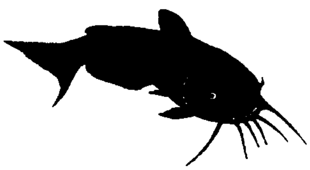
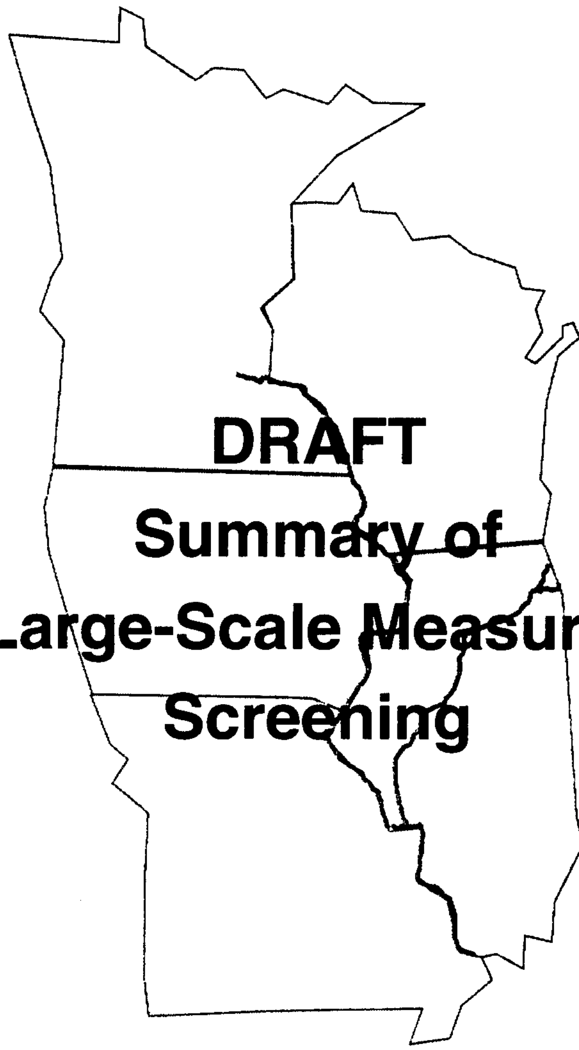
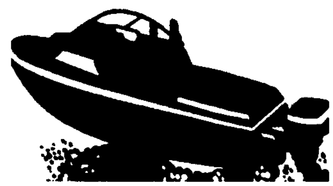
Upper Mississippi River - Illinois Waterway System Navigation Study

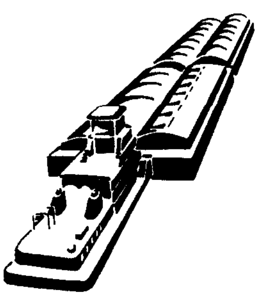






DRAFT

Summary of Large-Scale Measures Screening



INTERIM REPORT

October 1999

US Army Corps of Engineers

Rock Island District
St. Louis District
St. Paul District

SYLLABUS

The Upper Mississippi River-Illinois Waterway System Navigation Study (Navigation Study) is a feasibility study addressing navigation improvement planning for the Upper Mississippi River and Illinois Waterway (UMR-IWW) system for the years 2000-2050. This study assesses the need for navigation improvements at 29 locks on the Upper Mississippi River (UMR) and 8 locks on the Illinois Waterway (IWW) and the impacts of providing these improvements. More specifically, the principal problem being addressed is the potential for significant traffic delays on the system within the 50-year planning horizon, resulting in economic losses to the Nation. The study is to determine whether navigation improvements are justified and, if so, the appropriate navigation improvements, sites, and sequencing for the 50-year planning horizon. The feasibility study also includes the preparation of a system Environmental Impact Statement (EIS).

The goal of this report is to summarize the identification and screening of the large-scale measures. However, the final product of the Navigation Study is the feasibility report, which will constitute the decision document for processing to Congress. Large-scale measures are navigation improvements involving extending the existing lock or providing a second lock at an existing lock and dam.

The process first identified a universe of potential large-scale measures that might improve system efficiency. This universe included evaluating 16 potential lock sites (Locks 11-25 on the UMR and Peoria and La Grange Locks on the IWW), six alternative placement sites for the construction of a new lock at each of these existing lock and dam sites, three different design types (later expanded to four), and a variety of lock sizes. From this initial list, a two-part screening process was used to select the most promising measures.

The table on the following page shows the remaining locations and types. The only remaining size is the 1,200-foot by 110-foot lock. At most lock sites, the remaining alternatives include an option that provides for just one 1,200-foot lock, extending the existing lock (Location 2), and one option that would result in a new 1,200-foot lock in addition to the existing 600-foot lock. In most cases, any new lock would be placed in the auxiliary gate bay (Location 3). Exceptions include Lock 14 where a Location 3 lock was not viable; Locks 17 and 25 where new locks landward of the existing lock (Location 1) were carried forward as well; and Lock 19 where a 1,200-foot is already in place in Location 2. At the IWW locks, Location 1 locks appeared to be the preferred options, but Location 2 locks were also carried forward for further consideration.

REMAINING LOCK LOCATIONS AND TYPES FOLLOWING THE SECONDARY SCREENING						
	Location Number and Viable Types					
Lock and Dam Site	**1**	**2**	**3[3]**	**4[3]**	**5**	**6**
L/D 11		R	C			
L/D 12		R	C			
L/D 13		R	C			
L/D 14[1]		R		C		
L/D 15[1]		R	B			
L/D 16		R	C			
L/D 17	C	R	C			
L/D 18		R	C			
L/D 19[1]			B			
L/D 20[2]		R	B			
L/D 21		R	C			
L/D 22[1]		R	C			
L/D 24[2]		R	C			
L/D 25	C	R	C			
Peoria	C	R				
La Grange	C	R				

[1] These sites have rock foundations. All others (except for note 2) are sand-founded sites (requiring piles).

[2] These sites have mixed foundations; some locations would be rock-founded and some pile-founded.

[3] While only a Type B or C lock is shown, costs and performance evaluations to date have shown these lock options to be essentially equal. As a result, only the lower cost option is shown in the table, but if the system economic analysis shows justification for Location 3 or 4 locks, Types B, C, and possible hybrids of the two will be considered during the site-specific detailed design efforts.

These remaining large-scale measures will now be used together with the remaining small-scale measures to develop various alternative plans for analysis using the system economic model. These system analyses will allow the study team to eventually identify a NED Plan and Recommended Plan.

CONTENTS

SECTION 1 - SUMMARY AND BACKGROUND

SECTION 2 - INITIAL SCREENING

SECTION 3 - FURTHER QUANTIFICATION OF PERFORMANCE AND COST

SECTION 4 - SECONDARY SCREENING

Tables

Figures

CONTENTS (Continued)

Attachments:

SECTION 1 - SUMMARY AND BACKGROUND

PURPOSE

The goal of this report is to summarize the identification and screening of the large-scale measures. The large-scale analysis began with the development of an array of new locks that were possible from an engineering standpoint. This array included evaluating 16 potential lock sites (Locks 11-25 on the UMR and Peoria and La Grange Locks on the IWW), six alternative placement locations for the construction of a new lock at each of these existing lock and dam sites, three different lock design types (later expanded to four), and a variety of lock sizes. In addition, wicket dams, which allow tows to navigate over the dams in periods of high water, were considered at UMR Locks 17 and 20.

This report is organized into four general sections. Section 1 provides the background information on the study purpose and scope, definition and role of large-scale measures, and overview of the lockage process. The second section presents the process and results of the initial screening. The third section provides information from efforts to further quantify the benefits and costs of the measures surviving the initial screening. Finally, the report concludes with a secondary screening used to narrow the potential options to only the most promising set for use in developing alternative plans and evaluation with the system economic models.

SUMMARY

Given the vast number of potential combinations, it was critical to screen the potential combinations down to a more manageable level prior to developing alternative plans and evaluating them with the system economic model. To accomplish this screening, a multi-step process ensued. Due to time and funding constraints, developing detailed information on the measures and screening them was essentially a parallel process, with screening occurring as adequate information became available. The value of this analytical process, which continually screens out the least promising measures, is that study resources are continually concentrated on those items showing the greatest promise.

The huge number of potential combinations of improvements made it necessary to start screening by categories (location, size, and type). However, during this step, the input of various disciplines (environmental, economics, engineering, and plan formulation) was sought and considered. While efforts were made to consider site-specific conditions associated with each lock, this analysis was primarily conducted at the system level. Many of the site details will be looked at in greater detail if locks show justification in the system study. First, a primarily qualitative screening took place to eliminate any lock locations that obviously had fatal flaws or were clearly dominated by another location. Similarly, various possible lock sizes (lengths and widths) were evaluated to select the best for further consideration. This screening resulted in the finding that the two most effective chamber sizes were 110 feet by 1,200 feet and 110 feet by 600 feet. As additional qualitative cost and construction impact information became available, it was also possible to eliminate some of the potential lock design types. Based on the limited benefits and the potential for severe environmental impacts, navigable wicket dam options at UMR Locks 17 and 20 were eliminated.

After these initial screening efforts, additional quantitative information was developed to allow further screening that would consider the total life-cycle costs, construction impacts, and benefits of each alternative. Some of this information proved to be eliminating factors for an alternative. However, for most of the locks surviving the initial location, size, and type screenings, the detailed cost, benefit, and impact information was quantified for use in further evaluations.

Following the further quantification of benefits and costs, a secondary screening was conducted to evaluate the cost effectiveness of the various options. While cost effectiveness provided the framework, the screening also involved as assessment by the various technical disciplines and consideration of qualitative data. Results of the secondary screening show that for the UMR sites the development of a low-cost alternative lock extension (Location 2 Type R) resulted in elimination of other lock extension options and new 600-foot chamber options. In addition, an option was identified at each site that would provide a new 1,200-foot lock in addition to the existing 600-foot lock. In most instances, this was a new lock in the existing auxiliary gate bay (Location 3); however, at sites where a new lock landward of the existing lock (Location 1) is an option, it was carried forward for further consideration as well. More severe impacts to navigation are anticipated at IWW sites due to year-round navigation and the associated lack of a winter closure period to construct improvements. At these sites, a new 1,200-foot lock landward of the existing lock (Location 1) appears to be preferred to avoid these impacts, but the 1,200-foot lock extension was carried forward as well.

These remaining large-scale measures will now be used along with the remaining small-scale measures to develop various alternative plans for analysis using the system economic model. These system analyses will allow the study team to eventually identify a NED Plan (plan maximizing net benefits to the Nation consistent with protecting the environment) and a Recommended Plan.

Major steps and products in the large-scale measure development and screening process included: developing the universe of large-scale measures and qualitative screening summarized in the *Large Scale Measures of Reducing Traffic Congestion Location Screening* report (July 1999); *Large Scale Measures of Reducing Traffic Congestion: Conceptual Lock Designs* report (July 1996); quantifying the cost and performance information included in the draft *Engineering Appendix* (December 1997); and the summary of the screening of large-scale measures included in this report. The focus of this report is to document and summarize the entire large-scale screening process leading up to the analysis of the most promising measures using the system economic model.

BACKGROUND

Large-Scale Measure Definition and Role

Large-scale measures include improvements that involve extending the existing lock or providing a second lock at an existing lock and dam site. An additional measure—providing a wicket dam to allow navigation to pass over the dam—was considered at lock and dam sites that have a substantial period of uncontrolled flow. Uncontrolled flow occurs when the dam gates are raised clear of the water during periods of high river flow. Of the sites in the study, Locks and Dams 17 and 20 are those with the greatest duration of uncontrolled flow (besides Peoria and La Grange Locks and Dams that already have navigable dams).

The navigation benefits of large-scale measures are significantly greater than those for small-scale, however, the costs are also significantly higher. A 1,200-foot lock (corresponding to the maximum tow size presently used on the UMR-IWW system) would obviate the need for a double lockage, allowing a tow to transit through the lock in a single lockage. Providing an additional chamber of smaller size than 1,200 feet (e.g., 600 feet) would still require double lockages. However, this second chamber would reduce delay and congestion by allowing two tows to transit at one time.

Steps in the Lockage Process

Lock performance has been defined as the lock's ability to lock tows efficiently. The lower the lock's transit time for tows, the higher the efficiency. The focus of the large-scale measures is on improving overall lock efficiency by reducing the number of steps in the lockage process (1,200-foot chambers, wicket gates) or by simply providing an additional facility (second 600-foot chamber).

Most Mississippi River and Illinois Waterway locks are 600 feet long by 110 feet wide. Tows that are this size or smaller are able to lock through as a single lockage or in one piece. Larger tows, such as the prevailing 15-barge tow size that is nearly 1,200 feet long by 105 feet wide, must lock through as a double lockage or in two pieces. The double lockage adds several steps to the lockage process as well as considerable time. During this multi-step process, the tow sends half its barges through the lock at a time, tying up the lock while it disconnects the two sets of barges, sends each half through separately, and then reconnects and moves out of the way. At 600-foot chambers, double lockages typically take between 80 minutes and 2 hours, compared to a range of 20 minutes to 40 minutes for 600-foot single lockages. Considerable variability in lockage times occurs due to differences in lockage types, lock sites, river and weather conditions, and crew and boat factors.

The major elements of double and single lockages, the two most common types of lockage, are summarized below. For these lockages, the total lockage time equals the sum of the duration of each lockage step. Figures 1 and 2 compare a typical double lockage process with a single lockage process, which would occur if a 1,200-foot chamber were available (note: some steps have been consolidated for simplification).

<u>Double Lockage Steps</u>: Double lockages, the most common type of commercial lockage, are required when total tow length exceeds the chamber length.

