Current Status of Cost-Shared Deep-Draft Harbor Projects

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With passage of the Water Resources Development Act of 1986 (WRDA 86), a 16-year hiatus in major harbor improvement authorizations ended. This act authorized 39 channel improvement projects ranging in depth from 12 to 76 ft. It also introduced provisions requiring local sponsors to share the cost of harbor improvements with the federal government, the percentage being dependent upon the depth of the improvement. As of January 1989, 15 ports had signed local cooperation agreements, and another six are likely to be signed in 1989. In addition, passage of WRDA 88 authorized three additional deep-draft harbor projects and reinforced a goal of biannual water resources legislation, thus ensuring a steady pace of the new harbor improvement projects needed to keep U.S. ports competitive in the world economy.

On October 17, 1986, the last day of the 99th Congress, WRDA 86 was passed. This landmark legislation ended a 16-year hiatus in major harbor improvement authorizations as well as the historic tradition of 100 percent federal funding of navigation projects. Federal funds are still used for lands, easements, rights-of-way, relocations, and dredge material disposal sites (LERRD). Altogether, WRDA 86 authorized 39 channel improvement projects ranging in depth from 12 to 76 ft. It also introduced provisions requiring local sponsors to share the cost of harbor improvements.

The cost-sharing provisions of WRDA 86 applied not only to new projects, but also to those previously authorized but not yet constructed. The legislation requires local sponsors to cover 50 percent of the cost of deepening below 45 ft, 25 percent of the cost of deepening in the range of 20 to 45 ft, and 10 percent of the cost of deepening for projects 20 ft deep or less. For all depth categories, local sponsors must also repay an additional 10 percent of the total project cost that is initially covered by the federal government over a 30-year period. However, this 10 percent can be partially or totally offset on the basis of the value of the LERRD provided by the local sponsors (*1*). The legislation also authorized local entities to enact user fees that would help recoup their investment. However, intense competition between ports has precluded this option among the projects completed to date.

As of January 1989, 15 ports had signed Local Cooperation Agreements (LCAs) with the Assistant Secretary of the Army (Civil Works), which specified local and federal responsibilities for funding channel improvements (Office of the Chief of Engineers, Washington, D.C., unpublished data). Another six LCAs are being negotiated and are likely to be signed in 1989. Some of these agreements cover the full congressionally authorized project, but many only cover an initial phase of the total project and defer further improvements to a later date. Such project phasing has a number of advantages for local sponsors, including lower initial capital requirements, earlier realization of project benefits, and the opportunity to reassess various components of a project before making additional investments.

Figure 1 shows the location of pending deep-draft harbor improvement projects authorized by WRDA 86, the recently passed WRDA 88, or earlier legislation. Of these numerous authorized projects, only 12 were actually under construction in 1988. Each of these projects will be discussed in more detail in the following paragraphs.

KILL VAN KULL AND NEWARK BAY CHANNELS, NEW YORK AND NEW JERSEY

Deepening of Kill van Kull and Newark Bay channels was authorized by the Supplemental Appropriations Act of 1985 and then modified by WRDA 86 to comply with cost-sharing provisions. The Port Authority of New York and New Jersey is the local sponsor for the project. Kill van Kull Channel separates Bayonne, New Jersey, from Staten Island, New York, and connects Newark Bay with Upper New York Bay (see Figure 2). It provides access to terminals at Port Newark and Port Elizabeth on Newark Bay, which together form the nation's largest container port, handling over 13 million tons per year. The channel also provides access to refineries and other liquid and dry bulk terminals in New Jersey. Current channel depths limit the ability to handle the new generation of larger container vessels, as well as necessitating the loading and unloading of tankers by barges (lightering) in deeper water in Upper New York Bay.

The authorized project involves deepening about 5 mi of the Kill van Kull Channel and 3 mi of channels in Newark Bay from 35 to 45 ft, a turning basin at Port Elizabeth, and a 5-mi pierhead channel at Port Newark and Port Elizabeth. The total project cost is estimated at $342 million, of which $167.3 million would be funded by the federal government (*2*). However, the port has elected to construct the project in phases, and the current LCA (signed in May 1986 and modified in May 1987) provides for deepening to 40 ft initially. This first phase is estimated to cost $212 million, with the federal share anticipated to be $96.5 million. The first dredging contracts were let in July 1987 and completion of the 40-ft channel is scheduled for September 1989. Dredging is proceeding under five separate contracts; the last is scheduled to be awarded in February 1989 (*3*). Incremental deepening to the full project depth of 45 ft is unscheduled at this time.

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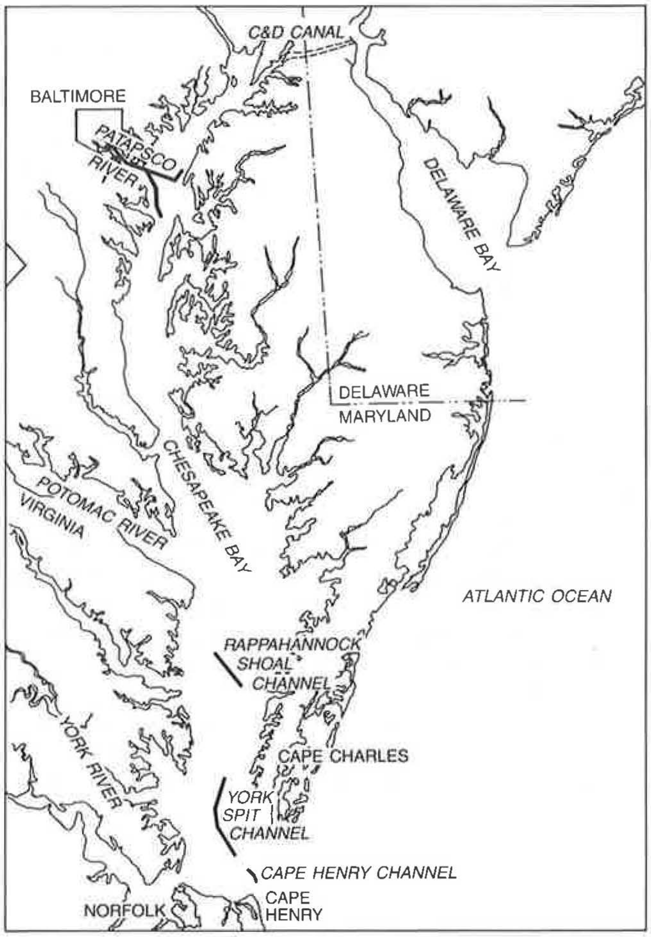

FIGURE 3 Baltimore Harbor and channels, Maryland and Virginia, deepening project.

channel was Phase I of a four-phase deepening project authorized by the Supplemental Appropriations Act of 1985 and WRDA 86. The authorized project includes deepening main channels from 45 to 55 ft in the harbor area and dredging a new 60-ft channel in the Atlantic Ocean approach lane. Widths vary from 800 to 1,300 ft over a total project distance of 37.6 mi (*5*). The authorization also includes deepening the Elizabeth River to 45 ft over a 6-mi stretch and to 40 ft over an additional 2.5 mi, as well as the deepening of two anchorage areas. The total project cost is estimated at nearly $232 million, of which about $102 million would be provided by the federal government. The Commonwealth of Virginia, acting through the Virginia Port Authority (VPA), is the local sponsor for the project. The project serves bulk commodities, particularly coal, which is generally shipped in vessels exceeding 100,000 deadweight tons, which cannot be fully loaded in 45-ft channel depths. The 55-ft project would allow these vessels to load to capacity, decreasing transportation costs to overseas markets and enhancing the U.S. position in the world coal trade.

VPA elected to construct the project in phases. An LCA was signed in May 1986 and modified in February 1987 to reflect cost-sharing provisions of WRDA 86. The agreement covered only the Phase I 50-ft outbound channel. The Commonwealth of Virginia will be required to modify the existing LCA or prepare a new LCA to provide for the cost-sharing of Phase II, which would further deepen the 50-ft outbound channel to 55 ft. The newly completed 50-ft channel was constructed at a cost of less than $33 million, with the federal share amounting to $17.5 million. The project involved 28 mi of channels (see Figure 4). Outbound lanes of the Norfolk Harbor and Thimble Shoal channels were widened to 650 ft. An 800-ft width (the full authorized dimension) was provided in the channel to Newport News to address safety concerns

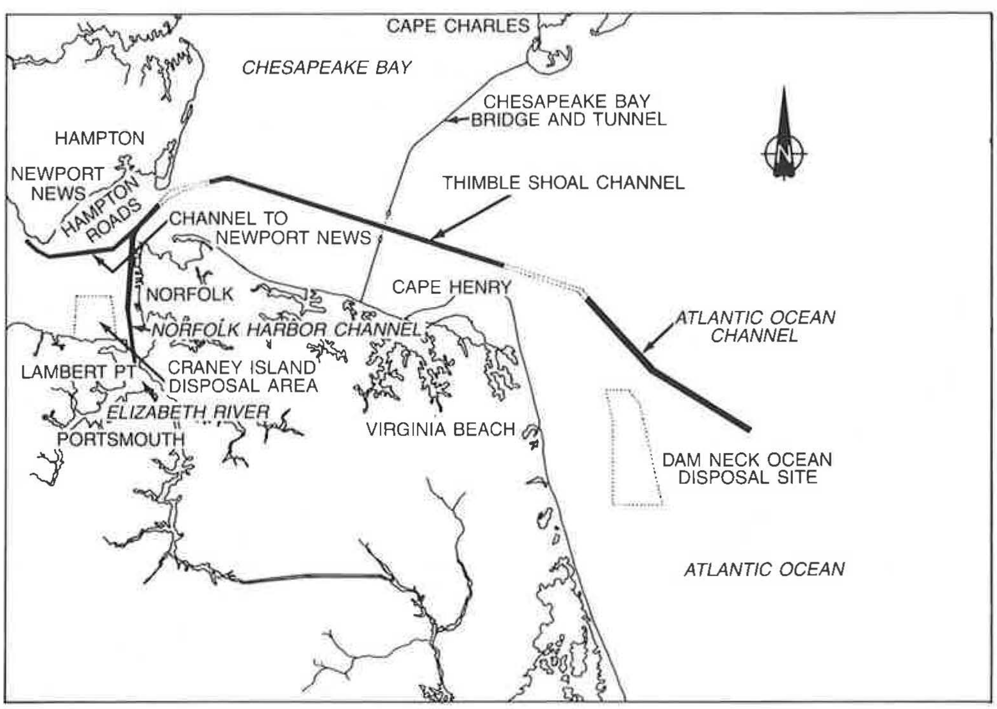

FIGURE 4 Norfolk Harbor and channels deepening project.

over currents in this section of the James River. The outbound channel improvements allow loaded coal colliers to exit the harbor while empty colliers travelling in ballast use the existing 45-ft inbound channel (*6*).

