industry and government agencies who might not otherwise have been involved in NWS public participation activities. Four Roundtable sessions were held, including the subjects of waterways history and evolution, impacts of regional development, waterways technology and port development, and a look ahead at U.S. waterways and ports. Two versions of the Proceedings were published. One is comprehensive, including speeches and discussions as well as all the papers presented at each of the four Roundtable sessions. An alternate version, aimed at waterway historians, was compiled solely from papers and discussion in the Roundtable session dealing with waterways history and evolution. (Available through GPO.)

National Waterways Study Final Report

This report summarizes and develops conclusions from all the extensive technical research, system capability evaluation, strategy development, and planning framework formulation conducted for the study. The report identifies characteristics of the existing waterways system and contrasts navigation on the inland waterways, coastal areas and the Great Lakes. Current and projected waterborne commerce is discussed in terms of volume, location and types of commodities. Waterway system problems and needs are identified, a framework is developed to accommodate projected needs, and a sequence for implementation is offered to assist decision makers in planning and budgeting future actions concerning the navigation system. Findings and conclusions from the framework formulation are presented with their implications for policy, programming and studies. An appendix to the report highlights waterway characteristics on a reach by reach basis. Lock and channel dimensions, existing waterway status, current and projected waterborne commerce, and anticipated navigation problems are summarized briefly for each reach based on preceding chapters of the report. The document also incorporates an Environmental Assessment, which examines current and future environmental consequences of commercial navigation and relates these to actions envisioned in the framework. Waterway system safety issues, and the potential role of the system in a national defense emergency, are also evaluated. (Available through GPO.)

APPENDIX I

ACKNOWLEDGMENTS

Appendix I

ACKNOWLEDGMENTS

Many organizations and individuals participated in the planning, development, preparation and review of the National Waterways Study (NWS). Section II of this report lists organizations and their type of participation in the NWS. The list includes individuals and groups responsible for policy guidance—Study Director and Steering Committee, for staff support—Institute for Water Resources (IWR) and the Board of Engineers for Rivers and Harbors (BERH), for technical assistance and detailed reviews—Corps of Engineers Office of the Chief of Engineers, divisions, districts, and laboratories, in addition to agencies represented on the Steering Committee, and for extensive technical support—several contractors.

A listing of individual participants who had major responsibilities for all or part of the duration of the study is as follows:

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BG Sam Kem
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BG Forrest Gay, III
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Final Report for National Waterways Study. This study was authorized by Congress in Section 158 of the Water Resources Development Act of 1976 (Public Law 94-587).

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This is the final report of the National Waterways Study. The report reviews the study's purpose and design, describes the existing system and its commerce, covers in detail the capability assessment of that system to meet economic, safety and defense needs and presents national frameworks for waterway development which will serve as blueprints for decision makers in meeting the problems identified in the assessment. The report closes with a section which highlights the study's key conclusions and implications.

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