(1) Approach the lock
(2) Enter the chamber
(3) Uncouple the tow and back the powered cut out of chamber*
(4) Close gates
(5) Fill or empty the lock chamber
(6) Open gates
(7) First cut exits lock chamber (with tow haulage assist)*
(8) Close gates*
(9) Fill or empty the lock chamber {opposite direction of step (5)}*
(10) Open gates*
(11) Powered/second cut enters the lock chamber*
(12) Close gates*
(13) Fill or empty the lock chamber {same as step (5)}*
(14) Open gates*
(15) Recouple the tow (powered cut to the unpowered cut previously locked through)*
(16) Exit the lock

*These steps are only involved with double lockages when the size of the tow exceeds the size of the lock chamber. The most common example of this in the current navigation system is with nearly 1,200-foot-long tows transiting through 600-foot-long locks.

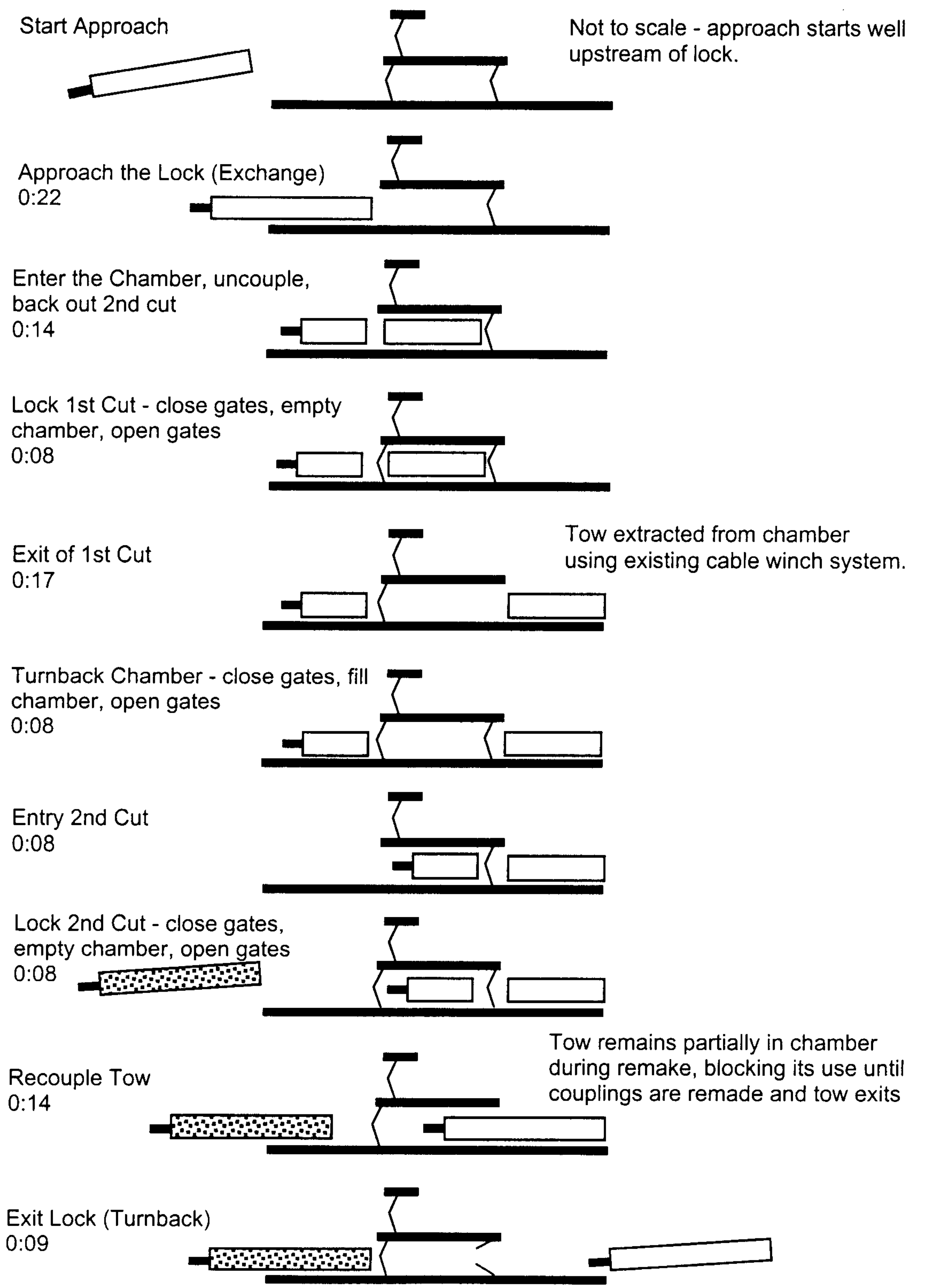
Double lockages require several steps. Vessels first approach the lock. The approach process includes the time for the tow to approach the lock, align with the guidewall, and place its bow (front of boat) over the sill of the chamber. For a vessel traveling downstream (downbound vessel), either before or during the approach the chamber is filled to the upper pool level and the upper gates opened. The vessel entry time extends from the time when the tow gets its bow over the sill until the tow is fully in the chamber and the gate can be closed. However, due to the tow's length, a first cut (unpowered section of tow) must be uncoupled from the front end of the tow and locked separately. These cuts, generally consisting of nine barges, fill the whole lock. Once the cut is secured inside the lock chamber, the towboat and remaining barges then back away and the upstream gates are closed. The vessel is then lowered by closing the filling valves and opening the downstream, or emptying, valves. The water in the chamber flows back into the culvert and then out into the lower pool, lowering the water level in the chamber until it is equal to the water level downstream of the lock.

Once the first cut is at the lower pool elevation, the gates are opened and some form of assistance (a tow haulage winch or a helper boat) must pull, or extract, the first cut from the chamber. The cut is typically pulled out along the guidewall and tied off to wait for the second cut. When the first cut is clear of the gates, the gates are closed and the chamber is turned back, filling to get the chamber back to the upper pool elevation of the second, or powered, cut. As soon as the upper gates are opened, the second cut can enter the chamber and be locked through as a single. The one difference is that before the tow can exit the lock facility it must move forward to the first cut and remake its couplings. At sites with 600-foot or shorter guidewalls, the second cut usually remains partially inside the chamber while the first cut is along the guidewall, which eliminates the ability to use the chamber to lock other tows. The process is reversed for tows going upstream (upbound vessels).

Single Lockage Steps: Only possible when lock chamber is at least as large as the tow (e.g., 600-foot or less tows at existing 600-foot facilities and 1,200 feet or less tows at 1,200-foot lock sites)

(1) Approach the lock
(2) Enter the chamber
(3) Close gates
(4) Fill or empty the lock chamber
(5) Open gates
(6) Exit the lock

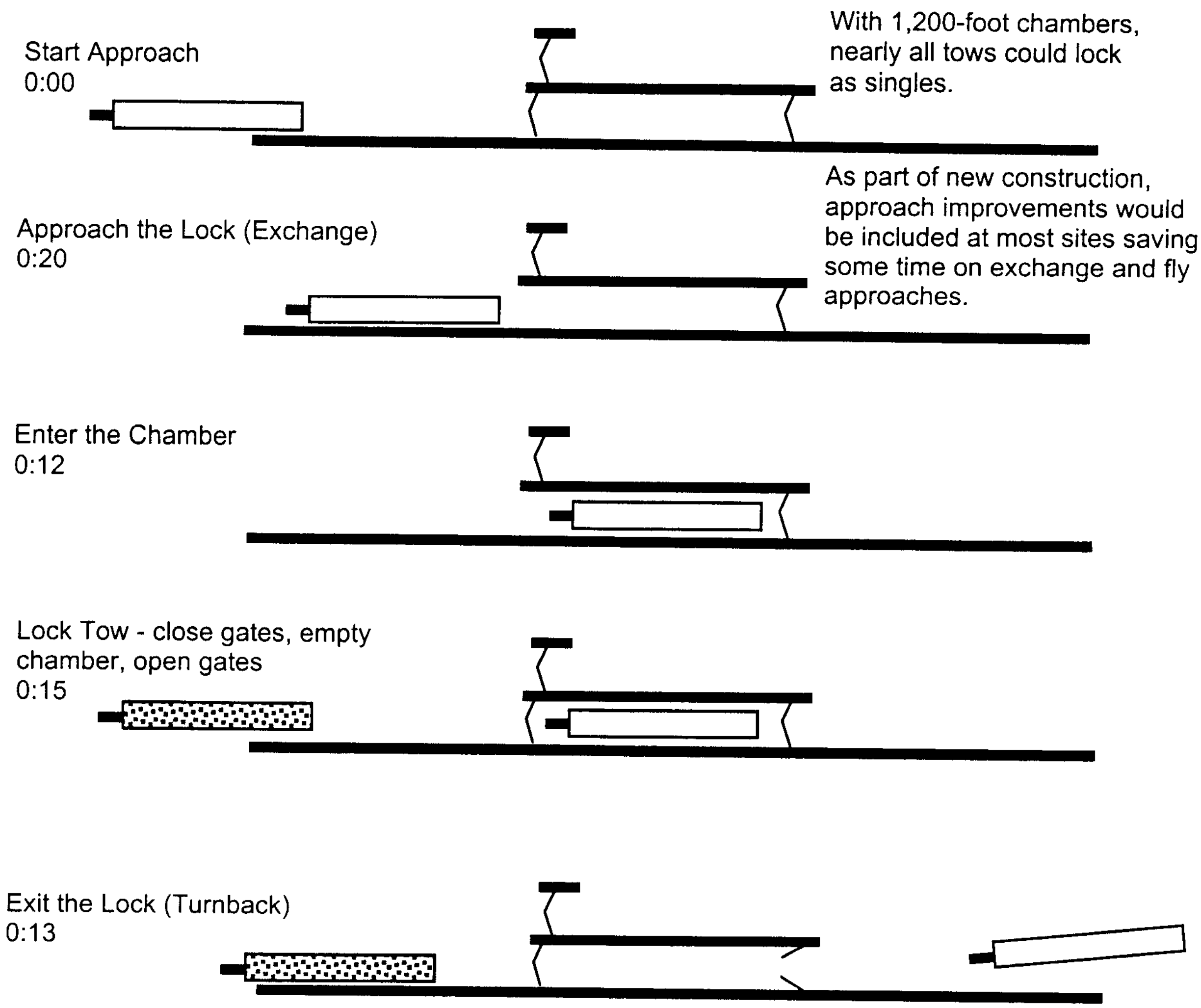
Single lockages follow the same general process but eliminate several steps. Just like a double lockage, the full tow approaches and enters the chamber. However, since the tow is the same size as the lock chamber, there is no need to break couplings and lock a portion of the tow separately. As a result, there is no need to break and remake couplings or turn back the chamber for a second cut. Eliminating these steps saves considerable time. The only factors that may increase lockage times to some extent for 1,200-foot chambers are the entry and exit times, which can take a little longer due to the greater chamber length and, depending on the filling and emptying system, it may require additional time to fill the chamber due to the greater chamber size. One additional difference is that extended guidewalls or channel improvements, if provided along with extended or new locks, could reduce approach times to some degree.



Total Lockage Time 1:48

Note: Approx. lockage time in hour:minutes by step. Diagram shows an exchange approach followed by a turnback lockage.

FIGURE 1: Double Lockage Elements Downbound at Existing 600-Foot Lock.



Total Lockage Time 0:60. Approximate Time Savings vs. Existing Double Lockage at 600-foot Lock is 45 to 50 minutes.
Note: Approx. lockage time in hour:minutes by step. Diagram shows an exchange approach followed by a turnback lockage.

FIGURE 2: Lockage Elements Downbound with Extended 1,200-Foot Lock.

SECTION 2 - INITIAL SCREENING

IDENTIFICATION OF MEASURES

In the Upper Mississippi River and Illinois Waterway Navigation Study Reconnaissance Reports completed in June 1991 and October 1990, respectively, 16 lock and dam sites were identified as having potential for new lock construction within the 50-year planning horizon. These sites included Peoria and La Grange Locks and Dams on the Illinois Waterway, and Locks and Dams 11-25 on the Mississippi River (there is no Lock and Dam 23) and were the focus of this feasibility study effort. Once it was determined that six alternative locations would be considered at each site with three design types at each location (later expanded to four at Location 2), the universe of large-scale measures was determined to be 288 separate lock alternatives (16 sites, times 6 locations per site, times 3 design types per location). That total is based upon only one lock chamber size; the actual total number of alternatives would be multiplied by the number of lock sizes considered. With such an enormous design task, a screening process was needed to identify only the most promising locations and designs.

The large-scale analysis began by developing an array of new locks that are possible from an engineering standpoint. The large-scale screening process followed the process of initially screening measures using a multi-disciplinary team and readily available information. After the least promising options were eliminated, the study team gathered more detailed, quantitative information to further analyze the remaining measures. For the initial evaluations, screening occurred separately for alternative lock locations, lock sizes, and lock types. The following sections have been organized to first present and explain the various lock locations, sizes, and types and then to review the available data and screening process employed to narrow the universe of measures.

Locations

Unless another meaning is obvious by the context, the use of "site" means any of the existing lock and dam sites included in the Navigation Study (e.g., Lock and Dam 20, Lock and Dam 24, Peoria Lock and Dam). This distinction is necessary to avoid confusion with lock "locations" defined below.