Plans for Phase II are not yet finalized, but local authorities hope to negotiate an LCA during 1990 and begin construction in 1991. Phase II would deepen the Norfolk Harbor, Thimble Shoal, and Newport News outbound channels to 55 ft and create a new 9.6-mi Atlantic Ocean Channel with a 60-ft depth. This project would also require the creation of a protective rock covering for the twin tubes of the Chesapeake Bay Bridge-Tunnel connecting Virginia Beach with the Delmarva Peninsula across the mouth of Chesapeake Bay. The estimated cost of Phase II is $133 million, of which $58.5 million would be federal funds. Phases III and IV would involve deepening the inbound channels to 50 and 55 ft, respectively. Both phases are unscheduled at this time.

CHARLESTON HARBOR, SOUTH CAROLINA

Deepening of the 35-ft channel at Charleston began in March 1988. The project was authorized by WRDA 86 and provides for a depth of 40 ft in the inland channels, 42 ft in the jetty and entrance channel, and 40 ft in the Wando River Extension (*2*). The project extends 27.6 mi from the 42-ft depth in the Atlantic Ocean to Goose Creek. The Wando River Extension is 2 mi long. Channel widths vary from 500 to 700 ft for the inland channel, 1,000 ft in the jetty entrance channel, and 450 ft in the Wando River (see Figure 5). The full project is scheduled for completion in 1995; however, project depths will be available in 1990. The total cost is estimated at about $125 million, of which $83 million would be federal.

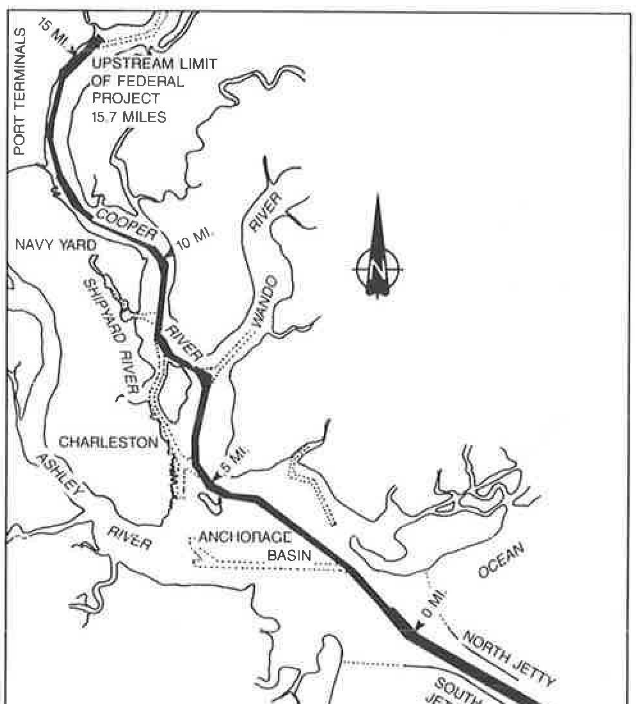

FIGURE 5 Charleston Harbor deepening project.

The South Carolina State Ports Authority is the local sponsor for the deepening project, and an LCA was signed in February 1988. The project was approximately 11 percent complete in October 1988. Four dredging contracts were awarded in 1988, and five were scheduled for 1989. By the end of 1990 most of the channel work is scheduled to be completed, including deepening to the upstream limit of the project. Remaining work will include a branch channel around Drum Island adjacent to downtown Charleston and an anchorage area in the open harbor near Ft. Sumter.

The Port of Charleston handles a wide variety of cargo that will benefit from a deeper channel, including containerized cargo and such bulk commodities as iron ore, soybeans, petroleum products, pulp, and fertilizer. The 40-ft channel will permit vessels of 80,000 to 90,000 deadweight tons to more fully load at the port and enter and leave with improved safety. Plans for the deeper channel have already helped Charleston secure additional traffic, such as a commitment by Maersk, Inc., to make a minimum of 100 vessel calls at Charleston and to load or unload at least 65,000 container 20-ft equivalent units (TEUs) (*7*). Containerized traffic at Charleston has been increasing about 20 percent per year since 1985, and for the year ended June 30, 1988, the port handled 645,000 TEUs, placing it second only to New York on the U.S. Atlantic Coast (*8*).

PONCE HARBOR, PUERTO RICO

Deepening of Ponce Harbor was authorized in 1976 under provisions of Section 201 of the 1965 Flood Control Act. The project provides for deepening the existing 30-ft channel to a 36- by 600-ft channel from the Caribbean Sea approximately 2.8 mi up to the port, a 36- by 400-ft channel in the port area, and a 36- by 950-ft diameter turning and maneuvering basin adjacent to the main port berthing area (*9*). The project was originally estimated to cost $10.4 million, of which $6.5 million was federal funds. However, the estimate for federal funds was subsequently lowered by half. In addition, bidding for the dredging contract was very competitive. Ultimately, the project cost is now estimated at only $3.0 million, of which $2.4 million would be federal (*10*).

The local sponsor for the project is the City of Ponce. An LCA was signed by the Mayor of Ponce on April 8, 1988. A contract was awarded in August 1988 and construction was initiated in December. Construction, originally scheduled to be completed by April 1989, was ahead of schedule and likely to be completed during February 1989.

Ponce has historically been a central distribution system for the southern region of Puerto Rico, and the recent improvement in facilities will enable the port to make a significant contribution to regional transportation. The deeper channel at Ponce will provide improved access to new and proposed terminal development and permit more efficient loading and unloading of vessels at the port. Containerized traffic particularly is expected to benefit. Other important commodities at Ponce include petroleum and petroleum products, fresh fish, cement, limestone, and basic chemicals.

TAMPA HARBOR AND BRANCH CHANNELS, FLORIDA

The port of Tampa is a major bulk center, ranking among the nation's 10 largest ports in terms of tonnage handled (*11*). Primary commodities handled by the port are bulk phosphate rock, phosphate products, fertilizers, coal, petroleum products, and sulfur (*11*). Transportation cost savings resulting from the employment of larger or more fully loaded bulk vessels have been used to justify past and continuing investment in channel improvements.

Several projects in the Tampa Bay area have been authorized or are under construction. The current project at Tampa Harbor was first authorized by the River and Harbor Act of 1970, and work began on the main channel in 1976. This initial authorization included deepening and widening the Tampa Bay entrance and main channels (to 45 and 43 ft by 700 and 500 ft, respectively), Hillsborough Bay Channel (to 43 by 500 ft), and three branch channels (Sparkman to 41 by 400 ft; Ybor to 39 by 300 ft; and Port Tampa Channel to 41 by 400 ft). Funds were never appropriated by Congress, however, for the branch channels and upper reaches of Hillsborough Bay Channel, known as Cut D. The Supplemental Appropriations Act of 1985 reauthorized these projects.

The project was reevaluated after implementation of the new cost-sharing legislation, and an LCA was signed in June 1986. The LCA with Tampa Port Authority specified deepening only two channels, not four, at a reduction in total cost from an estimated \$52 million to \$13 million. The federal share dropped from \$34 to \$8.6 million. Hillsborough Bay Cut D Channel would be deepened to the authorized 41 ft, and Sparkman Channel would be deepened to 36 ft instead of the original 41 ft (*12*). Another LCA was signed after passage of WRDA 86 and included federal assumption of maintenance dredging of East Bay Channel.

Construction began in February 1988 on Hillsborough Channel Cut D (see Figure 6). The first contract involved dredging 300,000 yd^3 and 3,700 ft of channel. Another contract was let in 1989. The schedule for future progress depends on availability of local funds. Because the project has been authorized and an LCA is in place, work will continue as Tampa Port Authority obtains additional funds. Eventually a total of about 1 million yd^3 will be dredged and placed in an existing diked disposal area in Hillsborough Bay.

In addition to the Tampa Harbor Branch Channels project, two other Tampa Bay projects have been authorized. WRDA 86 authorized the construction of a turning basin and enlarged widener on the southeastern shore of Tampa Bay and federal maintenance of the locally constructed 40 ft deep channel to Port Manatee. All material from initial construction and future maintenance is to be placed in diked upland disposal areas adjacent to the harbor. To mitigate the 6.6 acres of shallow

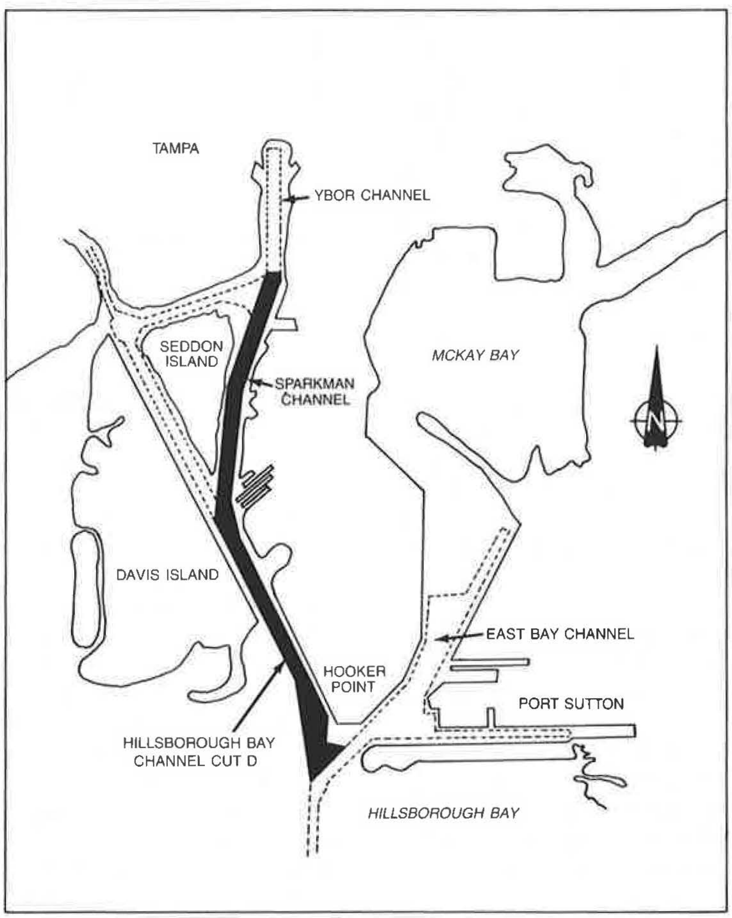

FIGURE 6 Tampa Harbor branch channels deepening project.

bay bottom lost in enlarging the turning basin, 10 acres of the emergent near-shore disposal island is to be excavated 2 ft below mean low water (*13*). The Corps is currently negotiating an LCA with Manatee City Port Authority. Construction should begin in 1990.

The channel at Port Sutton, located across the East Bay Channel from the port of Tampa, was authorized by WRDA 88 to be deepened to 42 ft for a length of 3,700 ft. Project benefits would accrue chiefly to large bulk vessels carrying phosphate rock and sulfur. Total costs are estimated to be $2.7 million (a $1.2 million federal share) (*2*). However, no LCA or construction schedule is in place.