During the initial phases of the feasibility study, options such as replacing two lock and dam sites with a single site were considered. However, engineering efforts demonstrated that the existing structures can continue to provide performance with continued rehabilitation. This finding, along with environmental concerns and potential needs to acquire additional land and raise levees, resulted in the determination that it was unnecessary and uneconomical to build new dams along with new locks. This left any potential lock placements to be made at the existing lock and dam sites. Six alternative "locations" at each lock and dam were considered (see Figure 3). With these six locations, any placement from overbank to overbank was possible; however, practical matters restricted some locations at particular sites. During the screening process, some of the six locations proved to be infeasible. The locations considered were as follows:

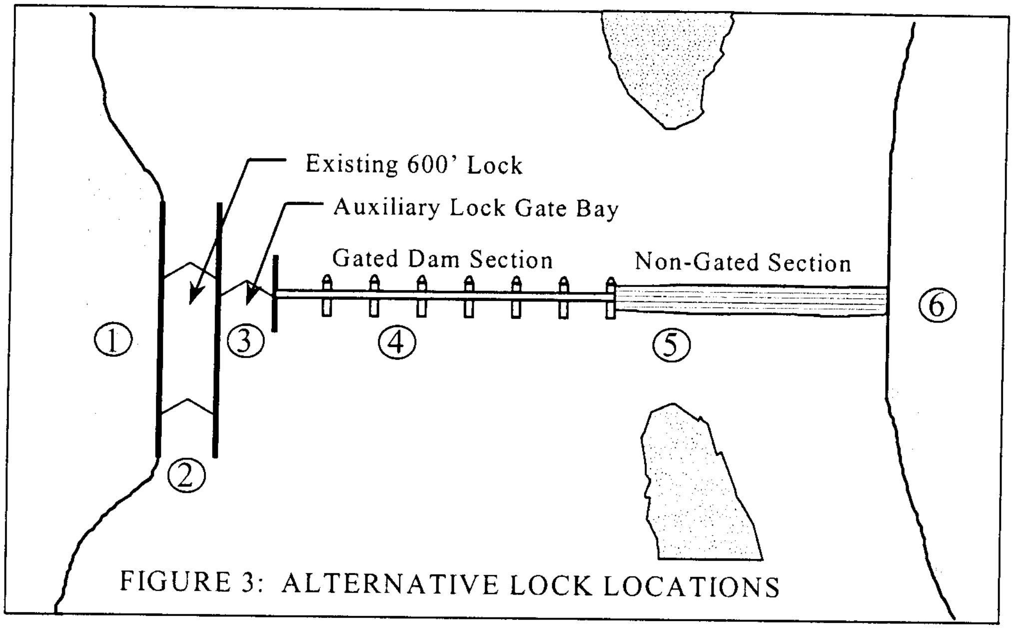


FIGURE 3: ALTERNATIVE LOCK LOCATIONS

Location 1 is landward of the existing lock. For most sites, Location 1 would entail land-based construction techniques as opposed to the more costly and difficult marine construction required at most other locations. Large quantities of soil and/or rock excavation would be required at this location. Location 1 typically would require relocations of railroad track, utilities, private property, and/or other infrastructure. For the most part, construction would not interfere with navigation access to the existing lock. A considerable amount of channel work would be required to allow tows to reach a Location 1 lock safely. Unlike locks at other locations, a Location 1 lock would disrupt access to the existing lock for materials and personnel. However, easier access (for personnel and supplies) would be available to the new lock site than locks at other locations.

Location 2 is an extension of the existing 600-foot-long lock to result in a 1,200-foot-long lock. The only viable designs are those that could be constructed while maintaining navigation with only minimal traffic interruptions and low accident risks. The lock extensions would generally be made downstream to work in shallower water. Also, the upper gate sills of the existing locks are too high to function as lower gate sills. Little or no channel work would be required at this location.

Location 3 utilizes the existing auxiliary lock miter gate bay (if present) to construct the new lock. This location would also require navigation interruptions during construction. However, it typically would require little or no channel work due to its close proximity to the existing channel. It also would make use of the existing intermediate lockwall and the existing auxiliary lock miter gate bay.

Location 4 is through the gated section of the dam. Although any placement through the gated section is possible, placement toward the existing lock side is generally preferred because less channel work is required and the lock would be more accessible to lock personnel. Siting a lock at Location 4 eliminates one or more of the existing dam gates. This loss of flow capacity would impact upstream water surface elevations. For the system study, it has been assumed that any dam gates removed would be replaced one-for-one at available space along the axis of the dam (where there presently is lesser or no flow capacity). At flood stages and after navigation has ceased, providing flow through the new lock chamber (controlled by an upstream lift gate) is a possibility as well.

Location 5 places the lock in the non-overflow or overflow sections of the dam (if present) beyond the gated section of the dam. Again, the preferred placement would be toward the existing lock side of the non-overflow or overflow sections. At most lock sites, a Location 5 lock would require extensive channel work and have adverse environmental impacts. In addition, it would require greater utility modifications and offer poor accessibility for operating personnel. Nevertheless, a Location 5 lock design was developed to determine its first cost for comparison with other locations.

Location 6 is a land-based location on the opposite bank from the existing lock. To a greater extent than at Location 5, Location 6 locks would require extensive channel work and have adverse environmental impacts. An additional problem at Location 6, resulting from the fact that there would be no flow adjacent to the new lock (unless additional dam gates were added), is that siltation would be a problem requiring frequent dredging work. No conceptual lock designs for Location 6 were developed because the concurrent location screening investigation determined that the added problems of this location were severe enough to eliminate all Location 6 locks. Nevertheless, the basic cost of a Location 6 lock would be expected to be similar to a Location 1 lock, the other land-based location.

Sizes

Various lock sizes were evaluated that varied both in length and width. The evaluated sizes included 200-foot increments from 200 feet to 1,200 feet for lock length, as well as widths of 110 feet to 220 feet. Based on further system constraints related to the channel as well as downstream locks, these sites represent a full range of options.

Types

As noted earlier, three conceptual lock design types were initially considered to provide an array of measures for the plan formulation process and a fourth was added later in the process. These ranged from traditional lock construction (with somewhat higher performance) to locks of low first cost (with reductions in performance). Innovative designs were also of central importance.

Cost savings was a paramount goal in the design approach for developing the lock concepts. To help achieve this goal, all past design criteria and construction standards were open for reevaluation. Several innovations were explored and developed by the three districts working on the Navigation Study. Most of the innovations were estimated to provide substantial cost savings compared to traditional lock construction. The study team also recognized the need to develop more environmentally friendly designs. Several design measures were included to avoid and minimize environmental impacts compared to traditional lock construction. These include use of less construction material through design innovations, beneficial use of dredged material, improved approach conditions to reduce tow maneuvering, designs of shorter construction duration, and construction without cofferdams. The potential locations for staging and disposal also were evaluated to help minimize site-specific environmental impacts.

Although there are site- and location-specific differences, the lock types evaluated are generally defined as follows:

Type A. A "Type A" conceptual lock design is a lock designed according to current design standards and traditional construction methods for locks. It would be constructed within a dewatered cofferdam as were all the existing locks and dams on the Mississippi River and Illinois Waterway. This lock type would typically have concrete gravity or U-frame walls, a side port filling and emptying system, and a downstream miter gate and either an upstream miter gate or a lift gate. A Type A lock would be expected to have the highest performance levels and durability, but also the highest first cost. Construction risks would be low for this type of lock.

Type B. A "Type B" conceptual lock design is a lower cost lock utilizing construction techniques proven in marine construction that heretofore have not commonly been used in lock construction. Use of these construction techniques, float-in and lift-in, would be innovative in the lock construction arena. A Type B lock would present slight reductions in performance but similar durability compared to a Type A lock. A Type B lock would present high risks to construct.

Type C. A "Type C" conceptual lock design is the lowest first cost design, using cellular sheet pile construction with precast concrete lockwall panels, that still is safe with predictable performance. This lock type would be expected to be less durable and less reliable than Types A and B locks. To accomplish the cost savings, certain design standards were relaxed with resulting tradeoffs in performance (sill depths, filling and emptying, etc.). A Type C lock would typically present low to moderate risks to construct.

Type R. A "Type R" lock was developed in FY 98 as a refinement of the Type C lock. Type R was only developed for use at Location 2, the extension of the lock to 1,200 feet. However, some similar types of savings could be identified for other locations as well. Again, it is a lowest first cost design using cellular sheet pile construction with precast concrete lockwall panels. However, additional design modifications were included to reduce the impacts to navigation during construction and further lower construction costs. These design features include: not extending the filling and emptying culverts into the extension, utilizing the existing lower guidewall by strengthening it for use as the landside lockwall, maintaining the same sill and floor depth as the existing lock (resulting in a sill 1.38 times draft at minimum tailwater versus 2 or 1.7 times draft considered for Types A-C), using float-in lower gate monoliths, not improving the approach, and only constructing a 600-foot downstream guidewall. By not extending the filling and emptying system, extending the upstream guidewall, or making channel improvements, resulted in reduced time savings of approximately 2 to 4 minutes.

Initial Quantification of Costs

The next section generally represents a preliminary qualitative screening. However, as quantitative information became available it was considered in the screening process. This overlap between quantitative and qualitative efforts resulted from the condensed study time frame, which required concurrent efforts in many areas. The following are the first cost estimates available by the end of the initial screening process. These costs were developed as part of the *Large Scale Measures of Reducing Traffic Congestion: Conceptual Lock Designs* report (July 1996). However, this quantification process was influenced by preliminary information from the qualitative assessment, as evidenced by the decision not to conduct detailed quantification of the costs of Location 6 locks or Type A locks at Locations 2 and 3.

The existing locks and dams on the Mississippi River and Illinois Waterway are either rock-founded or pile-founded. The new lock design concepts vary depending on their type of foundation. The resulting concepts are only typical of what could be done. Endless variation in design detail is possible, but the objective in the system phase of the study was to establish engineering feasibility rather than to optimize the various design elements. If the system study demonstrates justification for new locks, the designs will be further evaluated and analyzed on a site-specific basis.

Table 1 summarizes cost estimates for the rock-founded 1,200-foot and 600-foot locks. Table 2 shows cost estimates for the pile-founded locks. The *Conceptual Lock Designs* report contains backup cost estimates from which the summarized cost estimates were derived. Since the scope of the present investigation is very broad, these estimates are not absolute; however, they are useful for comparison and screening purposes. The reader will note that a 600-foot-long lock is considerably more costly than 50 percent of a 1,200-foot-long lock because the guidewall requirements, miter gate bays, and much of the lockwalls are the same for both lock sizes. In addition, there are other common costs for construction mobilization, overhead, and dewatering. The additional features to expand from a 600-foot lock to a 1,200-foot lock are chamber-type monoliths (lockwalls). These are the least expensive lock monoliths to construct.

TABLE 1: ROCK-FOUNDED 1,200-FOOT AND 600-FOOT LOCKS COMPARISON OF SUMMARIZED COSTS ($1,000's)[1]			
LOCK LOCATION AND TYPE[2]	BASIC LOCK COST[3]	OTHER FIRST COSTS[4]	TOTALS
LOCATION 1 - 1,200'			
TYPE A	$ 188,000	$ 18,000	$ 206,000
TYPE B	176,000	19,000	195,000
TYPE C	171,000	20,000	191,000
LOCATION 2 - 1,200'			
TYPE B	115,000	5,000	120,000
TYPE C	110,000	5,000	115,000
LOCATION 3 - 1,200'			
TYPE B	131,000	6,000	137,000
TYPE C	122,000	5,000	127,000
LOCATION 4 - 1,200'			
TYPE A	206,000	7,000	213,000
TYPE B	184,000	7,000	191,000
TYPE C	165,000	7,000	172,000
LOCATION 5 - 1,200'			
TYPE A	234,000	12,000	246,000
TYPE B	187,000	12,000	199,000
TYPE C	161,000	12,000	173,000
LOCATION 1 - 600'			
TYPE A	$ 168,000	$ 24,000	$ 192,000
TYPE B - 600'	152,000	24,000	176,000
TYPE C	147,000	25,000	172,000
LOCATION 3 - 600'			
TYPE B	109,000	5,000	114,000
TYPE C	96,000	5,000	101,000
LOCATION 4 - 600'			
TYPE A	176,000	7,000	183,000
TYPE B	163,000	7,000	170,000
TYPE C	154,000	7,000	161,000
LOCATION 5 - 600'			
TYPE A	195,000	12,000	207,000
TYPE B	159,000	12,000	171,000
TYPE C	146,000	12,000	158,000

NOTES:

[1] The cost estimates shown above are not comprehensive. They do not take into account economic impacts to navigation during construction, environmental impacts, and other site-specific costs and impacts.
[2] There are no Type A locks at Locations 2 and 3, and Location 6 was eliminated by the location screening effort. In addition, there already is a 600-foot lock at Location 2.
[3] The basic lock costs include the necessary dam modifications (mostly a consideration for Location 4 lock types), the 05 "Locks" account code, and the 05.60. "Guidewalls" account code. Contingencies; planning, engineering, and design; and construction management are included in these costs.
[4] The costs in this column include real estate costs, channel costs, and some of the other first costs that tend to be more site-specific.

TABLE 2: PILE-FOUNDED 1,200-FOOT AND 600-FOOT LOCKS			
COMPARISON OF SUMMARIZED COSTS ($1,000's)[1]			
LOCK LOCATION AND TYPE[2]	BASIC LOCK COST[3]	OTHER FIRST COSTS[4]	TOTALS
LOCATION 1 - 1,200'			
TYPE A	326,000	12,000	338,000
TYPE B	219,000	12,000	231,000
TYPE C	163,000	12,000	175,000
LOCATION 2 - 1,200'			
TYPE B	160,000	1,000	161,000
TYPE C	151,000	1,000	152,000
LOCATION 3 - 1,200'			
TYPE B	200,000	2,000	202,000
TYPE C	194,000	2,000	196,000
LOCATION 4 - 1,200'			
TYPE A	373,000	0	373,000
TYPE B	283,000	0	283,000
TYPE C	248,000	0	248,000
LOCATION 5 - 1,200'			
TYPE A	342,000	178,000	520,000
TYPE B	246,000	186,000	432,000
TYPE C	227,000	186,000	413,000
LOCATION 1 - 600'			
TYPE A	$ 273,000	$ 15,000	$ 288,000
TYPE B	191,000	14,000	205,000
TYPE C	149,000	16,000	165,000
LOCATION 3 - 600'			
TYPE B	172,000	1,000	173,000
TYPE C	160,000	1,000	161,000
LOCATION 4 - 600'			
TYPE A	339,000	0	339,000
TYPE B	232,000	0	232,000
TYPE C	217,000	0	217,000
LOCATION 5 - 600'			
TYPE A	287,000	179,000	466,000
TYPE B	205,000	185,000	390,000
TYPE C	181,000	185,000	366,000

NOTES:

[1] The cost estimates shown above are not comprehensive. They do not take into account economic impacts to navigation during construction, environmental impacts, and other site-specific costs and impacts.

[2] There are no Type A locks at Locations 2 and 3, and Location 6 was eliminated by the location screening effort. In addition, there already is a 600-foot lock at Location 2.

[3] The basic lock costs include the necessary dam modifications (mostly a consideration for Location 4 lock types), the 05 "Locks" account code, and the 05.60. "Guidewalls" account code. Contingencies; planning, engineering, and design; and construction management are included in these costs.

[4] The costs in this column include real estate costs, channel costs, and some of the other first costs that tend to be more site-specific.

LOCK LOCATION SCREENING

Once the array of possible measures was identified, a qualitative screening took place to eliminate any alternative lock locations that obviously had fatal flaws or clearly were dominated by another location. Looking at the universe of large-scale measures, it was obvious that some lock placements had serious problems. To help narrow the field of alternatives, a qualitative screening process was used, employing multi-disciplined study teams. The location screening work took place concurrently with the development of the lock concepts and is documented in an interim report entitled, *Large-Scale Measures of Reducing Traffic Congestion, Location Screening*. This effort resulted in recommending 43 of a potential 96 alternative lock locations under initial consideration (16 sites, times 6 locations) for further analysis.

As part of the screening, locations were evaluated based on environmental impacts, navigational concerns, operational concerns, civil and structural design concerns, real estate needs, and hydraulic concerns for both the construction and normal operating conditions. To complete the location screening, the multi-disciplined study teams used a multi-phased approach that is summarized below.

First, the team used available information for each lock and dam site, which included drawings, maps, navigation charts, photographs and individual knowledge of the area, to eliminate locations obviously unsuited for a new lock because of existing constraints that by observation alone made those locations undesirable. Examples of these obviously unsuitable locations include those requiring the relocation of an entire downtown business district or the relocation of a railroad penned in by a high bluff. All of the participating disciplines had equal weight, including construction, environmental, geotechnical, hydraulics, operations, real estate, and civil/structural design. Criteria used for this first screening were general in scope. Detailed criteria were developed as the screening process progressed. Table 3 shows the criteria grouped by discipline.

The second phase of the location screening involved site visits to each of the 16 lock and dam sites under consideration for new lock construction. The teams making the site visits included the environmental, hydraulics, and civil disciplines; Corps of Engineers lock personnel; and representatives of the U.S. Fish and Wildlife Service, State resource agencies, and the River Industry Action Committee (RIAC). On the site visits, each of the represented disciplines considered all that was observable in their area of expertise for each of the six alternative lock locations. Some of the observed items included:

- Physical advantages or constraints to construction of a new lock.
- Existing navigation conditions (both favorable conditions and conditions associated with time delays, hazards, or excessive tow maneuvering, such as outdraft conditions).
- Location of obvious environmentally significant resources relative to the potential construction area for a new lock and any channel changes.
- Access, safety, efficiency, and other operational concerns.

TABLE 3: CRITERIA FOR EVALUATING NEW LOCK LOCATIONS	
Discipline	Evaluation Criteria
CONSTRUCTION	-Land access to construction site
	-Water access to construction site
	-Existing navigation - impacts on work areas
	-Cofferdam constructibility
	-Project constructibility
ENVIRONMENTAL	-Existing Federal/State wildlife sanctuaries
	-Mitigation opportunities
	-Endangered species habitat
	-Existing habitat sites
	-Existing rare plant species
	-National Historic Register sites
	-Suspected historical sites
	-Archaeological sites
	-Suspected archaeological sites
	-Hazardous, toxic, and radioactive waste
	-Recreational activity/adjacent recreation areas
GEOTECHNICAL	-Geological profile of sites
	-Depth to sound rock
	-Rock/soil excavation limits
	-Major weak soil lenses
	-Anticipated rock/soil permeabilities
	-Anticipated soil stability problems
HYDRAULICS	-Existing channel alignment
	-Better location for channel
	-Locations of frequent channel maintenance (dredging)
	-Channel approach conditions
	-New channel requirements (wing dams, weirs, etc.)
	-Magnitude of excavation/dredging for new channel
	-Existing hydraulic constraints at lock and dam
	-Can gates be added to maintain existing flow capacity
	-Filling/emptying requirements (one or two channels)
OPERATIONS	-Access for operating personnel and equipment
	-Existing maneuvering problems at lock entrance/exit
	-Centralization/separation of operating personnel
	-Guidewall requirements
	-Maintenance of two channels (lock separation)
	-Ice flow characteristics
	-Land access for recreation boating and related activities
	-Safety concerns with expanded lock operations
REAL ESTATE	-Existing Government-owned property
	-Real estate needs
	-Extent of property development adjacent to lock and dam sites
CIVIL/STRUCTURAL	-Adjacent land topography
	-Required relocations (Hwy/RR/utilities/drainage)
	-Existing bridge restrictions on navigation channel
	-Disposal sites for maintenance dredging
	-Impacts to completed lock and dam rehabilitation work
	-Special needs to accommodate location
	-Construction sequencing and impacts on navigation
	-Impacts to existing lock and dam structure, stability, etc.
	-Compatibility with existing structures
	-Costs

This rating procedure was the final step in the initial location screening process. Based upon all the preceding information gathered, study team members of each discipline rated each location at each lock and dam site. The scale ranged from 5 for an excellent location for new lock construction to 1 for a poor location. Table 4 shows the results of this rating process. The combined ratings are the summation of the ratings of all disciplines. Team members used the criteria of Table 4 in assessing the locations. In general, the three highest-rated locations were kept for further analysis unless any of their combined ratings was significantly lower than the highest 1 or 2 rated alternative(s), or there were some disqualifying factors. A fourth alternative was not eliminated if it rated nearly the same as the third highest. For example, Locks 16, 18, and 24 all had Location 5 locks rated similar to some of the remaining locations. However, this location was eliminated due to disqualifying factors associated with environmental impacts and operational concerns (relocating channels, etc.). Location 4 at Lock 11 was eliminated due to concerns with potential endangered species impacts and flow replacement. It was estimated that to bring these Location 4 and 5 locks to an acceptable level of navigability, the costs would be exorbitant and the environmental impacts would be excessive. Conversely, at Locks 24 and 25, Location 2 was retained due to minimal environmental and real estate impacts despite a lower overall rating than some of the other options. The locations that were least preferred by the group assessment were eliminated from further study. The relative ratings of the remaining locations should not be construed as indicating a ranking from best to worst locations. Rather, the higher-rated locations are merely those that survived the location screening process to be considered in the quantitative screening. The location screening helped to narrow the scope of work to the most promising locations to be considered in the quantitative screening work.

The screening reduced the number of alternative lock locations from 96 alternatives to the 43 alternatives shown in Table 5. These remaining locations were further evaluated and screened in subsequent quantitative studies discussed later in this report.

TABLE 4: LOCATION SCREENING RESULTS

LOCK SITE	LOCK LOCATIONS	Construction Ratings	Environmental Ratings	Geotechnical Ratings	Hydraulic Ratings	Operations Ratings	Real Estate Ratings	Civil Ratings	Structural Ratings	Combined Ratings	Disposition
11	1	3	3	4	1	1	1	1	4	18	Eliminated
	2	4	4	4	4	2	4	3	2	27	Survived
	3	4	4	4	4	4	4	4	2	30	Survived
	4	4	2	4	4	3	4	4	2	27	Eliminated
	5	5	X	4	1	1	3	2	4	20	Eliminated
	6	5	X	4	1	1	1	1	2	15	Eliminated
12	1	4	1	4	1	1	1	1	4	17	Eliminated
	2	4	4	4	3	2	4	3	2	26	Survived
	3	4	4	4	4	4	4	4	2	30	Survived
	4	4	2	4	2	3	4	4	2	25	Survived
	5	5	X	4	1	1	1	2	4	18	Eliminated
	6	5	X	4	1	1	1	1	2	15	Eliminated
13	1	5	X	4	1	1	4	1	4	20	Eliminated
	2	4	5	4	3	2	4	3	2	27	Survived
	3	4	3	4	4	4	4	4	2	29	Survived
	4	4	3	4	4	3	4	5	2	29	Survived
	5	5	X	4	1	1	4	2	4	21	Eliminated
	6	5	X	4	1	1	1	1	2	15	Eliminated
14	1	4	3	5	1	2	4	2	4	25	Eliminated
	2	4	5	5	3	2	4	3	2	28	Survived
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	4	4	3	5	5	3	4	5	3	32	Survived
	5	5	X	4	1	2	5	1	4	22	Eliminated
	6	5	X	5	1	1	2	1	4	19	Eliminated
15	1	3	X	5	1	1	1	1	4	16	Eliminated
	2	4	5	5	3	2	3	4	2	28	Survived
	3	4	1	5	3	5	4	3	2	27	Survived
	4	4	1	5	1	2	4	1	1	19	Eliminated
	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	6	2	5	5	1	1	1	1	1	17	Eliminated
16	1	5	3	4	1	1	4	2	4	24	Eliminated
	2	4	5	4	1	2	4	3	2	25	Survived
	3	4	3	4	4	4	4	4	2	29	Survived
	4	4	3	4	5	3	4	5	2	30	Survived
	5	5	X	5	3	2	5	2	4	26	Eliminated
	6	5	X	5	1	1	1	1	4	18	Eliminated
17	1	5	2	4	3	1	4	4	4	27	Survived
	2	4	4	4	4	2	4	3	2	27	Survived
	3	4	4	4	4	4	4	4	2	30	Survived
	4	4	2	4	5	3	4	5	2	29	Survived
	5	5	X	4	2	1	5	2	4	23	Eliminated
	6	5	X	4	2	1	2	1	4	19	Eliminated
18	1	5	X	4	3	1	3	1	4	21	Eliminated
	2	4	3	4	4	2	4	3	2	26	Survived
	3	4	3	4	5	4	4	4	2	30	Survived
	4	4	2	4	5	3	4	5	2	29	Survived
	5	5	X	4	3	2	5	2	4	25	Eliminated
	6	5	X	4	2	1	3	1	4	20	Eliminated

5= excellent location, 4=minor concerns, 3=many minor/few major concerns, 2=several major concerns,
1= poor location, X= not at all viable, N/A= not applicable (location doesn't exist at this site)

TABLE 4: LOCATION SCREENING RESULTS (CONTINUED)											
LOCK SITE	LOCK LOCATIONS	Construction Ratings	Environmental Ratings	Geotechnical Ratings	Hydraulics Ratings	Operations Ratings	Real Estate Ratings	Civil Ratings	Struct-ural Ratings	Combined Ratings	Disposition
19	1	5	5	5	1	1	1	1	1	20	Eliminated
	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	3	4	3	5	4	3	4	4	3	30	Survived
	4	4	1	-	1	1	4	1	3	15	Eliminated
	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	6	X	X	-	1	1	1	1	4	8	Eliminated
20	1	5	3	5	3	2	3	1	4	26	Eliminated
	2	4	5	5	5	2	4	3	3	31	Survived
	3	4	3	5	5	4	4	4	2	31	Survived
	4	4	3	4	4	3	4	4	3	29	Survived
	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	6	5	1	4	1	2	2	1	4	20	Eliminated
21	1	5	4	4	2	1	1	1	4	22	Eliminated
	2	4	5	4	2	2	4	3	2	26	Survived
	3	4	3	4	5	4	4	4	2	30	Survived
	4	4	3	4	4	3	4	5	2	29	Survived
	5	5	X	4	1	2	5	2	4	23	Eliminated
	6	5	X	4	1	1	4	1	4	20	Eliminated
22	1	5	X	5	1	1	1	1	4	18	Eliminated
	2	4	5	5	3	2	4	3	3	29	Survived
	3	4	3	5	4	4	4	4	3	31	Survived
	4	4	3	5	5	3	4	5	3	32	Survived
	5	5	X	4	1	2	5	2	4	23	Eliminated
	6	5	X	4	1	1	4	1	4	20	Eliminated
24	1	4	3	1	2	3	1	1	5	20	Eliminated
	2	1	5	1	4	1	5	3	1	21	Survived
	3	2	5	3	4	4	5	5	1	29	Survived
	4	5	5	4	5	5	5	5	2	36	Survived
	5	2	1	5	1	1	5	2	4	21	Eliminated
	6	1	1	1	1	1	1	5	3	14	Eliminated
25	1	4	3	5	2	1	4	1	5	25	Survived
	2	1	5	1	4	2	5	3	1	22	Survived
	3	4	5	2	4	4	5	5	1	30	Survived
	4	5	5	3	5	5	5	4	2	34	Survived
	5	2	1	4	1	1	5	2	4	20	Eliminated
	6	1	1	1	1	1	1	1	3	10	Eliminated
Peoria	1	3	2	4	5	2	1	2	1	20	Survived
	2	4	3	4	4	2	4	3	2	26	Survived
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	4	4	3	-	1	2	4	2	2	18	Eliminated
	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	6	3	1	-	1	2	1	1	1	10	Eliminated
La Grange	1	5	5	4	5	2	4	5	5	35	Survived
	2	4	5	4	4	2	4	3	2	28	Survived
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	4	4	3	-	1	2	4	2	2	18	Eliminated
	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	6	3	X	-	1	1	4	1	5	15	Eliminated

5= excellent location, 4= minor concerns, 3= many minor/few major concerns, 2= several major concerns,
1= poor location, X= not at all viable, N/A = not applicable (location doesn't exist at this site)

TABLE 5: REMAINING LOCATIONS FOR FURTHER STUDY						
	Location Number					
Lock and Dam Site	**1**	**2**	**3**	**4**	**5**	**6**
L/D 11		X	X			
L/D 12		X	X	X		
L/D 13		X	X	X		
L/D 14[1]		X		X		
L/D 15[1]		X	X			
L/D 16		X	X	X		
L/D 17	X	X	X	X		
L/D 18		X	X	X		
L/D 19[1]			X			
L/D 20[2]		X	X	X		
L/D 21		X	X	X		
L/D 22[1]		X	X	X		
L/D 24[2]		X	X	X		
L/D 25	X	X	X	X		
Peoria	X	X				
La Grange	X	X				

[1]These sites have rock foundations. All others (except for note 2) are sand-founded sites (requiring piles).
[2]These sites have mixed foundations; some locations would be rock-founded and some pile-founded.