MOBILE HARBOR, ALABAMA

Situated at the mouth of Mobile River and the head of Mobile Bay, Mobile Harbor is one of the nation's largest export ports, handling over 37 million tons of cargo annually (based on the most recently published data from the Army Corps of Engineers) (*11*). Mobile's role as an export center is enhanced by its access to the U.S. agricultural and industrial heartland via the Gulf Intracoastal and Tennessee-Tombigbee waterways, as well as by a vast inland river network. Commodities transshipped at the port are primarily bulk products: coal and lignite, gasoline, fuel oil, iron ore, crude petroleum, limestone, sand, gravel and crushed rock, soybeans, corn, and wheat (*11*).

The economies of scale enjoyed by large bulk carriers and the resulting transportation cost savings have been used to justify past and continuing investment in channel improvements. Large coal vessels calling at McDuffie Coal Terminal, in particular, require channel deepening and navigational improvement features for safe and efficient transits. Savings of $5 to $6 per ton on coal exports to Europe and $16 per ton on shipments to Japan would be realized by using larger bulk vessels (in the 100,000+ deadweight tonnage range) (*14*). Coal exports are expected to reach 19 million tons annually by 2015, pushing Mobile's total cargo throughput to 45 million tons (*2*).

Improvements to Mobile Harbor were authorized in the 1985 Supplemental Appropriations Act and WRDA 86. The authorization provides for deepening and widening the existing ship channel from 40 by 400 ft to 55 by 550 ft along the present ship channel alignment. The ship channel extends from the Gulf of Mexico through Mobile Bay to the Mobile River for 39 mi (see Figure 7). The total estimated cost of the entire project is $482 million (of which $213 million would be federal) and will require the excavation of 121 million yd^3 of dredged material.

The project will be constructed in phases. The LCA signed in June 1986 between the state of Alabama and the Army Corps of Engineers (and subsequently amended in 1987) applies only to the first phase. Phase I consists of deepening the bar channel to 47 by 600 ft and the bay channel to 45 by 400 ft from the Gulf of Mexico to the vicinity of the McDuffie Coal Terminal in Upper Mobile Bay, a total length of approximately 37 mi. Because Phase I does not include widening the channel and because of the reduction in deepening from the original 55 to 45 ft, Phase I will require excavation of only 18 million yd^3 (versus the original 121 million yd^3). This downsizing also produced a corresponding reduction in estimated construction costs: Great Lakes Dredge and Dock Company won the $38.2 million contract in May 1987 ($28.7 million of this amount will be funded by the federal government). This cost represented only 8 percent of that originally estimated for the total project.

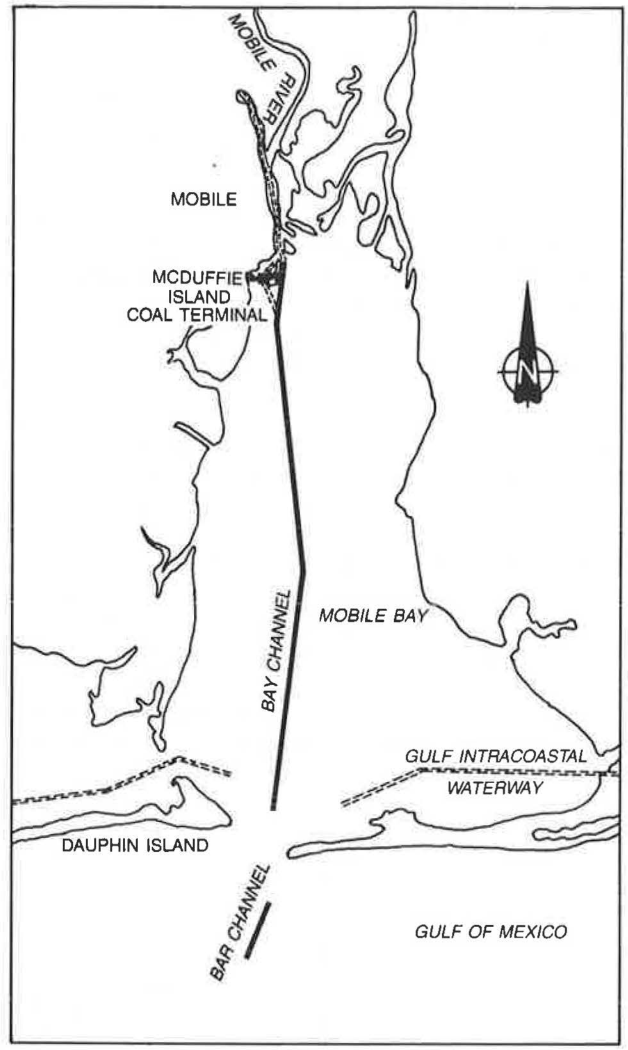

FIGURE 7 Mobile Harbor deepening project.

Dredging commenced in October 1987. The Great Lakes Company developed a larger, more efficient clamshell dredge for the Mobile project, capable of excavating 50 yd^3 per movement (*3*). Because of the dredge's enhanced capacity and speed, Phase I is 35 percent complete and on schedule, and should be completed by June 1990. The remaining authorized project (unofficially dubbed Phases II and III, which would bring the bay channel down to 50 and 55 ft, respectively) is currently unscheduled. Future construction depends on the availability of local funds from the state of Alabama.

The material being dredged from Mobile Harbor will be placed in an offshore stable berm structure south of Dauphin Island, Alabama, as part of an ongoing study on the beneficial uses of dredged material. The underwater berm structure is expected both to provide fish habitat and to reduce the height of potential storm waves.

MISSISSIPPI RIVER SHIP CHANNEL, GULF TO BATON ROUGE

The ports of New Orleans and Baton Rouge, Louisiana, are the largest and fifth largest in the United States, respectively, on the basis of the most recent traffic statistics published by the U.S. Army Corps of Engineers (*11*). Situated at the confluence of shallow-draft (mostly domestic) barge traffic and deep-draft (mostly foreign) ocean-going traffic on the lower Mississippi River, both ports are major bulk centers for the import and export trades. Primary commodities handled by the ports include crude petroleum, petroleum products, chemicals, fertilizers, coal, wheat, corn, feed grains, soybeans, iron and aluminum ores, and sulfur (*11*).

Before initiation of Phase I deepening (identified below), depth restrictions imposed by the then-existing deep-draft approaches to the ports of New Orleans and Baton Rouge prevented an increasing percentage of vessels in the world fleet from navigating the approaches fully loaded. This limitation, together with the projected increase in commerce through the ports, justified initial deepening (*2*). In addition, transportation cost savings resulting from the employment of larger or more fully loaded bulk vessels contribute to the overall benefits from improved navigation.

The Mississippi River Ship Channel project was authorized by the Supplemental Appropriations Act of 1985. WRDA 86 formalized the cost-sharing provisions and gave the local sponsors the right to charge user fees to recoup their share of the cost. The authorized project calls for deepening the channel from 40 to 55 ft and widening it to 750 ft from the Gulf of Mexico through the Southwest Pass to Baton Rouge, Louisiana, at River Mile 233 above head of passes (AHP); the total estimated cost was $490 million ($120.7 million federal). See Figure 8 for a map of the project area.

In addition to the increased channel dimensions, the plan includes the construction of an underwater sill of dredged fill across the Mississippi River at River Mile 63.7 AHP. Its purpose is to mitigate the increased saltwater intrusion into the New Orleans metropolitan area's water supply during the river's low-flow periods. The submarine sill was constructed and functioned for the first time as planned during the record-breaking drought of 1988. A permanent plan to mitigate the increased saltwater intrusion into the water of towns downstream of the sill in the lower Delta area is currently being negotiated with the state of Louisiana and Plaquemines Parish. In the interim, fresh water was shipped by barge to the area in 1988 and will be in the future, if needed.

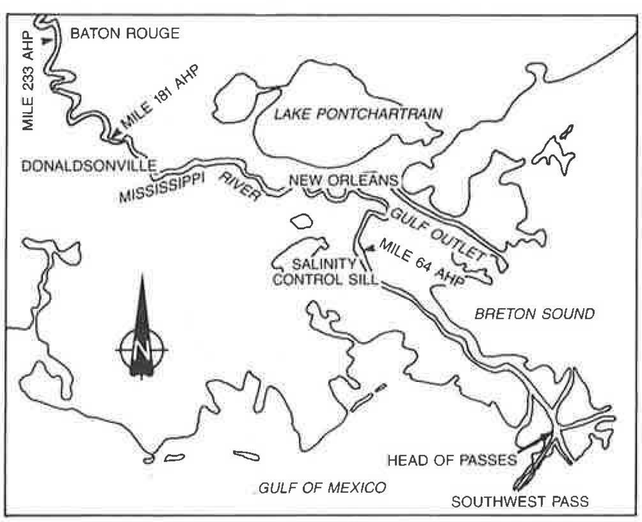

FIGURE 8 Mississippi River Ship Channel, Gulf to Baton Rouge, deepening project.

As in several other ports, the LCAs signed between the state of Louisiana and the Corps of Engineers in 1986 and 1987 provide for only a segment of the authorized project: the so-called Phase I. This consists of a channel 45 ft deep by 500 to 600 ft wide from the Gulf to River Mile 181 AHP near Donaldsonville, Louisiana. Dredging was initiated in July 1987 and completed by the end of 1988 at a total cost of just $39 million, a savings of about $21 million under the original cost estimates for Phase I. Dredged material from construction of the project was used for bank nourishment and the creation of marsh.

Construction beyond Mile 181 AHP and deeper than 45 ft is dependent upon the negotiation of additional LCAs between Louisiana and the Corps of Engineers. The state of Louisiana has requested that the Corps proceed with preparation of the LCA for the extension of the 45-ft channel to Baton Rouge. Construction will most likely proceed in 1991, pending LCA approval and the state's ability to provide its required funds. The deepening of the channel beyond 45 ft remains unscheduled (*2*).

FREEPORT HARBOR, TEXAS

The port of Freeport, Texas, is located just upstream of the mouth of the Old Brazos River and the Gulf of Mexico (see Figure 9). The port has handled an average of over 17 million tons of traffic annually during the last 10 years. Crude petroleum makes up nearly 70 percent of the port's cargo, followed by chemicals and petroleum products (*11*). Major users of the existing project, and hence major beneficiaries of proposed channel improvements, are the bulk vessels serving Freeport's numerous petroleum storage facilities and the massive Dow Chemical Company complex.