LOCK SIZE SCREENING

The purpose of the size screening analysis was to assess the various lock size options and provide further screening of the potential measures in order to focus the study resources on only the most beneficial sizes. This assessment looked at the 600-foot and 1,200-foot by 110-foot lock sizes for which conceptual designs and preliminary cost estimates already had been developed. Additionally, it examined other potential chamber sizes, either to verify that it was sufficient to move forward with the two sizes already identified or to identify other sizes for which conceptual designs and costs needed to be prepared.

The process verified that the only lock sizes meriting further examination were 110 feet by 1,200 feet and 110 feet by 600 feet. Longer, shorter, narrower, and wider locks were all examined and found to provide smaller net investment returns than locks 110 feet wide by 1,200 feet long. In addition, if the need for a lower cost, "budget constrained" option was identified, the 110-foot by 600-foot locks were identified as the lowest cost size that still provides significant benefits. As a result, these two sizes were carried forward for further quantification of costs, benefits, and impacts.

Potential Chamber Sizes

The screening process first focused on identifying what potential chamber sizes needed to be evaluated. This analysis began by looking at the size of tows using the system, since this is a strong indicator of the chamber size needs. Many factors, both physical and economic, influence tow sizes. The assumption for this analysis was that the current mix of tow sizes utilizing the locks provides a strong indication of likely future sizes. A summary of existing tow size data was developed and is shown in Tables 6 and 7.

TABLE 6: SELECTED TOW WIDTH DISTRIBUTIONS BY LOCK SITE			
	Tow Width in Feet (Percentage)		
Lock	**< 40**	**40-75**	**75-110**
Lock 11	3.56	11.40	85.04
Lock 15	15.32	12.22	72.46
Chmbr 1	6.08	10.02	83.90
Chmbr 4	70.74	25.39	3.88
Lock 19	2.44	11.12	86.44
Lock 20	3.59	10.38	86.04
Lock 21	5.60	12.18	82.22
Lock 22	2.68	13.20	84.12
Lock 24	2.21	15.30	82.49
Lock 25	2.49	15.41	82.10
Lock 26	7.39	18.16	74.45
La Grange	2.95	22.00	75.05

Source: Corps of Engineers Lock Performance Monitoring System (LPMS) Data.

TABLE 7: SELECTED TOW LENGTH DISTRIBUTIONS BY LOCK SITE							
	Tow Length in Feet (Percentage)						
Lock	**<200**	**200-400**	**400-600**	**600-800**	**800-1000**	**1000-1,200**	**>1,200**
Lock 11	1.58	3.92	13.69	14.61	19.54	46.62	0.05
Lock 15	1.16	19.87	11.53	11.47	15.07	40.90	0.00
Chmbr 1	0.48	7.82	13.09	13.29	17.59	47.72	0.00
Chmbr 4	5.23	92.05	2.13	0.58	0.00	0.00	0.00
Lock 19	0.60	4.50	7.75	7.90	12.46	66.80	0.00
Lock 20	1.15	5.17	7.20	7.61	9.73	69.14	0.00
Lock 21	0.75	7.82	6.71	8.24	9.85	66.60	0.03
Lock 22	0.70	4.72	8.29	8.79	9.55	67.93	0.03
Lock 24	0.27	4.66	8.94	10.46	9.61	66.06	0.00
Lock 25	0.48	4.63	8.98	10.78	9.51	65.62	0.00
Lock 26	3.77	7.46	9.48	13.64	12.80	52.81	0.02
La Grange	0.51	2.87	13.74	17.20	20.49	45.08	0.11

Source: Corps of Engineers Lock Performance Monitoring System (LPMS) Data.

The above data indicate that the most common length is nominally 1,200 feet and the most common width is nominally 110 feet. Tows can be locked through shorter chambers in multiple "cuts," but locking 110-foot-wide tows in narrower chambers is impractical due to coupling and operations requirements. Therefore, the minimum chamber width considered was 110 feet.

The jumbo hopper, which has a nominal length of 200 feet, is the predominant barge type on the UMR and IWW. Therefore, it was reasonable to consider chamber lengths in 200-foot increments. As a result, the cost and performance differences were evaluated between 200-, 400-, 600-, 800-, 1,000-, and 1,200-foot locks, all with 110-foot width. Vessels other than commercial tows also utilize system locks. These vessels include pleasure boats and passenger vessels. As a result, smaller non-commercial chambers devoted solely to these vessels also were evaluated.

It is also reasonable to question whether locks longer than 1,200 feet or wider than 110 feet might be economically advantageous. To answer this question required some systemic analysis of the benefits and costs. The benefits of operating increasingly larger tows are fairly limited. For example, the barge costing model by Reebie Associates, transportation management consultants, indicated that even doubling tow sizes to 30 barges as opposed to 15 would only provide a 30 percent cost reduction. If this practice were universally adopted from below Lock 19 to below St. Louis, the net present value of the savings obtained would be about $130 million (based on rough estimates of cost for tow trips through this reach times a 30 percent savings). However, much of the existing towboat fleet does not have the horsepower to adopt this practice, even if the channel were sufficient to accommodate this size tow, so the actual benefits are probably far less. In any event, this benefit is insufficient to provide for the added costs of modifying the two farthest downstream locks (Locks 26 and 27). Both Locks 26 and 27 have a 110-foot by 1,200-foot chamber and a 110-foot by 600-foot chamber in place, and these locks are not anticipated to need additional capacity in the near term. Given the system nature of movements, if larger locks were constructed upstream, these two locks also would need to be enlarged for the system to work efficiently. Therefore, it can be concluded that the 110-foot by 1,200-foot lock is the largest lock size that needs to be considered.

Costs Evaluated

The costs for 600-foot and 1,200-foot locks were prepared as part of the *Conceptual Lock Design* report and presented previously in this report. Cost estimates for other chamber sizes were developed as part of this analysis using interpolation/extrapolation of the 600- and 1,200-foot costs. Costs for all sizes evaluated are included as Attachment 1.

Another cost that was considered in the analysis was the impact to navigation during construction of a new chamber (i.e., delays to tows during periods that a lock is unavailable). The impact costs were estimated using construction schedules available at the time of the analysis. These initial analyses indicated that impacts to navigation could be severe, up to $50 million or more for some locations and types. However, subsequent analyses using the system models and revised construction schedules have shown lower impacts to navigation due to changes in economic assumptions and methodology. Impacts to navigation can influence the preferred lock locations and types. However, the impacts to navigation costs were not a deciding factor in the lock size screening.

Quantitative Size Screening Analysis

The methodology employed to compare alternative lock sizes was straightforward. The analysis used a model to evaluate the relative costs and benefits of various chamber sizes, but it did not attempt to assess the justification of large-scale measures. Such an analysis will be done using the system economic model. Rather, the analysis estimated the incremental benefits of one large-scale measure compared to another. The basic assumption for the analysis was that all major systemic constraints would be relieved (measures implemented) in a timely fashion.

The analysis was conducted using the estimated construction costs and delay costs to estimate the reasonable time to implement and the useful life of the various large-scale improvement measures. From the point of implementation, the difference in benefits (delay cost reductions) between various potential measures was estimated over a 50-year project life. Since many of the alternatives have a project life of less than 50 years, the cost of additional capital investment was also included as appropriate. For this analysis, the project life equals the time it takes under the assumed traffic growth and level of improvement for delay times to reach the pre-project level. As an example, if a particular improvement reduces delay from 10 hours per tow to 5 hours, but in 20 years traffic has grown such that delay is again 10 hours, the project life is shown as 20 years. Improvements with delay reductions lasting 50 years or more are shown with 50-year project lives.

The analysis was conducted using an economic model. The model was written and executed in three parts, all using TK Solver software. Part 1 estimated the traffic level at which implementation of a large-scale improvement was reasonable (i.e., what traffic level results in delay cost reductions exceeding construction costs). Part 2 prepared the stream of annual costs associated with transit times for the site, including an extension or an additional chamber for a 50-year period or until the limit of traffic was reached. Finally, Part 3 compared the cost streams for various alternatives and factored in the cost of future investments if needed.

Key Parameters/Assumptions

A. Tow Delay Cost $300 per hour for 4,000-4,400 hp tows (based on FY 1997 Planning Guidance Shallow Draft Vessel Cost).

B. Traffic Growth Rate 1.5 percent per annum (based on initial traffic forecast study results).

C. Discount Rate 7.375 percent (Federal rate in effect for FY 1997).

D. Lock processing times (estimated from current LPMS data with appropriate modifications).

Results

To provide a representative sample, the model was run using information on Lock 22, Lock 25, Lock 19, and La Grange Lock. At Lock 22, Locations 2, 3, and 4 were evaluated. At Lock 25, Locations 1, 2, and 3 were evaluated. At La Grange Lock, Locations 1 and 2 were evaluated. Only Location 3 was evaluated at Lock 19. Completing the analysis at four sites provided some indication of the robustness of the basic conclusion that 1,200-foot by 110-foot locks are preferred. By evaluating Locks 22 and 25, the study team considered both a rock-founded and a pile-founded site. In addition, considering La Grange Lock allowed the study team to evaluate the impact of open pass, while considering Lock 19 accounted for a site where a 1,200-foot by 110-foot chamber already exists. All of these analyses support the conclusions.

The results of these runs are displayed in matrices (see Attachments 2 through 10). They provide the benefits gained (positive numbers) or foregone (negative numbers) of one chamber size over another. In addition, they show the estimated project life of the measure, the period of time the delay reductions remain below the pre-project level. Further, at Locks 22, 25, and La Grange, they show the comparison of 1,200-foot chambers at different locations; however, these only provide estimates of the relative values that will ultimately be determined through analysis with the system economic model. The project life is also displayed in these matrices.

For example, in looking at Attachment 3 for a lock chamber extension (Location 2) at Lock 25, it is apparent that both the extensions to 800 feet and 1,000 feet provide very little benefits and have a very short project life of 3 years. In contrast, there are huge incremental benefits of over $200 million (present worth) in moving to a 1,200-foot chamber, which eliminated the need for time-consuming double lockages. This alternative in contrast has a project life of approximately 40 years before traffic grows such that delays again reach pre-project levels.

The matrices for the options showing new lock construction (Locations 1, 3, and 4) can be understood in a similar manner by again looking at changes in incremental benefits and project life. Attachment 6 evaluating options for Location 3 at Lock 22 shows that incremental benefits and project life increase as the size is increased. After the initial gain of benefits in getting to 400 feet, the greatest incremental benefits accrue in moving to 600-foot chambers ($20 million) and 1,200-foot chambers ($39 million). The 800-foot and 1,000-foot lock options provided less relative incremental benefits, while the smaller 200- and 400-foot chambers had much shorter economic lives. Even for La Grange Lock, which due to site conditions has open pass conditions and a somewhat higher percentage of smaller tows, the incremental benefits in moving from a 1,000-foot to a 1,200-foot chamber of $7 million exceed the incremental costs of $5 million (for a Location 1 Type C lock).

Sensitivity Analysis

A sensitivity analysis was conducted to further verify that the lock size screening conclusions would hold over a range of varying parameters. Two very important parameters that were not varied in the initial evaluations were the growth rate (1.5 percent) and the discount rate (7.375 percent). The effects of varying these parameters (using Lock 22, Location 4 as an example) were tested (see Attachment 11). The attachment illustrates that the conclusions hold under a range of traffic growth rates (0 percent to 3.0 percent annually) and discount rates (5 percent to 9 percent). This sensitivity analysis provides additional confidence in the validity of the overall results of the analysis.

Conclusions of Size Screening

The results of this analysis in combination with information on system traffic, engineering options, and the professional judgement of study team allowed the following conclusions to be drawn regarding lock sizing:

1. In every case, for the preferred location and construction type, the 1,200-foot chamber provides enough incremental benefits to justify the incremental costs. The 1,200-foot locks are the preferred large-scale alternative in terms of net benefits.
2. While providing fewer benefits than 1,200-foot locks, 600-foot options can be carried forward as the "budget constrained" alternative. These locks represented the lowest first cost option at the time of this analysis that still provides significant net benefits. (However, the development of the revised lock extension (Type 2R), presented later in this report, provided a lower cost 1,200-foot option allowing 600-foot locks to be screened out during the secondary screening.)
3. When considering lock extensions (Location 2), only extensions to 1,200 feet provide substantial benefits.
4. Locks larger than 110 feet by 1,200 feet will not provide enough incremental benefits to justify the additional costs.
5. Non-commercial (recreation) chambers represent a poor option relative to other chamber sizes.

As a result of the analysis and conclusions, the only lock sizes carried forward for further analysis were the 110-foot by 1,200-foot and 110-foot by 600-foot. This conclusion was reached based on the economic analysis summarized here as well as considering available information on traffic, engineering options, and the professional judgment of the study team.

LOCK TYPE SCREENING

The initial screening of lock types involved an iterative process. Two separate screening efforts and even the development of a new lock type occurred as efforts progressed and new information and insights were gained.

Initial Lock Screening

With three lock types (Types A, B, and C) to consider at each of the 43 locations that survived the location screening, 129 different 1,200-foot lock designs were left to investigate.[1] Similar to the screening of lock locations, a screening of lock types was conducted to eliminate any alternative lock type that was clearly dominated by another lock type at the same location.