Improvements to Freeport Harbor were authorized by the 1970 River and Harbor Act and the 1985 Supplemental Appropriations Act. Plans call for deepening, realigning, and enlarging the 7-mi entrance channel from 38 by 200 ft to 47 by 400 ft and the jetty and main channels from 36 by 200 ft to 45 by 400 ft. Three turning basins would also be deepened to 45 ft. The Brazos Harbor channel and turning basin would be dredged from 30 to 36 ft. Part of the project includes relocating the 3,700-ft north jetty and rehabilitating the south jetty, both of which protect the entrance channel. A U.S. Coast Guard station would also have to be relocated.

Justification for this project was based on transportation cost savings that would result from the use of larger and more fully loaded vessels, primarily oil tankers. The current 36-ft-deep and 200-ft-wide channel is deemed inadequate and unsafe for larger vessels, many of which will not call at Freeport. This problem will only be compounded as the average size of vessels in the world fleet increases. Because of the hazards of narrow channels, sharp curves, and limited maneuvering

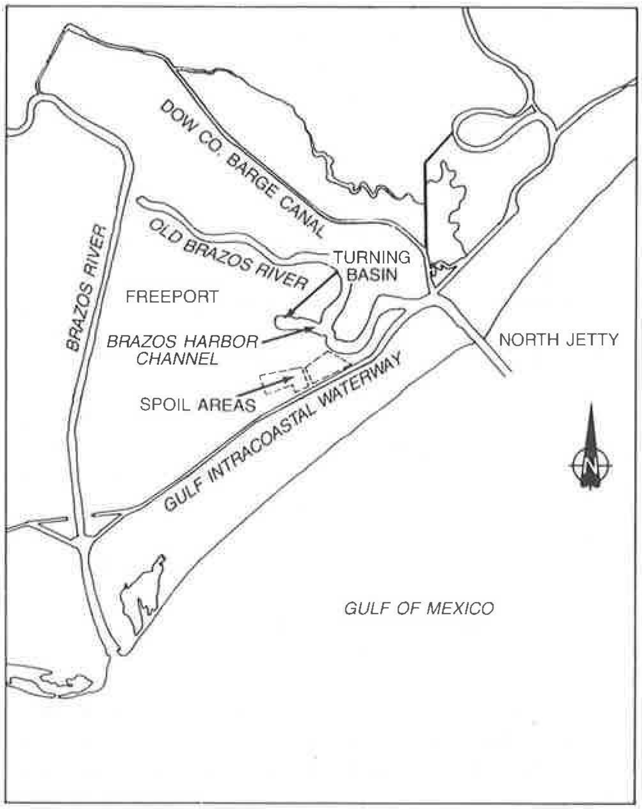

FIGURE 9 Freeport Harbor, Texas, deepening project.

areas in the existing turning basins, deep-draft vessel movements are limited to one-way traffic, with no passing or meeting in the channels inland from the jetty entrance. Strong crosswinds and currents, and periods of fog or other adverse weather may delay or prevent traffic from entering or leaving the jetty channel at all. To minimize these risks, vessels are operated at low or dead-slow speeds, which in turn sometimes leads to loss of effective rudder control. Harbor tugs are necessary to maneuver and assist vessels in the turning basins (*2*).

Because of the perceived necessity of these harbor improvements for economic and safety reasons, the LCAs signed in 1986 and 1987 between the Corps of Engineers and the Brazos River Harbor Navigation District, the local sponsor, provide for full construction of the authorized project. Construction of the new north jetty, relocated 640 ft north of its present alignment, started in May 1987 and is currently 50 percent complete. Progress was unexpectedly halted when a shipwreck site was discovered within the alignment of the jetty. The site was determined to be eligible for inclusion in the National Register of Historic Places. The jetty contractor will leave a gap in the new jetty until the shipwreck recovery operations are complete. Dredging of the first channel deepening, the Brazos Harbor Channel and turning basin, will commence in 1989. The local sponsor is nearing completion of dredged material disposal area levees. The entire authorized project is scheduled and should be completed by 1992 at an estimated cost of $88.2 million (of which $58.5 million is federal).

LOS ANGELES AND LONG BEACH HARBORS, SAN PEDRO BAY, CALIFORNIA

The Los Angeles and Long Beach Harbors complex is one of the most extensive in the world. Commercial cargoes passing through the ports include a wide range of commodities, which totaled more than 90 million tons in 1987. More than half of the total consists of crude petroleum and petroleum products. Other major commodities include chemicals, coke, cement, iron and steel products, automobiles, electrical machinery, miscellaneous manufactured goods, and food products (*11*). Of particular importance to the ports is the phenomenal increase in high-value container traffic through Los Angeles and Long Beach, which grew at an average annual rate of more than 20 percent in the 1980s. The combined volume of more than 3 million container TEUs ranks these ports as the second largest container ports in the world (*16*).

Improvements to the harbors of Los Angeles and Long Beach (LA/LB) were authorized by Congress in WRDA 86, subject to a favorable report by the Chief of the Army Corps of Engineers and the determination of federal interest in the project. WRDA 86 authorized channel deepening to 70 ft at Los Angeles and 76 ft at Long Beach and the creation of 800 acres of landfill with dredged material. The Water Resources Development Act of 1988, signed into law in November 1988, modified the authorization to the effect that the ports may receive financial credit for advance construction (i.e., in advance of the Corps' final feasibility report, which is scheduled for completion in the summer of 1989).

The comprehensive "2020 Master Plan" for the ports calls for $1.2 billion worth of construction to handle the anticipated doubling of waterborne traffic to 205 million tons by the year 2020 (*2*). (If a federal interest in the project is in fact determined, the federal share would amount to about half of all channel dredging costs, or $183 million.) Together, both ports plan to create some 2,500 acres from dredged material, filling one-fifth of San Pedro Bay (*17*). Construction will be implemented in five phases, the first of which is deepening Long Beach Channel from 62 to 76 ft and widening it to 1,000 to 1,200 ft. The objective of this increment would be to improve access to the existing liquid bulk (petroleum) terminals at Berth 121 and to use the 15.6 million yd^3 of dredged material as landfill for a 146-acre seaward extension of the Pier J container terminal (*18*). Long Beach started work in September 1988 on 2 mi of dike to support the landfill. Completion of Phase I by 1991 is estimated to cost about $145.7 million (of which only $33 million is eligible for reimbursement by the federal government).

As previously mentioned, the project would ultimately consist of five phases, to be constructed through 2010. Subsequent deepening of Los Angeles Channel in phases from 52 to 72 ft, the creation of two new 66-ft channels and one 50- ft channel, and the creation of 650 additional acres for harbor expansion are components of the proposed final federal project (see Figure 10). The federal interest in the LA/LB project would be in dredging the existing navigation channels to realize transportation cost reduction benefits from using larger, more efficient deep-draft vessels, particularly oil tankers. The ports would receive additional benefits from using the dredged material as landfill on which to construct new bulk cargo and container terminals. This in turn would enable the ports to handle additional vessels, reduce congestion, mini-

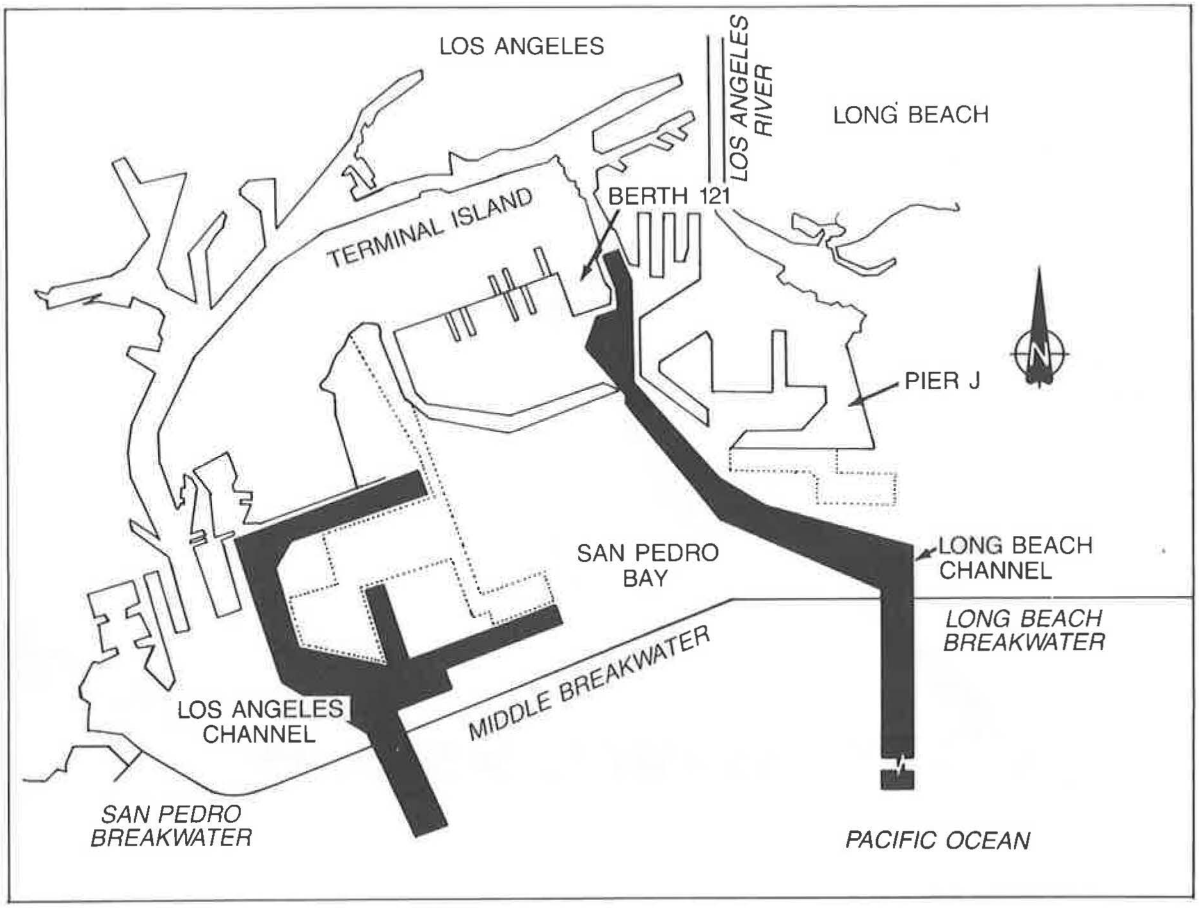

FIGURE 10 **Los Angeles and Long Beach harbors deepening project.**

mize transportation delay of container shipments, and redivert containers to the LA/LB area that were not able to be accommodated because of capacity constraints on existing lands (*18*).

An additional benefit from this project is the plan by the Port of Los Angeles to construct a 106-acre landfill island as a crude-oil-handling facility. Alaskan crude oil that is currently shipped via the Panama Canal pipeline to the U.S. East and Gulf coasts could be diverted to PacTex Island, as the facility is called, and then transported through the soon-to-be-completed Pacific Texas (PacTex) pipeline to Texas. Benefits are derived from the projected decrease in transportation transit times and costs resulting from the diversion of crude oil from the Panama Canal pipeline to the PacTex pipeline.