At the start of this evaluation, it was noted that Type A locks alternatives are not a practical option for either Location 2 or Location 3. For Location 3, constructing a traditional cellular cofferdam around the entire construction area (per Type A design criteria) would severely encroach on the approach to the existing lock. Since such a cofferdam would be required to remain in place for an extended period of time, the adverse economic impact to commercial navigation during the construction period would be prohibitive. Placing a cofferdam around the existing lock to extend it to 1,200 feet (a "Location 2" new lock) would have even worse economic consequences because there would be no access for navigation throughout the construction period. Therefore, Type A locks were eliminated at Location 2 and Location 3, reducing the total number of lock alternatives from 129 to 101 (i.e., 129 minus the 28 Location 2 or Location 3 Type A's at the remaining locations).[2]

However, this new total number of alternatives needed to be further reduced to allow the more promising alternatives to be given more detailed attention and to narrow the field of alternatives. For that purpose, a screening of lock types was made. Whereas lock locations were screened based primarily upon factors over and above the basic lock construction (e.g., environmental concerns, channel realignment, relocations, etc.), lock types were screened primarily by comparing first costs for the basic lock construction at a given location. Cost estimates of the three alternative lock types at five alternative locations at a typical rock-founded site and a typical pile-founded site were presented in Tables 1 and 2. As can be noted from these tables, a large separation in first costs exists between locks of certain locations and certain types. These differences in first cost were found to be a sufficient basis to screen lock types. That is true because costs other than the basic lock cost (e.g., costs for channel work and environmental mitigation) are largely constant for all lock types at a given location, and lock performance does not vary greatly between lock types.

The lock type initial screening was completed utilizing the quantified costs discussed earlier. Based on this information, the following conclusions, applicable to both 600-foot and 1,200-foot locks, were drawn:

(1) Rock-Founded Lock Types. The separation in first cost between the lock Types B and C at Locations 2 and 3 was too small to eliminate either lock type at this point. For Location 4, however, the Type A lock is sufficiently more expensive than the Type B lock (without sufficient

[1] This number of lock alternatives is for 1,200-foot-long locks only. In addition, 600-foot-locks, totaling 84, needed to be screened. The number of 600-foot lock alternatives is less because there are no new 600-foot lock alternatives at Location 2.

[2] The remaining number of 600-foot lock alternatives after eliminating Location 3 Type A's is 71.

performance improvement) so that the Type A lock is eliminated from further consideration. For the remaining lock types, a more detailed analysis is required, quantifying all costs and benefits.

(2) Pile-Founded Lock Types. Based on the cost differentials, the following lock types are screened from further consideration:

Pile-Founded Lock Types Eliminated

Location 1 - Types A and B

Location 4 - Type A

After the above lock type screening, the remaining lock locations and types are as indicated below in Table 8. This represents a total of 82 1,200-foot lock alternatives and 52 600-foot lock alternatives. This total compares with the initial total of 288 1,200-foot alternatives in the universe of large-scale measures and 129 1,200-foot alternatives after the screening of lock locations.

TABLE 8: LOCATIONS AND TYPES REMAINING AFTER INITIAL LOCK TYPE SCREENING

	Location Number and Viable Types					
Lock and Dam Site	**1**	**2[1]**	**3**	**4**	**5**	**6**
L/D 11		B, C	B, C			
L/D 12		B, C	B, C	B, C		
L/D 13		B, C	B, C	B, C		
L/D 14[2]		B, C		B, C		
L/D 15[2]		B, C	B, C			
L/D 16		B, C	B, C	B, C		
L/D 17	C	B, C	B, C	B, C		
L/D 18		B, C	B, C	B, C		
L/D 19[2]			B, C			
L/D 20[3]		B, C	B, C	B, C		
L/D 21		B, C	B, C	B, C		
L/D 22[2]		B, C	B, C	B, C		
L/D 24[3]		B, C	B, C	B, C		
L/D 25	C	B, C	B, C	B, C		
Peoria	C	B, C				
La Grange	C	B, C				

[1]There are no new 600-foot lock alternatives at Location 2. Therefore, the Location 2 column is blank for the 600-foot lock case (the 1,200-foot lock case is shown). All other columns are the same for both lock sizes.
[2]These sites have rock foundations. All others (except for note 2) are sand-founded sites (requiring piles).
[3]These sites have mixed foundations; some locations would be rock-founded and some pile-founded.

Continuation of Lock Type Screening

Additional analysis and quantification of benefits and costs allowed some additional screening. During the expert elicitation process (February 1997) used to determine the delays to navigation during construction, further justification for screening lock alternatives was identified. As a result, the pile-founded Location 2, Type C and Location 3, Type B locks were eliminated due to the reasons discussed below. As a result, more detailed cost information was not developed for these sites. (Subsequent analysis of the impacts to navigation revealed that these costs might be less of a factor than initially anticipated. As a result, the screening discussed below, which was used to eliminate Location 2, Type C locks and Location 3, Type B locks at pile-founded sites, is weakened. As shown later in this report, the revised Type 2R lock would have screened out the 2C lock option regardless. However, for Location 3 locks, if subsequent analysis shows justification for locks at this location, both Types B and C will be considered during the detailed site-specific design efforts.) Additional engineering efforts at Lock 19 also revealed the ability to eliminate 600-foot locks and Location 3, Type B 1,200-foot locks at this site.

The Location 2, Type C lock features a weeping floor slab system composed of numerous precast blocks, filter layers, and evenly spaced pile-founded struts between the lockwalls that resist tension and compression forces. The Type B lock features large precast box-beam-like slabs that span from wall to wall. The navigation impacts to construct the two floor systems were subjectively determined by experts. Compared to the Type B floor system, the Type C system would require a much longer time to install, would require additional winter-time lock closure with dewatering, and overall would be more complicated to construct. Although the Type C lock is slightly cheaper to construct than the Type B lock, the economic impacts to navigation during construction and increased risks and uncertainty outweigh the savings in construction cost. Thus, all of the pile-founded Location 2, Type C locks were eliminated from further consideration.

For Location 3, both lock Types B and C feature an extension of the existing downstream guidewall. However, the Type B lock features a permanent extension of the existing downstream guidewall, and the Type C a temporary one. The permanent construction offers a fixed location with high first cost. Navigation industry representatives reviewing this plan concluded that, after the lock at Location 3 is complete, the wall would likely hinder upbound approaches to the lock. Thus, the wall would have to be removed, resulting in additional costs. The permanent wall also provides for no adjustment in its location to suit navigation in the interim. The temporary wall consists of a series of connected barges that are moored with spud piles. The Type C "spud barge wall" is advantageous in that it is easily installed and removed, cheaper than permanent construction, and mobile/adjustable to suit navigation needs. (This type of guidewall extension was successfully used at the old Lock 26 on the Mississippi River.) The Type C lock also features a little less concrete in the lockwall than a Type B lock which would reduce the walk/storage surface available on the walls. Otherwise, the Type B and Type C locks are the same. The guidewall associated with the Type C lock is preferred mainly due to its lower cost and the flexibility of the location of the temporary guidewall extension versus a permanent wall. Basically, the Type C offers preferred features at a lower cost than does its competitor. Therefore, it is a preferred alternative, and all of the pile-founded Location 3, Type B locks are eliminated from further consideration. (As discussed above, if the system economic analysis shows justification for a Location 3 lock, both Types B and C locks will receive some consideration during the detailed design efforts due to their similarities in cost and performance.)

In addition, the following was determined regarding Lock 19, a rock-founded site. Due to the higher lift at Lock 19 (38 feet maximum), the Type C, Location 3 lock concept (consisting of sheet pile cellular lockwalls) is not practical and was eliminated from consideration. While an alternative concept could be developed (or the Type B lock economized), this refining effort is considered unwarranted for the system study. In addition, due to the high relative cost to construct and the lower performance of 600-foot locks at this high lift site, constructing a new 600-foot lock was eliminated as an option at Lock 19.

The array of alternative locks remaining after all of the screening steps noted above is as shown in Table 9.

TABLE 9: LOCK LOCATIONS AND TYPES REMAINING AFTER CONTINUED LOCK TYPE SCREENING						
	Location Number and Viable Types					
Lock and Dam Site	**1**	**2[1]**	**3**	**4**	**5**	**6**
L/D 11		B	C			
L/D 12		B	C	B, C		
L/D 13		B	C	B, C		
L/D 14[2]		B, C		B, C		
L/D 15[2]		B, C	B, C			
L/D 16		B	C	B, C		
L/D 17	C	B	C	B, C		
L/D 18		B	C	B, C		
L/D 19[2]			B			
L/D 20[3]		B, C	B, C	B, C		
L/D 21		B	C	B, C		
L/D 22[2]		B, C	B, C	B, C		
L/D 24[3]		B, C	B, C	B, C		
L/D 25	C	B	C	B, C		
Peoria	C	B				
La Grange	C	B				

[1]There are no new 600-foot lock alternatives at Location 2. Therefore, this column is blank for the 600-foot lock case (the 1,200-foot lock case is shown). All other columns are the same for both lock sizes.
[2]These sites have rock foundations. All others (except for note 3) are sand-founded sites (requiring piles).
[3]These sites have mixed foundations; some locations would be rock-founded and some pile-founded.

Additional Design Efforts - New Lock Type

Through the evaluation of the lock concepts discussed above, it became apparent that the lowest first cost 1,200-foot alternative was the construction of a lock extension (Location 2). However, with the type of construction proposed, the delays/closures to the navigation industry were found to be excessively high. The risks and uncertainties of building a lock extension (Location 2) also are greater than building away from tow traffic (Location 1 or Location 4). The results of these investigations highlighted the need for continued engineering and design with a focus on significantly reducing the cost of impacts to navigation during construction of a lock extension.

Therefore, the study team undertook an additional investigation of lock extension designs to identify further opportunities to minimize the delays and closures. Additional departures from standard criteria (above those explored in the original analysis) were required to obtain the maximum amount of cost savings and reduced impacts to navigation. This effort resulted in a revised Location 2 lock type (Type R). The revised lock concept consists of primarily five items:

1. The new culverts are not extended into the new extension.
2. The existing intermediate wall is extended with concrete-filled sheet pile structures.
3. The existing guidewall is modified for reuse as a lockwall.
4. The new lower guidewall is shortened to 600 feet and consists of concrete beams spanning cells.
5. The new lower gate monoliths are float-in units that may be placed in the wet.
6. Approach channel improvements would not be made unless necessary to utilize the lock.

One of the key decisions that allowed these revised concepts was the decision to maintain the elevation of the existing lock floor and also leave the sill depth unchanged (1.38 times draft for clearance over the sill at minimum tail water). This decision allowed the existing lower guidewall to be incorporated into the design as part of the landside lockwall, since lowering the sill and chamber depth would have undermined the wall and necessitated its removal.

As a result of this additional design effort, Type R locks were added as an option at Location 2, increasing the total number of potential alternative locks.

TABLE 10: LOCK LOCATIONS AND TYPES CARRIED FORWARD FOR FURTHER QUALITATIVE EVALUATION

	Location Number and Viable Types					
Lock and Dam Site	**1**	**2[1]**	**3**	**4**	**5**	**6**
L/D 11		B, R	C			
L/D 12		B, R	C	B, C		
L/D 13		B, R	C	B, C		
L/D 14[2]		B, C, R		B, C		
L/D 15[2]		B, C, R	B, C			
L/D 16		B, R	C	B, C		
L/D 17	C	B, R	C	B, C		
L/D 18		B, R	C	B, C		
L/D 19[2]			B, C			
L/D 20[3]		B, C, R	B, C	B, C		
L/D 21		B, R	C	B, C		
L/D 22[2]		B, C, R	B, C	B, C		
L/D 24[3]		B, C, R	B, C	B, C		
L/D 25	C	B, R	C	B, C		
Peoria	C	B, R				
La Grange	C	B, R				

[1]There are no new 600-foot lock alternatives at Location 2. Therefore, this column is blank for the 600-foot lock case (the 1,200-foot lock case is shown). All other columns are the same for both lock sizes.
[2]These sites have rock foundations. All others (except for note 3) are sand-founded sites (requiring piles).
[3]These sites have mixed foundations; some locations would be rock-founded and some pile-founded.

For each of the remaining lock alternatives, the costs and performance factors were further quantified and are shown following the wicket dam discussion.

OTHER LARGE- SCALE OPTIONS SCREENING

Wicket Dam Alternatives

In addition to lock extensions and new locks based upon historic flow records, Locks and Dams 17 and 20 appear to have merit for construction of a navigable dam. For the period of time that flows are sufficient for open pass, a navigable dam allows tows to bypass a lock and avoid the delay of locking through. Tows still have to cover the distance from the starting and ending points for measurement of current lockage times. However, they can cover this distance, traveling at closer to open river speeds, without slowing or stopping.

One limitation to open pass is that it is not schedulable very far in advance. On the Mississippi, there can be about 2 weeks of notice based upon river forecasting models. In any given year, there may be no open pass conditions. Other years, there may be extended periods of open pass.

Another limitation concerns the wintertime closure experienced each year. That is, if the flow conditions for open pass occur during the wintertime closure period, there would be no traffic on the river to benefit from these conditions.

A further limitation is similar to the last one. That is, for the very high flows there might be open pass at Locks and Dams 17 and 20, but the flows are too high to allow navigation at other locks or channel reaches. This could be the case because of adverse currents or because the lockwalls at the other locks become inundated. Thus, there would be no system benefits to the open pass at these times. A review of hydraulic records, however, indicates that this limitation is rarely experienced.

Table 11 indicates the average annual occurrence of open pass conditions at Locks and Dams 17 and 20. Since there is a significant cost in mobilizing to lower the wickets and remobilizing to raise them again, this operation would not be done if the open pass conditions were expected to last only a few days, which is likely to be the case in most months.[3]

TABLE 11: COST AND PERFORMANCE OF WICKET DAM IMPROVEMENTS

Lock	Percent Open Pass[1]	Equivalent Days per Month[1]	First Cost Constr. and Equipment[2] ($1,000)	Operations & Maint. Costs[3] ($1,000)	Site-Specific Env. Cost ($1,000)[4]	Total Cost ($1,000)
Lock 17 Average (Mar-Dec)	23.5	7.2	$62,400	$4,510	$8,250	$75,160
Lock 20 Average (Mar-Dec)	13.0	4.0	$86,100	$7,470	$4,125	$97,695

[1] Potential open pass conditions, based on average by month for period of record 1936 through 1996.