OAKLAND HARBOR, CALIFORNIA

Oakland Harbor is the fifth-largest container port in the United States, handling more than 8 million tons of cargo and nearly 1 million container TEUs in 1987 (*16*). The port, which boasts 28 vessel berths and 21 container cranes, services 85 percent of all general cargo moving through San Francisco Bay. Commercial cargo is varied, but the majority consists of iron and steel products, petroleum products, chemicals, plastics, food products, fresh and frozen fruits and vegetables, cotton, and machinery (*11*).

Federal involvement in Oakland Harbor dates back to 1874, when jetties were constructed along the entrance to the Oakland estuary. Although subsequent dredge and fill operations lowered the channel to a depth of 35 ft, the existing federal navigation channel is considered inadequate for efficient shipping operations and vessel safety. The trend toward larger containerships possessing greater economies of scale has made Oakland less accessible to a growing share of the world containership fleet (and therefore less competitive with other ports). Cargo movement by larger, more efficient vessels with lower unit transportation costs is hampered by the need to wait for high tides to avoid grounding hazards. The current plan of improvement is therefore justified on the basis of providing for further development of the harbors, helping to avoid container shipment delays, allowing safe vessel traffic, and providing maximum efficiency of harbor operations (*2*).

The Oakland Inner and Outer Harbor channel improvements were authorized by WRDA 86. The projects were subsequently combined under a single LCA in 1987. The authorized project calls for deepening the Inner and Outer Harbor channels to 42 ft from 35 ft, as well as widening the entrance channel to 1,000 ft, the Outer Harbor turning basin to 1,800 ft, and the Inner Harbor turning basin to 1,200 ft. Approximately 7 million yd^3 of material would be dredged at an originally estimated cost of \$74 million (a \$47.2 million federal share). Figure 11 shows the layout of the harbor channels.

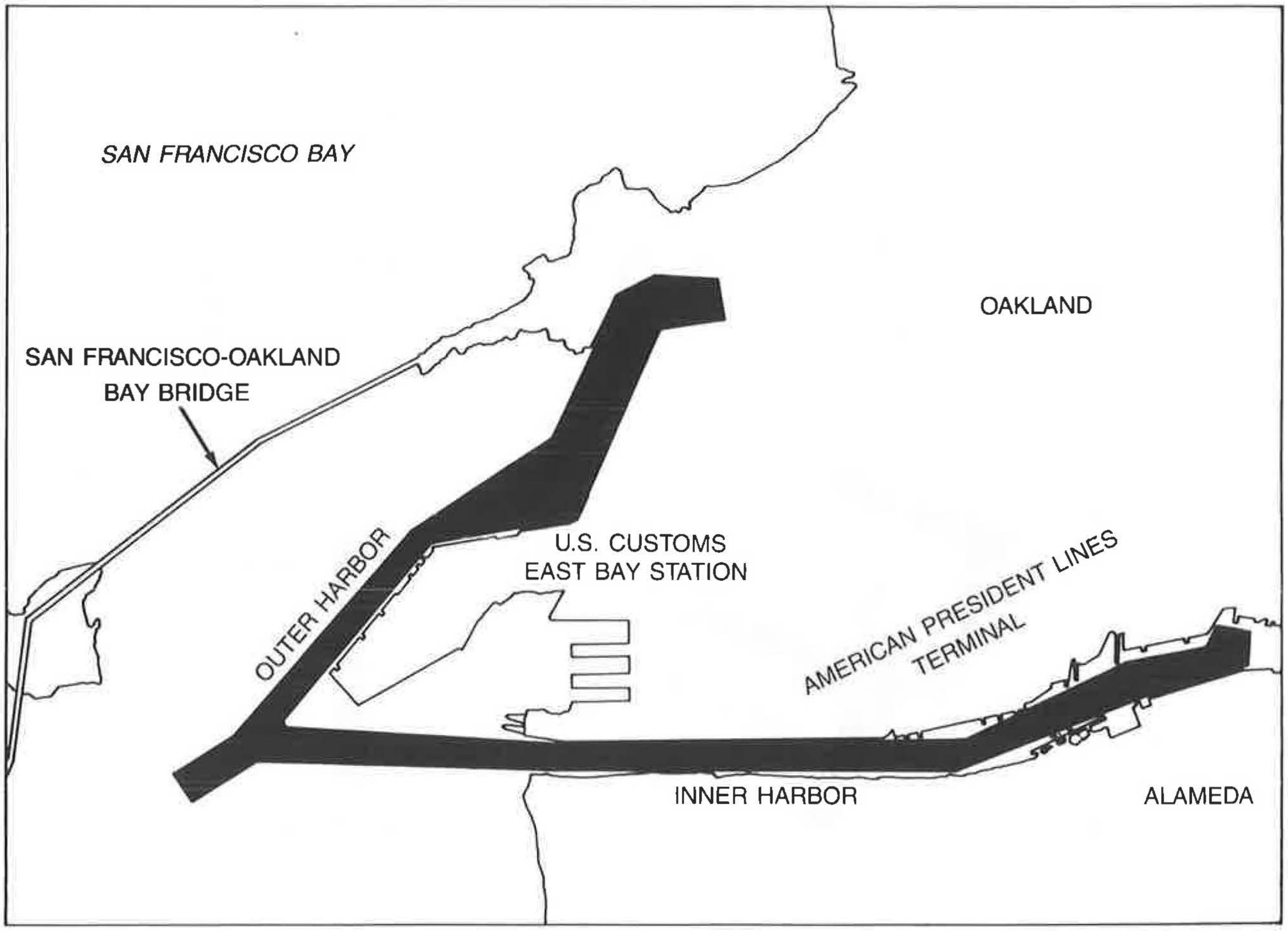

FIGURE 11 Oakland Harbor deepening project.

Phase I of the project, initially scheduled to begin in May 1988, consists of dredging the Inner Harbor channel to 38 ft and constructing a 1,200-ft turning basin to accommodate the new post-Panamax C-10 containerships that began arriving at the American President Line (APL) Oakland terminal in June 1988. Currently, APL's massive vessels must light-load and wait for high tides before docking at Oakland (*19*). Harbor tugs are necessary to maneuver and assist vessels in the turning basins. Phase I involves only 0.5 million yd^3 and would have taken just 90 days to complete.

No sooner had the dredging commenced in May 1988, however, before a local fishermen's association brought a court injunction against the port, halting all dredging. The dredged material disposal site is located outside San Francisco Bay, 11 mi off Pillar Point at Half Moon Bay, in 50 ft of water. The site was selected by the Corps of Engineers with the approval of the Environmental Protection Agency. The local fishermen objected to the site, however, claiming that nearby prime fishing grounds would be endangered. Since then, state and local governments and the California Coastal Commission have joined in the all-out legal battle (*3*). The port is currently awaiting a decision from the California Water Quality Control Board on the quality of the dredged material and its suitability for an upland disposal site in the San Joaquin River delta area. At this time, the legal questions are still undecided and a disposal site has not been selected. Phase I is behind schedule and further deepening (to 42 ft) of both Inner and Outer harbors is dependent on a resolution of the disposal issue.

CONCLUSION

Although this paper has concentrated on only the 12 ports with ongoing construction, the map in Figure 1 highlights several additional authorized deep-draft channel improvement projects. These "next wave" harbor projects are at various stages in the preconstruction process. Some have already gone through lengthy reconnaissance and feasibility studies, negotiation with local sponsors for cost-sharing, and preconstruction engineering and design. (Some have even received federal appropriations but have been delayed for various reasons.) Projects that are likely to begin construction in 1989 or 1990 include Portsmouth, New Hampshire; Savannah, Georgia; Sacramento, California; Port Manatee, Florida; Gulfport, Mississippi; and Grays Harbor, Washington. At the other end of the spectrum, a few projects, although congressionally authorized, might never get off the ground for lack of federal or local interest. Regardless of status, however, all of these projects warrant further monitoring.

In conclusion, it bears repeating that WRDA 86 represented a watershed: 16 years had passed since the last major authorization bill, and 7 years since the last new construction start. The breaking of the logjam with almost 40 projects in WRDA 86 and the reinstitution of the biannual authorization process with WRDA 88 make this a truly significant period in America's port development.

Similarly, the introduction of local cost-sharing of harbor improvements has had a significant impact on the way projects

TABLE 1 SUMMARY OF DEEP-DRAFT HARBOR PROJECTS

	Originally Authorized Project		Phased Project		
Project Name	Scope	Estimated Cost ($ millions)	Scope	Revised Cost ($ millions)	Current Status
Kill Van Kull/Newark Bay	Deepen to 45 ft	342	Deepen to 40 ft	212	Under construction
Delaware River near Camden, NJ	Deepen to 37 ft	2.2	No phasing	—	Completed
Baltimore, MD	Deepen to 50 ft	330	Deepen to 50 ft, reduced channel widths	246	Under construction
Norfolk, VA	Deepen to 55 ft	232	Phase I: Deepen to 50 ft outbound	33	Completed
Charleston, SC	Deepen to 40 ft	125	No phasing	—	Under construction
Ponce, PR	Deepen to 36 ft	10.4	No phasing	3	Completed
Tampa, FL	Deepen four channels to 41 ft	52	Deepen one channel to 41 ft	13	Under construction
Mobile, AL	Deepen to 55 ft	482	Deepen to 45 ft	38	Under construction
Mississippi River Ship Channel	Deepen 55 ft to Baton Rouge	490	Deepen 45 ft to Donaldsonville, La.	39	Completed
Freeport, TX	Deepen to 45 ft	88	No phasing	—	Under construction
Los Angeles/Long Beach, CA	Deepen LA to 70 ft, LB to 76 ft	560	Deepen one channel to 76 ft	146	Under construction; federal interest pending
Oakland, CA	Deepen Inner and Outer channels to 42 ft	74	Deepen one channel to 38 ft	Undetermined	Delayed; in litigation

are conceived, designed, and ultimately built. Local sponsors are playing an active role in project planning and, in many cases, have scaled down their needs in the face of escalating construction costs. Dredging channels to shallower depths than their fully authorized dimensions, at least in the initial construction phases, was a cost-saving method employed by local sponsors in the Kill Van Kull/Newark Bay, Norfolk, Tampa, Mobile, Mississippi River Ship Channel, Los Angeles/Long Beach, and Oakland projects. The state of Maryland opted to dredge Baltimore's shipping channels to the fully authorized depths but minimized costs by scaling back the channel widths. In addition, most of the projects benefited from an exceptionally competitive climate in the private dredging industry, resulting in substantially lower construction costs than had been estimated. Table 1 summarizes the phasing and cost-saving elements for each of the ongoing projects.