[2] Costs shown only include the first cost of construction and purchase of equipment to operate the wickets (towboat, maneuver boat, and barge-mounted backhoe/hook).

[3] Present worth of operations and maintenance costs are shown based on discount rate of 7.4 percent. Annual operating cost of $61,600 would be incurred to raise and lower the wickets an average of five times each during the period of March through July each year. This annual cost includes labor for a crew of five people, fuel costs, and equipment charges. In addition, annual maintenance cost assumes need for replacement of 15 percent of the wicket gates/year (5 gates at Lock and Dam 17 at a cost of $550,000 and 9 gates at Lock and Dam 20 at a cost of $990,000). This maintenance cost would not be incurred until about the 10th year of operation. No major rehabilitation is expected to be required within the 50-year planning horizon.

[4] Environmental costs shown are habitat replacement values, based on the *Site-Specific Habitat Assessment* report for Lock 20 and extrapolation of earlier estimates for Lock 17.

Wicket Dam Screening

The wicket dam option was evaluated in terms of the benefits produced compared to the costs, also taking into consideration other relevant qualitative factors. Table 11 summarizes the performance and costs of the wickets, plus it includes the present worth of operations and maintenance and costs of site-specific environmental habitat replacement. The environmental costs for Lock 20 are habitat replacement values developed as part of the *Site-Specific Habitat Assessment* report. Site-

[3] The determination of the value of lowering the wickets to allow open pass navigation would depend upon the extent of the queue built up at the time. Therefore, a specific number of days of high flows above which lowering the dam would be worthwhile cannot be set at this time. In addition, the flow capacity of the wicket dam section may be needed to prevent a backwater effect that would raise the upper pool. Thus, some of the wickets may have to be lowered anyway.

specific costs for Lock 17 are shown as double the Lock 20 costs. This is a rough estimate based on the fact that a popular walleye fishing area at Lock 17 would be impacted downstream, and the State and Federal resource agencies expressed strong opposition to closing connecting channels in the area of Turkey Island and Turkey Chute.

The wicket dams were screened out based on limitations in performance for the relatively high cost and site-specific environmental resource concerns. The costs are over one-half of the costs of new Location 2R locks. Wicket dams only provide navigation benefits when river stages are such that the wickets can be lowered and allow open pass. As the table shows, the percent of the navigation season during which this is anticipated to occur is relatively limited and unpredictable, especially at Lock 20. Even during open pass, the effective system benefits are limited by the performance of the adjacent upstream and downstream locks. In addition, during shorter periods of potential open pass conditions (only a few days) the cost and time required to just lower and raise the gates would significantly diminish the benefits. While Lock 17 shows somewhat lower costs and greater performance, the greater environmental concerns at this site reinforce the decision to screen out this measure from further consideration.

SECTION 3 - FURTHER QUANTIFICATION OF PERFORMANCE AND COST

With the new lock alternatives narrowed to the several most promising alternatives at each site, it was no longer sufficient to compare them on the basis of first cost of construction alone. Instead, after the initial lock location, size, and type screening was completed, it became necessary to further quantify the remaining alternatives' life cycle costs, impacts, and performance "time savings benefits." In considering all of the factors that needed to be quantified to compare lock alternatives, the following list of Lock Design Evaluation Factors was developed.

TABLE 12: LOCK DESIGN EVALUATION FACTORS
Cost Factors
Life Cycle Costs
First Costs
Basic Lock & Guidewall Construction
Channel Work and Levees (as needed)
Relocation & Real Estate Requirements
Replacement Costs (as needed)
Maintenance Costs
Routine Maintenance
Major Rehabilitation
Operation Costs
Economic Impacts to Navigation During Construction (delays and closures)
Environmental Resource Impacts
Cultural and Historic Resource Impacts
Benefits Factors
Performance
Lockage Time
Disposition of Existing Lock

While the reminder of this section provides additional descriptions and detail, Table 13 summarizes the cost information and performance (new lockage times) for each of the remaining lock locations and types. The 16 sites shown in the table were identified in the reconnaissance studies as having a potential need for new lock construction within the 50-year planning horizon. The table also provides averages for the various locations and types and information on the relative costs.

Although at first look it might appear that all of the lock and dam sites are similar, each site is unique in at least some aspects. The limited field investigations of this system study did not allow complete consideration of all site-specific conditions. Some of the site design considerations were considered, but many of these items need to be looked at in greater detail if justification is shown as part of the system study. Additional foundation exploration is especially important for the foundation design and accuracy of the cost estimates.

TABLE 13: SUMMARY OF PERFORMANCE AND COST

				Costs ($1,000)					
Lock Site/ Length	Lock Alter-native	Type	Avg Lockage Time[1]	First Cost (lock and guidewalls)[2]	First Cost Channel Work and Levees	Real Estate and Reloca-tions	Operation and Maint. (Present Worth)[3]	Major Rehab. (Present Worth)	Total Cost w/out Env or Impacts to Nav[4]
LaGrg.	Existing Lock		103						
1,200ft	Loc 1	1C	60	$145,000	$17,000	$500	$5,900	$1,000	$169,400
	Loc 2	2B	57	$152,000	$0	$50	$0	$0	$152,050
		2R	60	$110,000	$0	$50	$0	$4,200	$114,250
600 ft	Loc 1	1C	105	$131,000	$17,000	$500	$5,900	$700	$155,100
Peoria	Existing Lock		107						
1,200ft	Loc 1	1C	64	$144,000	$3,700	$18,900	$5,900	$1,000	$173,500
	Loc 2	2B	59	$146,000	$500	$3,500	$0	$0	$150,000
		2R	62	$117,000	$0	$50	$0	$4,200	$121,250
600 ft	Loc 1	1C	112	$131,000	$3,700	$18,900	$5,900	$700	$160,200
25	Existing Lock		101						
1,200ft	Loc 1	1C	56	$165,000	$9,300	$2,800	$5,900	$1,000	$184,000
	Loc 2	2B	51	$160,000	$1,000	$200	$0	$0	$161,200
		2R	54	$119,000	$1,000	$200	$0	$4,200	$124,400
	Loc 3	3C	50	$195,000	$1,000	$30	$5,900	$1,000	$202,930
	Loc 4	4B	50	$282,000	$0	$30	$5,900	$0	$287,930
		4C	50	$248,000	$0	$30	$5,900	$10,700	$264,630
600ft	Loc 1	1C	108	$151,000	$13,000	$2,800	$5,900	$700	$173,400
	Loc 3	3C	99	$160,000	$1,000	$30	$5,900	$700	$167,630
	Loc 4	4B	99	$231,000	$0	$30	$5,900	$0	$236,930
		4C	99	$217,000	$0	$30	$5,900	$7,000	$229,930
24	Existing Lock		107						
1,200ft	Loc 2	2B	53	$133,000	$800	$30	$0	$0	$133,830
		2C	53	$131,000	$800	$30	$0	$1,000	$132,830
		2R	56	$116,000	$0	$30	$0	$4,200	$120,230
	Loc 3	3B	54	$195,000	$800	$30	$5,900	$0	$201,730
		3C	54	$189,000	$800	$30	$5,900	$3,000	$198,730
	Loc 4	4B	51	$253,000	$800	$30	$5,900	$0	$259,730
		4C	51	$251,000	$800	$30	$5,900	$10,700	$268,430
600ft	Loc 3	3B	105	$162,000	$800	$30	$5,900	$0	$168,730
		3C	105	$150,000	$800	$30	$5,900	$2,000	$158,730
	Loc 4	4B	105	$225,000	$800	$30	$5,900	$0	$231,730
		4C	105	$233,000	$800	$30	$5,900	$7,000	$246,730
22	Existing Lock		112						
1,200ft	Loc 2	2B	63	$117,000	$4,800	$30	$0	$0	$121,830
		2C	63	$110,000	$4,800	$30	$0	$1,000	$115,830
		2R	68	$97,000	$0	$30	$0	$4,200	$101,230
	Loc 3	3B	64	$131,000	$5,100	$30	$5,900	$0	$142,030
		3C	64	$124,000	$5,100	$30	$5,900	$3,000	$138,030
	Loc 4	4B	63	$194,000	$6,900	$30	$5,900	$0	$206,830
		4C	63	$182,000	$6,900	$30	$5,900	$5,200	$200,030
600ft	Loc 3	3B	107	$109,000	$5,100	$30	$5,900	$0	$120,030
		3C	107	$96,000	$5,100	$30	$5,900	$2,000	$109,030
	Loc 4	4B	107	$182,000	$6,900	$30	$5,900	$0	$194,830
		4C	107	$173,000	$6,900	$30	$5,900	$3,500	$189,330
21	Existing Lock		98						
1,200ft	Loc 2	2B	51	$149,000	$2,000	$60	$0	$0	$151,060
		2R	55	$108,000	$0	$60	$0	$4,200	$112,260
	Loc 3	3C	57	$188,000	$2,200	$60	$5,900	$1,000	$197,160
	Loc 4	4B	54	$277,000	$5,500	$30	$5,900	$0	$288,430
		4C	54	$267,000	$5,500	$30	$5,900	$10,700	$289,130
600ft	Loc 3	3C	95	$154,000	$2,200	$60	$5,900	$700	$162,860
	Loc 4	4B	95	$227,000	$5,500	$30	$5,900	$0	$238,430
		4C	95	$235,000	$5,500	$30	$5,900	$7,000	$253,430

TABLE 13 (Continued)

Lock Site/ Length	Lock Alter-native	Type	Avg Lockage Time[1]	Costs ($1,000) First Cost (lock and guidewalls)[2]	First Cost Channel Work and Levees	Real Estate and Reloca-tions	Operation and Maint. (Present Worth)[3]	Major Rehab. (Present Worth)	Total Cost w/out Env or Impacts to Nav[4]
20	Existing Lock		104						
1,200ft	Loc 2	2B	54	$103,000	$13,200	$3,700	$0	$0	$119,900
		2C	54	$102,000	$13,200	$3,700	$0	$1,000	$119,900
		2R	58	$90,000	$3,100	$1,900	$0	$4,200	$99,200
	Loc 3	3B	54	$132,000	$10,200	$3,000	$5,900	$0	$151,100
		3C	54	$134,000	$10,200	$3,000	$5,900	$3,000	$156,100
	Loc 4	4B	53	$189,000	$6,300	$30	$5,900	$0	$201,230
		4C	53	$175,000	$6,300	$30	$5,900	$10,700	$197,930
600ft	Loc 3	3B	101	$110,000	$10,200	$3,000	$5,900	$0	$129,100
		3C	101	$106,000	$10,200	$3,000	$5,900	$2,000	$127,100
	Loc 4	4B	101	$158,000	$6,300	$30	$5,900	$0	$170,230
		4C	101	$156,000	$6,300	$30	$5,900	$7,000	$175,230
19	Existing Lock		58						
1,200ft	Loc 3	3B	68	$265,000	$6,100	$50	$5,900	$0	$277,050
18	Existing Lock		99						
1,200ft	Loc 2	2B	52	$143,000	$300	$3,100	$0	$0	$146,400
		2R	55	$103,000	$100	$3,100	$0	$4,200	$110,400
	Loc 3	3C	52	$190,000	$300	$50	$5,900	$1,000	$197,250
	Loc 4	4B	50	$274,000	$100	$50	$5,900	$0	$280,050
		4C	50	$256,000	$100	$50	$5,900	$10,700	$272,750
600ft	Loc 3	3C	98	$156,000	$300	$50	$5,900	$700	$162,950
	Loc 4	4B	97	$225,000	$100	$50	$5,900	$0	$231,050
		4C	97	$225,000	$100	$50	$5,900	$7,000	$238,050
17	Existing Lock		105						
1,200ft	Loc 1	1C	57	$150,000	$20,400	$400	$5,900	$1,000	$177,700
	Loc 2	2B	55	$148,000	$8,900	$200	$0	$0	$157,100
		2R	59	$107,000	$6,200	$200	$0	$4,200	$117,600
	Loc 3	3C	53	$186,000	$11,900	$200	$5,900	$1,000	$205,000
	Loc 4	4B	54	$275,000	$11,900	$200	$5,900	$0	$293,000
		4C	54	$267,000	$11,900	$200	$5,900	$10,700	$295,700
600ft	Loc 1	1C	104	$137,000	$25,000	$400	$5,900	$700	$169,000
	Loc 3	3C	101	$153,000	$11,900	$200	$5,900	$700	$171,700
	Loc 4	4B	101	$226,000	$11,900	$200	$5,900	$0	$244,000
		4C	101	$235,000	$11,900	$200	$5,900	$7,000	$260,000
16	Existing Lock		100						
1,200ft	Loc 2	2B	51	$149,000	$13,600	$300	$0	$0	$162,900
		2R	55	$119,000	$1,000	$300	$0	$4,200	$124,500
	Loc 3	3C	50	$189,000	$15,500	$300	$5,900	$1,000	$211,700
	Loc 4	4B	50	$267,000	$16,000	$300	$5,900	$0	$289,200
		4C	50	$265,000	$16,000	$300	$5,900	$10,700	$297,900
600ft	Loc 3	3C	98	$155,000	$15,500	$300	$5,900	$700	$177,400
	Loc 4	4B	98	$219,000	$16,000	$300	$5,900	$0	$241,200
		4C	98	$233,000	$16,000	$300	$5,900	$7,000	$262,200
15	Existing Lock		111						
1,200ft	Loc 2	2B	59	$104,000	$1,400	$30	$0	$0	$105,430
		2C	59	$96,000	$1,400	$30	$0	$1,000	$98,430
		2R	62	$85,000	$1,400	$30	$0	$4,200	$90,630
	Loc 3	3B	62	$129,000	$1,400	$30	$5,900	$0	$136,330
		3C	62	$151,000	$1,400	$30	$5,900	$3,000	$161,330
600ft	Loc 3	3B	109	$106,000	$1,400	$30	$5,900	$0	$113,330
		3C	109	$119,000	$1,400	$30	$5,900	$2,000	$128,330