In the new world of cost-sharing, the goal has become to maximize the economic benefits while keeping project costs within the reach of local sponsors. It has therefore become increasingly important to develop more sophisticated techniques to evaluate a project's economic impacts and ensure that scarce local dollars are spent more wisely. It will take months or even years to begin to fully assess the impacts of these new harbor-deepening projects. Those now under construction have local and federal support and will most likely be completed. Some, but not all, of those authorized will be constructed. Further updates will be necessary.

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Economic Analysis for Long-Term Operation and Maintenance of a Waterway: The Case of the Monongahela River

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Recent advances in navigation planning emphasize systemwide economic analysis as the appropriate context for estimating benefits of improving a single navigation facility within the system. These planning techniques ensure that the benefits to improving any one navigation project are net of the costs that may be induced by other other system projects. For example, the economic benefits of expanding capacity at one lock are estimated net of delay costs at other navigation facilities induced by the additional traffic drawn to the waterway by improvements to the first lock. Despite these advances, navigation planning continues to emphasize identifying and solving problems at single facilities rather than formulating a plan for continued operation, maintenance, and improvement of the entire system. The results of a study incorporating elements of a systemwide planning approach are presented. Specifically, an economic analysis of the long-term operation and maintenance of the Monongahela River navigation system is described. Consisting of nine locks and dams, this system currently has five facilities that will require major rehabilitation or replacement to continue navigation during the next 50 years. The analysis demonstrates the economic justification for improving two of them (Locks and Dams 7 and 8) as the first component of a 50-year system plan that incorporates operation, rehabilitation, and replacement at the other seven facilities.

During the 1970s, navigation planners in the U.S. Army Corps of Engineers made enormous strides in systems analysis of lock capacity expansion. Based on the pioneering efforts of Howe, Carroll, Bronzini, and others (*1*, *2*), the first preauthorization planning study to apply systems analysis techniques—the Gallipolis locks and dam study (*3*)—was completed in 1980. This study evaluated alternatives for expanding capacity at Gallipolis using a model of the U.S. waterway system. In 1982 the Upper Mississippi River Basin Commission provided an economic evaluation of capacity expansion within the context of a waterway system model (*4*).

Although capacity expansion continues to be an important Corps planning problem requiring the application of systems analysis methods, aged and decaying navigation facilities are posing new analytic challenges during the 1980s. Within the Ohio River navigation system alone, the average age of 60 navigation projects is 50 years. The age of 31 of these 60 locks and dams is at least 50 years, the design life of navigation facilities. As detailed engineering condition studies of older projects have progressed, long-term, dependable maintenance of the waterway system has become an important feature of the Corps navigation planning program.

For example, in condition studies of Locks and Dams 7 and 8 on the Monongahela River, it was found that major investment will be essential to continued, reliable navigation at these projects (*5*). The Corps' North Central Division has faced similar problems on the Illinois Waterway and the Upper Mississippi River. In 1984 the Rock Island District completed the first of a series of reports documenting the need for rehabilitation of navigation facilities on the Illinois (*6*). In 1985 the Louisville District of the Ohio River Division completed a study of Locks and Dams 52 and 53 on the lower Ohio River (*7*). This study addressed both lock capacity requirements and the consequences and costs of potential component failure at these two critical projects. Risk or "probability of failure" analysis was applied to the two locks and dams within the context of a comprehensive benefit-cost analysis of the Ohio River navigation system.

This paper presents an economic evaluation of the stream of investment in construction and rehabilitation, as well as annual operation and maintenance expenditure, necessary to continue long-term navigation on the entire Monongahela River. Supplementing the Pittsburgh District's feasibility report for Locks and Dams 7 and 8 on this river, the analysis demonstrates that system benefits for continued navigation over the planning horizon significantly exceed the economic costs of this plan.

Projected long-term improvements to the Monongahela River include the recommended improvements for Locks and Dams 7 and 8 as well as major maintenance or replacement at each of the other seven locks and dams on the river. Modernization of Locks and Dams 7 and 8 is shown to be justified not only when analyzed independently from system investment costs but also when considered as the first step in a long-term program for the entire Monongahela system.

This paper differs from most of the previously cited studies of aged, deteriorating projects in that detailed risk assessment techniques were not applied. Instead, preliminary results of detailed engineering studies and the Pittsburgh District's extensive experience with maintenance and rehabilitation were used to develop a forecast of future actions to sustain Monongahela River navigation. Detailed engineering studies, including risk assessment, are currently under way and will

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form the basis for more specific future recommendations at particular projects. As in the previously cited studies, transportation benefits for the forecast maintenance plan are rate savings to commercial navigation traffic on the Monongahela River (*5*).

The next three sections present background information on the Monongahela River navigation system, modernization projects previously undertaken, the Locks and Dams 7 and 8 study, and improvement studies currently under way. The motivation and conceptual framework for the economic analysis of continued navigation on the river is presented, and the remaining sections discuss the development of costs and benefits attributable to a long-term plan of investments and annual operation and maintenance expenditures for continued navigation during the period 1990 to 2040; the benefit-cost analysis; and brief evaluation of the level of confidence inherent in the study's results and the potential role of this methodology in other navigation planning contexts.

MONONGAHELA RIVER NAVIGATION SYSTEM

The Monongahela River rises in northeastern West Virginia and flows north into western Pennsylvania to join the Allegheny River in forming the Ohio River at Pittsburgh. By means of a system of nine locks and dams, the Monongahela River navigation project provides a minimum navigation depth of 9 ft throughout the entire 129-mi length of the river from Pittsburgh, Pennsylvania, to Fairmont, West Virginia (Figure 1). Federal interest in the river was established in 1872 with the construction of two locks and dams on the upper river and was renewed in 1896 when Congress authorized acquisition of the original seven locks and dams constructed on the lower river by the Monongahela Navigation Company, a private enterprise. Summary data on the present system are shown in Table 1. Locks and Dams 2 through 8 are in Pennsylvania; the other three are in West Virginia.

The Monongahela River carries more tonnage than any other Ohio River tributary and is one of the great industrial waterways of the world. Several municipalities have provided terminals along the river. A modern river freight terminal is located on the riverfront in Pittsburgh. A large number of private dock facilities are maintained for the handling of coal and coke, sand and gravel, iron and steel products, petroleum products, and other commodities. In 1984, 34.5 million tons of waterborne commerce used the Monongahela River navigation system. Figure 2 shows the distribution of this tonnage by commodity. Additional information related to historic commodity movements and forecasts of future traffic demand for the Monongahela may be found in the Locks and Dams 7 and 8 interim feasibility report (*5*).

MODERNIZATION EFFORTS

The current modernization program for the Monongahela River navigation system continues work begun with the reconstruction of Locks and Dam 2, started in 1949. Since then, the river above Locks and Dams 7 and 8 has been improved by constructing new navigation facilities: Morgantown Lock and Dam (1950), Hildebrand Lock and Dam (1960) and Opekiska Lock and Dam (1964). Each of these facilities has a single 84-ft by 600-ft lock chamber and a gated dam. On the middle river below Lock and Dam 7, the new Maxwell Locks and Dam was placed in operation in 1964. Maxwell also has a gated dam but, unlike the upper river locks and dams, has twin lock chambers, each 84 ft wide by 720 ft long. The dam at Locks and Dam 2 and Locks and Dams 3, 4, 7, and 8 are now the oldest facilities in the system (see Table 1). At both Locks and Dams 3 and 4, the main chambers are 56 ft wide by 720 ft long, and the auxiliary chambers measure 56 ft wide by 360 ft long. At each of Locks and Dams 7 and 8, the lock chamber is 56 ft wide by 360 ft long with no auxiliary chamber.

The age, physical condition, and stability of these projects present significant potential challenges to maintaining dependable navigation service. In addition, because the chambers were designed to handle standard-size barges (26 ft wide by 175 ft long), these locks pose severe restrictions on the use of jumbo barges (35 ft long by 195 ft long). Jumbo barges are more competitive in today's water transportation markets because they carry larger loads and are efficiently accommodated within the chambers at locks on the mainstem Ohio, Tennessee, and Upper Mississippi rivers.

In response to the problems of age, project condition, and lock size, recent Corps planning studies have concentrated on Locks and Dams 3, 4, 7, and 8 together with Locks and Dam 2 where the age and condition of the dam are expected to warrant near-term investment. Preauthorization planning for the modernization of Locks 2, 3, and 4 is continuing. As previously noted, the Pittsburgh District completed a feasibility study for the improvement of Locks and Dams 7 and 8 in early 1984 (*5*). Because the analysis described in this paper was undertaken to supplement the feasibility study, the Corps' findings and recommendations will be summarized as background for subsequent discussions.

LOCKS AND DAMS 7 AND 8 STUDY

The feasibility study found that severe physical deterioration of Locks and Dams 7 and 8 has resulted from adverse weather conditions, acidity of water due to acid mine drainage, and the age of the structures. Costly operation and maintenance were anticipated, and engineering studies indicated significant risks associated with continued reliance on the structures to maintain navigation service in the future. Damage to the concrete guide, guard, and lock walls at both structures was found to be extensive, and detailed engineering studies demonstrated that components were seriously deficient in their overall structural stability. Valves, miter gates, operating controls, and embedded concrete were deteriorated. In addition, the concrete apron at Dam 7 was found to be undermined for most of its length. The concrete spillway at Dam 7 was also severely eroded over its surface and leakage occurred through the monoliths. Although the structural condition of Dam 8 was found to be generally good, exposed concrete was deteriorated and scouring has occurred downstream of the dam apron. The right abutment was found to have stability problems and to be in poor condition. Condition studies concluded that replacement or rehabilitation of the structures is needed as soon as possible but not later than the early 1990s.

The existing 56-ft by 360-ft locks were found to be incommensurate with the size of barge tows using the waterway.

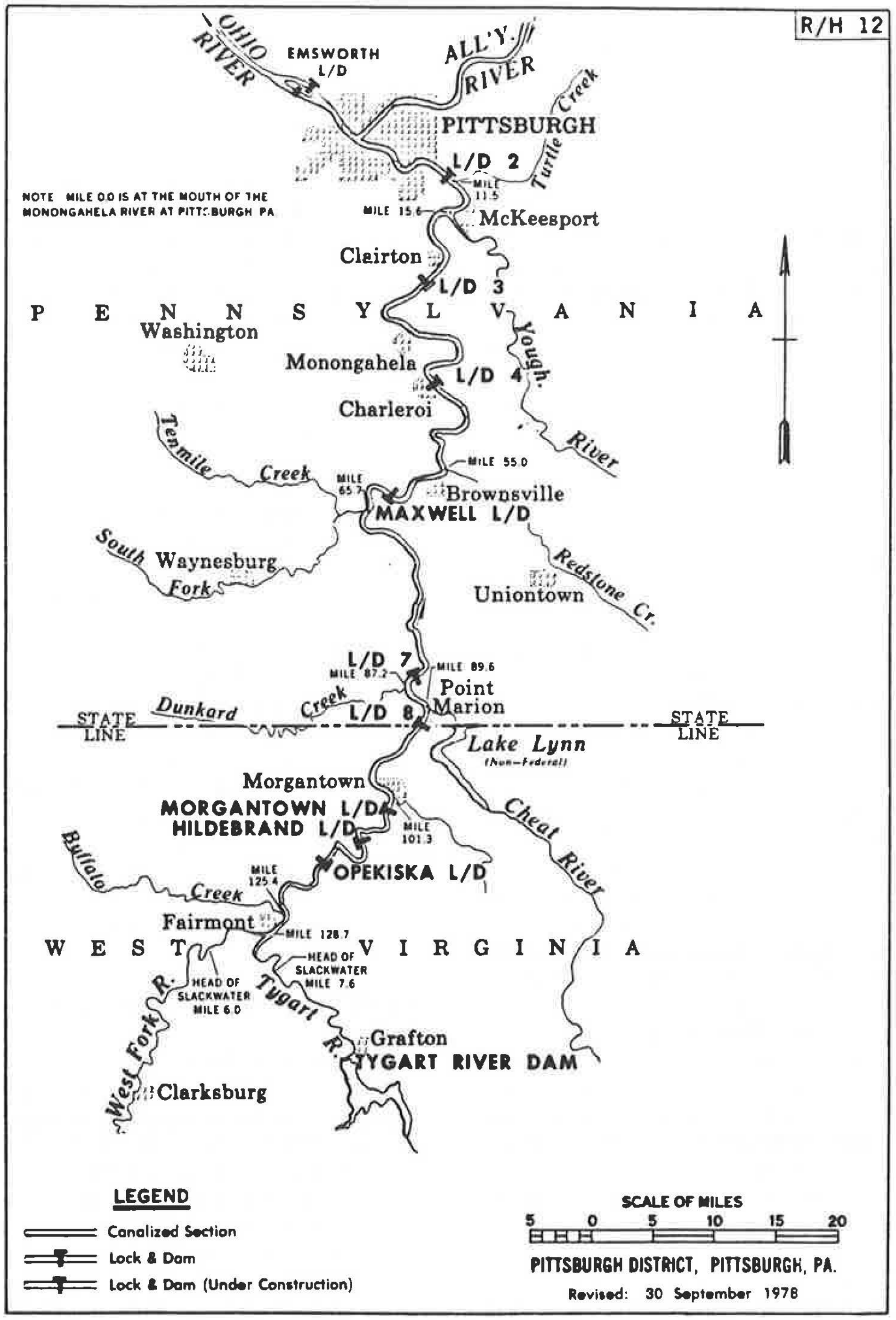

FIGURE 1 Index map of Monongahela River river and harbor project.

Larger locks are needed to facilitate passage of projected traffic and larger tows, to improve operating efficiency by elimination of double lockages, and to reduce existing and future tow delays and related tow operating costs.

The Pittsburgh District considered an extensive array of structural and nonstructural measures to address these problems. These alternatives included several plans for continued rehabilitation, maintenance, and operation of the existing structures and several replacement plans with various lock sizes. The District Commander recommended construction of a new lock and fixed crest dam to replace existing Lock and Dam 7 and a new, replacement lock chamber at Lock and Dam 8 to be built landward of the existing lock. The new lock and dam replacing Lock and Dam 7 would be named Grays Landing Lock and Dam. Lock and Dam 8 would be renamed Point Marion Lock and Dam.

The District's recommended plan was identified as the National Economic Development (NED) plan—the plan that maximizes net benefits. In the feasibility report, total annual benefits of the plan were $61,200,000 and total annual costs

TABLE 1 MONONGAHELA RIVER NAVIGATION SYSTEM: PROJECT CHARACTERISTICS

Locks & Dam	River Mile	Up Pool Elev.	Lock Size Main[a]	Lock Size Aux[a]	Year Opened	Pool Length[b]
No. 2 [c]	11.2	718.7	110 x 720	56 x 360	1906	12.7
No. 3 [d]	23.8	726.9	56 x 720	56 x 360	1907	17.7
No. 4 [e]	41.5	743.5	56 x 720	56 x 360	1932	19.7
Maxwell	61.2	763.0	84 x 720	84 x 720	1964	23.8
No. 7	85.0	778.0	56 x 360	None	1925	5.8
No. 8 [f]	90.8	797.0	56 x 360	None	1925	11.2
Morgantown	102.0	814.0	84 x 600	None	1950	6.0
Hildebrand	108.0	835.0	84 x 600	None	1960	7.4
Opekiska	115.4	857.0	84 x 600	None	1964	13.3

a. In feet

b. Length in miles; pool depth is 9 feet.

c. Locks reconstructed 1949-1953; original dam (1906) remains in service

d. Major rehabilitation of locks completed, 1984

e. Dam reconstructed, 1963-1967

f. Dam reconstructed and crest raised, 1958-1959

were $15,900,000, giving net benefits of $45,300,000 and a benefit/cost ratio of 3.8 based on 8⅛ percent interest and 1983 price levels.

The Division Commander subsequently concurred with the District's report and recommendation, the Board of Engineers for Rivers and Harbors approved in March 1984, the Chief of Engineers concurred in September 1984, and the Assistant Secretary of the Army (Civil Works) forwarded the recommendation to Congress in July 1986. The recommended replacement projects were authorized for construction by the Water Resources Development Act of 1986 (Public Law 99-662). Construction was initiated on the new Grays Landing Lock and Dam in fiscal year 1988 and is scheduled to start at Point Marion in fiscal year 1990.

CONTINUED OPERATION OF MONONGAHELA RIVER NAVIGATION SYSTEM

Replacements for Lock and Dam 7 and Lock 8 will meet only the most immediate needs for continuing navigation on the Monongahela River. Ongoing studies indicate that the age, condition, and lock sizes of Locks and Dams 2, 3, and 4 will require additional investment in the future. Following completion of the Locks and Dams 7 and 8 study, it became clear that the investments recommended at these two projects should be placed in the context of a long-term plan for continued navigation on the entire river. If the benefits to Monongahela River navigation exceed the economic costs of this plan or projected stream of investments and annual operation and maintenance, the recommendations at Locks and Dams 7 and 8 are not only justified under standards applicable to project planning but also warranted under criteria appropriate for long-term systems planning.

The economic costs of a projected schedule of investments and annual operation and maintenance for continued navigation are described next. This forecast was based on preliminary results of ongoing detailed investigations of Locks and Dams 2, 3, and 4; the completed study of Locks and Dams 7 and 8; and the construction, rehabilitation, and maintenance experience of the Pittsburgh District.

ECONOMIC COSTS OF CONTINUED NAVIGATION

The overall age and general condition of each component of the Monongahela River navigation system were reviewed to

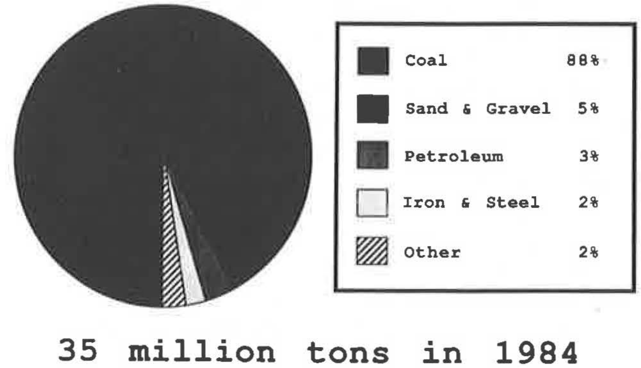

FIGURE 2 Monongahela River commodity traffic.

develop a forecast of future actions for continued safe and reliable operation throughout the analysis period, 1990–2040. This period was chosen to conform with the analysis period for Locks and Dams 7 and 8. In addition to normal operation and maintenance, projected requirements include extraordinary maintenance such as the repair or replacement of major facility components and the rehabilitation or replacement of entire projects as required by sound engineering and maintenance practices.

In developing this investment schedule, it was projected that major rehabilitation would be required at or shortly after the 60th year of each project's life. This time frame is consistent with the Pittsburgh District's experience in the ongoing rehabilitation program on the upper Ohio River and has been confirmed by detailed engineering and condition studies conducted to date. The replacement of existing Lock and Dam 7 and Lock 8, as recommended in the 1984 feasibility report, is also included in the projected schedule of investments. In addition, the age and overall condition of three of the existing facilities are forecast to require replacement-in-kind: the fixed crest dam at Locks and Dam 2 (opened in 1906), both the locks and the dam at Locks and Dam 3 (opened in 1907), and the locks at Locks and Dam 4 (opened in 1932).

Rehabilitation and replacement are also expected to require temporary closures of lock chambers, which would delay or interrupt traffic to varying degrees in the future. Additional costs likely to be incurred by river shippers during these lock closures are reflected in this analysis.

The following required work has been forecast at each of the Monongahela facilities:

Locks and Dam 2: A new fixed crest dam (estimated cost, $53,700,000) would be constructed to replace the existing 81-year-old structure and major rehabilitation would be performed on both locks (estimated cost, $19,900,000), both in 2010. During lock rehabilitation, the large, landward lock chamber would be closed for about 6 months, and all river traffic would use the small auxiliary chamber. This would result in navigation delays and an increase in shipping costs estimated at $47,800,000.

Locks and Dam 3: Notwithstanding the rehabilitation work completed in 1980, the present age (80 years) and the overall condition of this facility would require replacement-in-kind at a cost of $187,500,000 in 2000. During construction of the replacement facility, which would be located as close to the existing facility as possible, normal traffic would be maintained with no appreciable delays.

Locks and Dam 4: Considering the present age of this project (54 years) and the overall condition of the locks, replacement-in-kind would be necessary in 2005 at an estimated cost of $108,700,000. The existing gated dam, reconstructed during 1963–1964, would be rehabilitated in 2030 at an estimated cost of $3,000,000. During in-kind replacement of the locks, closure of one or both existing locks would be required periodically. These interruptions and delays to traffic would increase costs to shippers by an estimated $64,800,000 over a 3-year period.

Maxwell Locks and Dam: The Maxwell facility would require major rehabilitation in 2030 at an estimated cost of $24,900,000. During rehabilitation, each lock chamber would be closed to traffic for a successive period of 6 months. Closure of the locks would result in traffic delays, increasing shipping costs by an estimated $2,200,000.

Lock and Dam 7: As recommended in the 1984 feasibility report, this facility would be replaced with a new lock and dam (Grays Landing Lock and Dam) at an estimated cost of $94,300,000.

Lock and Dam 8: Consistent with the feasibility report, the existing lock would be replaced at an estimated cost of $67,400,000. The existing gated dam, constructed in 1959, is currently being rehabilitated. This rehabilitation is considered sufficient to ensure continued operation of the dam throughout the analysis period.

Morgantown Lock and Dam: This facility, constructed in 1950, would require major rehabilitation at a cost of $15,100,000 in 2010. During this work, interruptions and delays to traffic would result in increased costs to shippers, estimated at $13,800,000.

Hildebrand Lock and Dam: Constructed in 1960, this project would be rehabilitated in 2020. The work, estimated to cost $15,500,000, would cause delays and interruptions of traffic, increasing shipper costs by an estimated $5,300,000 during construction.

Opekiska Lock and Dam: The Opekiska facility was completed in 1967 and would be rehabilitated, at an estimated cost of $14,800,000, in 2030. During rehabilitation, delays and traffic interruptions would increase shipper costs by an estimated $3,000,000.

Tygart Dam: The Tygart Dam, constructed in 1938, provides augmentation flows to the Monongahela River for navigation and would require major rehabilitation, estimated to cost $25,000,000 in 2010. Because navigation is only one purpose of this project, a portion of this investment (40 percent) has been allocated to navigation.

The schedule of major investments for continued navigation on the Monongahela River navigation system is shown in Table 2. Estimated average annual costs, including closure costs and operation and maintenance costs, are developed in Table 3. Figure 3 presents a graphic summary of investment and closure costs. Annual costs in Table 3 are based on a period of 50 years (1990–2040), an interest rate of 8⅛ percent, and October 1983 prices to achieve comparability with the economic analysis of the Locks and Dams 7 and 8 feasibility report. To allow comparison of system facilities having service lives that extend beyond the 50-year evaluation period, a salvage value was estimated for each structure at year 2040. This value was based on the relative age and projected value at that time. As shown in Table 3, annual system costs to continue navigation on the Monongahela River from 1990 to 2040 were estimated to be $42,100,000.

ANNUAL SYSTEM BENEFITS

The estimated benefits for continued operation of the Monongahela River navigation system are developed in the Locks and Dams 7 and 8 feasibility report (*5*, Appendix J, pp. 71–77). Estimated annual transportation benefits for continued operation of the Monongahela River navigation system, including replacements at Locks and Dams 7 and 8 as recommended in the feasibility report, total $330,800,000.

TABLE 2 MONONGAHELA RIVER NAVIGATION SYSTEM: REHABILITATION AND REPLACEMENT SCHEDULE

Locks & Dam 2	1953	Rehab. Locks	2010	19,900
	1906	Replace Dam	2010	53,700
Locks & Dam 3	1907	Replace Locks & Dam	2000	187,500
Locks & Dam 4	1932	Replace Locks	2005	108,700
	1967	Rehab. Dam	2030	3,000
Maxwell L/D	1963	Rehab. Locks & Dam	2030	24,900
Lock & Dam 7	1926	Replace Lock & Dam	1990	94,300
Lock & Dam 8	1926	Replace Lock	1990	67,400
Morgantown L/D	1950	Rehab. Lock & Dam	2010	15,100
Hildebrand L/D	1960	Rehab. Lock & Dam	2020	15,500
Opekiska L/D	1967	Rehab. Lock & Dam	2030	14,800
Tygart Lake[a]	1938	Rehab. Dam	2010	10,000

a Total Rehabilitation Cost $25,000,000 (40% allocated to navigation).

TABLE 3 MONONGAHELA RIVER NAVIGATION SYSTEM: AVERAGE ANNUAL COST FOR CONTINUED OPERATION AND MAINTENANCE

Structure	Future Action Item	Future Action Year	Total[a] Invest	Closure[b] Cost	Salvage[c] Value	Net Ann Imp[d] Cost	O&M	Total Ann Cost
			(Millions of Dollars)					
Locks & Dam 2	Rehab. Locks	2010	21.5	47.8	2.0	1.20		
	Replace Dam	2010	53.7	-	10.0	.92	1.50	3.62
Locks & Dam 3	Replace L/D	2000	217.4	-	28.1	8.20	1.20	9.40
Locks & Dam 4	Replace Locks	2005	122.5	64.8	21.7	4.77		
	Rehab. Dam	2030	3.0	-	.6	.01	1.96	6.74
Maxwell L/D	Rehab. L/D	2030	26.7	2.2	4.9	.10	1.70	1.80
Lock & Dam 7	Replace L/D	1990	104.1	-	14.1	8.61	.70	9.31
Lock & Dam 8	Replace Lock	1990	76.8	-	10.1	6.35	.90	7.25
Morgantown L/D	Rehab. L/D	2010	16.1	13.8	1.5	.52	.90	1.42
Hildebrand L/D	Rehab. L/D	2020	16.5	5.3	2.3	.17	.90	1.07
Opekiska L/D	Rehab. L/D	2030	15.8	3.0	2.9	.06	.90	.96
Tygart Lake	Rehab. Dam	2010	10.00	-	1.0	.17	.36	.53
Total								42.10

Note: A dash (-) denotes not applicable.

a. Construction cost plus interest during construction based upon appropriate construction period.

b. Closure costs are shipper costs from delays or interruptions to traffic caused by the need to close a lock chamber during construction of a replacement or rehabilitation of the chamber.

c. Salvage value is estimated at 2040.

d. Net Annual Implementation Cost: annual equivalent of the 1990 present value of investment and closure less the 1990 present value of salvage.

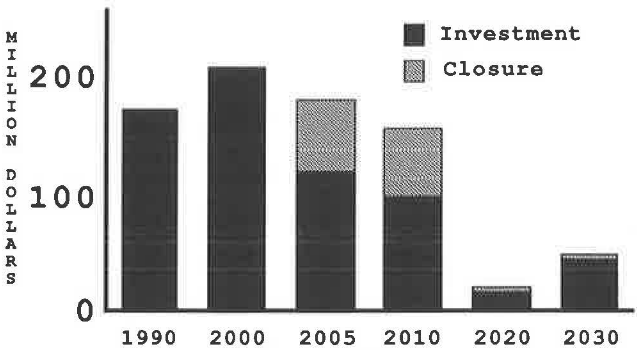

FIGURE 3 Monongahela River economic costs.

COMPARISON OF SYSTEM COSTS AND BENEFITS

Benefits and costs of continued navigation on the entire Monongahela River navigation system are summarized as follows:

Total annual system benefits = $330,800,000

Total annual system costs = $42,100,000

Benefit-to-cost ratio (BCR) = 7.9

Consistent with detailed investigations included in the feasibility report (*5*, Appendix J), this analysis assumes projected traffic growth on the Monongahela River system throughout the 1990–2040 period. An alternative scenario was examined to determine the sensitivity of the benefit-cost analysis to the assumption of constant traffic during this period. The system benefits that would result if the 1980 traffic levels were to continue without additional growth are estimated to be $276,000,000. When this is compared with the previously developed system cost of $42,100,000, the benefit-to-cost ratio is 6.6.

CONCLUSIONS

As the foregoing section indicates, the estimated benefits for continued navigation on the Monongahela River exceed estimated costs by a wide margin. This paper concludes, not with a comprehensive evaluation of the analysis employed here, but with some reasons for the authors' conviction that the results are useful indications of how similar studies might be used in other areas of navigation planning, and an evaluation of the prospects for expanding the methods used here to form a basis for systemwide planning.

First, many of the criticisms that could be made of this study fall under the general rubric of risk and uncertainty, both in engineering and economics. A logical question is, How much confidence should one have in the estimated investment costs used in the study? Fortunately, the mechanics of capitalizing the cost stream (discounting) render annual costs relatively insensitive to very large changes in costs that are farther in the future and about which therefore there is likely to be less certainty. Conversely, annual costs will be very sensitive to changes in the costs of actions that are likely to occur in the near term. In this study, the cost estimates with the greatest certainty are those that were drawn either from a completed feasibility study (Locks and Dams 7 and 8) or from preliminary detailed investigations for an ongoing survey study (Locks and Dams 2, 3, and 4). In other words, the authors' best engineering data are from detailed investigations of navigation projects at which current problems dictate near-term solutions. With regard to system benefits, a dramatic, unprecedented, and permanent decline in Monongahela River traffic would have to occur to upset the overwhelming justification for continued navigation. Given the reasonably high level of confidence in projected near-term actions and the wide margin of net benefits, the previously described analysis shows strong economic justification for undertaking investments in the modernization of Locks and Dams 7 and 8 and for continuing detailed investigations to prepare optimum investment plans at Locks and Dams 2, 3, and 4.

The authors are unaware of other studies that address the long-term navigation planning issues considered in this paper and that also account for projected benefits and costs for an entire major navigation system or subsystem. Although the analysis of this paper is at a lesser level of detail than is characteristic of a full-scale feasibility report, even the abbreviated methodology employed here can be valuable in other contexts. As demonstrated in this paper, such studies can be used to supplement detailed project studies and provide a framework for placing the individual project in the context of a long-term plan for an appropriately defined system or subsystem. Navigation program managers can also use such an analysis to examine project priorities and focus on data needed to reduce uncertainty. In addition, the methodology provides a useful means of summarizing the long-term program envisioned for a waterway and communicating that program and the economic justification for it to navigation program decision makers.

Finally, the authors' experience with this study suggests that current evaluation methods are adequate to support development of a systems planning capability. In this context systems planning may be contrasted with project planning. Traditionally, navigation planning has emphasized identification and formulation of solutions to problems at individual projects within the system. Systems planning stresses identification of the entire collection of existing and future problems (i.e., all projects in the system are evaluated for necessary improvement) and formulates a unified, optimally timed, and scaled investment plan for modernization, rehabilitation, maintenance, and operations.

If implemented in the spirit of long-standing water resources policies, navigation systems planning would identify a program of future investments that are simultaneously optimal in type (e.g., rehabilitation versus replacement, structural versus nonstructural), scale (e.g., lock size or cost), and timing (the implementation date for each component). If conventional criteria were applied, optimality would be defined as achieving maximum system net benefits.

The authors have no intention of thoroughly examining the desirability of implementing a systemwide planning approach. However, their experience with this study suggests that analytic techniques already developed for systems analysis of project benefits are probably adequate to pursue systemwide planning. This conclusion is easier to support in those cases in which future system needs are related to constrained lock

capacity and associated delays. Modern systems analysis methods have been designed with emphasis on congestion problems.

On the other hand, the application of risk analysis techniques to aging and deteriorating projects is still in its infancy. For the most part, these techniques have been applied to outage risks at a single project, not an entire waterway or navigation system. If a dominant concern for future navigation is aged and deteriorating projects, as is the case in the Ohio Valley, much additional development and refinement of risk analysis techniques are essential to a viable systems planning discipline.

In addition to analytic tractability, institutional features currently pose an important limitation on applying a systemwide planning approach. The existing framework of navigation development is structured around projects, not the system. Consideration of the institutional changes necessary for systems planning is beyond the scope of this paper, but clearly significant change would be required to separate study authorization, programming, and funding from individual projects. It also seems reasonable that effective systemwide planning would be dependent on broader and longer-lived congressional authority for Corps navigation modernization actions than is currently available under project-specific planning and construction authorizations.

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