TABLE 13 (Continued)

				Costs ($1,000)					
Lock Site/ Length	Lock Alter- native	Type	Avg Lockage Time[1]	First Cost (lock and guidewalls)[2]	First Cost Channel Work and Levees	Real Estate and Reloca- tions	Operation and Maint. (Present Worth)[3]	Major Rehab. (Present Worth)	Total Cost w/out Env or Impacts to Nav[4]
14	Existing Lock		104						
1,200ft	Loc 2	2B	56	$104,000	$6,300	$30	$0	$0	$110,330
		2C	56	$99,000	$6,300	$30	$0	$1,000	$106,330
		2R	59	$92,000	$6,300	$30	$0	$4,200	$102,530
	Loc 4	4B	57	$192,000	$9,800	$500	$5,900	$0	$208,200
		4C	57	$182,000	$9,800	$500	$5,900	$5,200	$203,400
600ft	Loc 4	4B	103	$172,000	$9,800	$500	$5,900	$0	$188,200
		4C	103	$170,000	$9,800	$500	$5,900	$3,500	$189,700
13	Existing Lock		92						
1,200ft	Loc 2	2B	46	$146,000	$0	$400	$0	$0	$146,400
		2R	49	$106,000	$0	$400	$0	$4,200	$110,600
	Loc 3	3C	47	$187,000	$2,000	$400	$5,900	$1,000	$196,300
	Loc 4	4B	47	$273,000	$1,500	$400	$5,900	$0	$280,800
		4C	47	$252,000	$1,500	$400	$5,900	$10,700	$270,500
600ft	Loc 3	3C	93	$153,000	$2,000	$400	$5,900	$1,000	$162,300
	Loc 4	4B	93	$224,000	$1,500	$400	$5,900	$0	$231,800
		4C	93	$221,000	$1,500	$400	$5,900	$7,000	$235,800
12	Existing Lock		95						
1,200ft	Loc 2	2B	47	$145,000	$800	$300	$0	$0	$146,100
		2R	50	$116,000	$800	$300	$0	$4,200	$121,300
	Loc 3	3C	47	$187,000	$4,700	$300	$5,900	$1,000	$198,900
	Loc 4	4B	46	$268,000	$4,400	$300	$5,900	$0	$278,600
		4C	46	$254,000	$4,400	$300	$5,900	$10,700	$275,300
600ft	Loc 3	3C	93	$153,000	$4,700	$300	$5,900	$700	$164,600
	Loc 4	4B	93	$220,000	$4,400	$300	$5,900	$0	$230,600
		4C	93	$223,000	$4,400	$300	$5,900	$7,000	$240,600
11	Existing Lock		102						
1,200ft	Loc 2	2B	49	$104,000	$5,700	$400	$0	$0	$110,100
		2R	53	$75,000	$1,600	$400	$0	$4,200	$81,200
	Loc 3	3C	49	$190,000	$5,700	$400	$5,900	$1,000	$203,000
600ft	Loc 3	3C	100	$156,000	$5,700	$400	$5,900	$700	$168,700
Avg All Existing Lock			103						
Averages New 1,200-foot Locks									
1,200 ft	Loc 1	1C	59	$151,000	$12,600	$5,650	$5,900	$1,000	$176,150
	Loc 2	2B	54	$133,533	$3,953	$822	$0	$0	$138,309
		2C	57	$107,600	$5,300	$764	$0	$1,000	$114,664
		2R	57	$104,000	$1,433	$472	$0	$4,200	$110,105
	Loc 3	3B	59	$146,750	$4,375	$773	$5,900	$0	$157,798
		3C	53	$175,833	$5,067	$403	$5,900	$1,667	$188,869
	Loc 4	4B	52	$249,455	$5,745	$173	$5,900	$0	$261,273
		4C	52	$236,273	$5,745	$173	$5,900	$9,700	$257,791
Averages New 600-foot Locks									
600 ft	Loc 1	1C	107	$137,500	$14,675	$5,650	$5,900	$700	$164,425
	Loc 3	3B	106	$121,750	$4,375	$773	$5,900	$0	$132,798
		3C	100	$142,583	$5,067	$403	$5,900	$1,158	$155,111
	Loc 4	4B	99	$209,909	$5,745	$173	$5,900	$0	$221,727
		4C	99	$211,000	$5,745	$173	$5,900	$6,364	$229,182

Notes:

[1]Average lockage times shown are based on equal percentages of fly, exchange, and turnback lockages. The numbers shown assume turnback approaches occur during the lockage of the previous tow, this may understate overall lockage time slightly.

[2]Cost estimates prepared for these conceptual designs were prepared to the same level of detail as those presented in the *Conceptual Lock Designs Report*. The project element costs are based on 1996 prices and include 25 percent contingencies.

[3]The Operations and Maintenance Costs and the Major Rehab Costs reflect only the incremental life cycle costs for each alternative discounted at 7.4 percent. Total O&M costs would be $13,100 million for Location 2 locks and $19,000 million for other locations leading to the existence of two locks. However, this $13,100 million associated with Location 2 would be required for O&M of the existing lock and as such does not represent a with-project cost.

[4]The total costs shown are not all inclusive. They do not include the costs related to environmental impacts, cultural impacts, or impacts to navigation during construction.

The individual cost factors and performance improvements are reviewed below. The cost factors are presented first. Each of the cost factors, as applicable, was quantified in monetary terms on a present worth basis for the 50-year planning horizon for both 600- and 1,200-foot locks. Present worth values were determined for all measures using a common interest rate of 7.4 percent. However, the actual systems evaluation using the economic model will use the Federal discount rate in effect at the time of the final analysis. Following the discussion of costs, the performance improvements were quantified in terms of minute changes in lockage times and disposition of the existing lock. The Engineering Appendix and other engineering reports present greater detail on these cost items and other site-specific factors.

COST FACTORS

First Costs. Includes those costs incurred associated with the initial construction of an improvement.

Costs of Basic Lock and Guidewall Construction. First costs for the lock concepts were developed for and are presented in Appendix A of the *Conceptual Lock Designs* report and summarized in Table 13 above. Costs for the 600-foot locks were developed by applying a ratio that had been identified for relating costs of 1,200-foot chambers to costs for 600-foot chambers based on detailed evaluations of both sizes at Locks 22 and Lock 25.

Costs for Channel Work and Levees. For most lock alternatives, new lock construction requires some channel work upstream and downstream of the new lock chamber. This channel work can be extensive for a Location 1 lock, but usually is relatively minor for Locations 3 or 4 where only a slight shift in the channel may be needed. For some sites, the existing approach conditions are poor. Thus, an upgrade in the channel design would be recommended along with construction of a Location 2 lock.

The channel requirements (and costs) are the same for 600-foot locks as for 1,200-foot locks since the tows have to travel the same path regardless of the lock size. Levee relocation costs are only necessary at some of the Location 1 locks.

Costs for Relocation and Real Estate Requirements. The right-of-way and relocations cost is another part of the first cost that was a relatively small component of the total cost for most alternatives. Estimates of the value of the lands that would need to be purchased were made based on estimates of the acreage at each lock and dam site required for construction. These estimates are preliminary and would need to be revisited if any large-scale measures are recommended for implementation.

Replacement Costs. Most of the existing locks within the study area have been in service since the 1930's and are still functional. However, those locks were built with conservative design assumptions (similar to Type A locks). Some of the Type B and Type C locks (the only types to survive the screening steps) did not result in the massive concrete gravity walls that have proved so durable for the Type A locks. Therefore, the possibility of their needing replacement in the 50-year planning horizon had to be investigated. None of the lock concepts was found to require a complete replacement within the planning horizon and therefore this factor dropped from consideration.

Maintenance Costs. Maintenance costs are discussed in their two basic categories below.

Routine Maintenance. Routine or normal maintenance occurs frequently and includes grounds keeping, building maintenance, and equipment maintenance. These items would not vary significantly from one type of lock to another, and the maintenance estimates were uniform, except as noted below. The additional wall monoliths of a 1,200-foot lock are low maintenance sections, so the maintenance costs of 600-foot and 1,200-foot locks are essentially equal.[4] Therefore, routine maintenance is not a significant screening factor. The only significant maintenance cost difference is between maintenance of a lock at Location 2 (a single 1,200-foot lock) and maintenance of a 1,200-foot lock at Locations 1, 3, or 4 plus maintenance of the existing lock (i.e., maintaining two locks). The annual maintenance cost for a Location 2 (single 1,200-foot lock) is estimated to average $197,000.[5] The annual maintenance cost for the existing 600-foot lock plus a 1,200-foot lock at either Locations 1, 3, or 4 is estimated to average $394,000 ($197,000 each for the two locks).[6] However, the $197,000 annual cost of maintaining one lock (for Location 2 options) is a without-project cost and as such does not represent a new with-project cost since it would be incurred regardless. The only cost to be accounted for in the with-project condition is the additional $197,000 annually associated with options resulting in an additional lock (Locations 1, 3, or 4).

Major Rehabilitation. If only routine maintenance is performed, the lock structures would deteriorate to the point where they are less reliable and less able to efficiently perform their function of locking boats. As noted earlier, most of the existing locks were built in the 1930's and are still fully functioning. However, these locks had deteriorated significantly since their construction and needed to have maintenance above the routine level at about 50 years of age. For simplicity, this discussion will refer to any of this type of extra maintenance as major rehabilitation. Major rehabilitation of locks and dams was addressed in the without-project discussion of the Engineering Appendix.

Since major rehabilitation expenses are incurred in the future, they are heavily discounted when viewed as a present worth. For example, a $50 million major rehabilitation contract in year 50 would be equivalent to $1.443 million today. While this is a large cost, it is relatively insignificant compared to the first cost of construction that is typically at least $100 million. Nevertheless, the major rehabilitation costs were estimated for those lock concepts that are expected to require major rehabilitation within the 50-year planning horizon.

The following are general descriptions of the major rehabilitation for the lock types that are expected to require this above normal maintenance. The associated costs for this work are shown in Table 14 for 1,200-foot and 600-foot locks. These items include rehabilitating sheet pile cell walls, replacing concrete lockwall panels, and grouting. The actual future rehabilitation needs for a lock are very uncertain and depend upon a number of site-specific factors such as: quality of original construction (influenced by quality of materials, construction methods and workmanship, weather during construction, etc.), environmental factors (freeze-thaw cycles, corrosive influences, predominant weather), random events (accidents, extreme weather), and extent and timing of routine maintenance. However, since the major rehabilitation costs are heavily discounted,

[4] This conclusion may not be intuitive. While a longer chamber represents more total structure, this is offset by the fact that a 600-foot lock will go through many more lock operations than a 1,200-foot lock to pass the same traffic. This added "wear and tear" affects the lock components that require the most maintenance (machinery, gates, valves, etc.).

[5] The present worth of 50 years of routine maintenance costs for a Location 2 lock is estimated at $2,600,000 based upon an 7.4 percent discount rate and the annual maintenance cost of $197,000 (Jan 96 price levels).

[6] The present worth of 50 years of routine maintenance costs for the existing 600-foot lock plus a 1,200-foot lock at either Location 1, 3, or 4 is estimated at $5,200,000, based upon an 7.4 percent discount rate and the annual maintenance cost of $394,000 (Jan 96 price levels).

extensive refinement of the estimates and definition of the uncertainties is considered unwarranted for the system feasibility study.

TABLE 14: MAJOR REHABILITATION SUMMARY (1,200-FOOT AND 600-FOOT LOCKS)			
Location and Type	Major Rehab. Cost	Year(s) Incurred	Present Worth[1]
Pile-Founded Locks - 1,200'			
Loc 1, Type C	$3,500,000 [2]	20, 40	$1,000,000
Loc 2, Type B	0	N/A	0
Loc 2, Type C	0	N/A	0
Loc 2, Type R	$25,000,000	25	$4,200,000
Loc 3, Type B	0	N/A	0
Loc 3, Type C	$3,500,000 [2]	20, 40	$1,000,000
Loc 4, Type B	0	N/A	0
Loc 4, Type C	$90,000,000	30	$10,700,000
Rock-Founded Locks - 1,200'			
Loc 2, Type B	0	N/A	0
Loc 2, Type C	$3,500,000	20,40	$1,000,000
Loc 2, Type R	$25,000,000	25	$4,200,000
Loc 3, Type B	0	N/A	0
Loc 3, Type C	$25,000,000	30	3,000,000
Loc 4, Type B	0	N/A	0
Loc 4, Type C	$44,000,000	30	5,200,000
Pile-Founded Locks - 600'			
Loc 1, Type C	$2,300,000 [2]	20, 40	$700,000
Loc 3, Type B	0	N/A	0
Loc 3, Type C	$2,300,000 [2]	20, 40	$700,000
Loc 4, Type B	0	N/A	0
Loc 4, Type C	$60,000,000	30	$7,000,000
Rock-Founded Locks - 600'			
Loc 3, Type B	0	N/A	0
Loc 3, Type C	$17,000,000	30	2,000,000
Loc 4, Type B	0	N/A	0
Loc 4, Type C	$30,000,000	30	3,500,000

Notes:
1. The present-worth values were calculated with a discount rate of 7.4 percent.
2. This would not technically qualify as "Major Rehabilitation" by current requirements. However, the work would need to be done, however it is funded.

Major Rehabilitation Savings. The without-project condition forecasts that the next cycle of major rehabilitation at Locks 14-25 will occur sometime in the 2015-2025 timeframe. If lock extensions are accomplished at these sites prior to this time, the construction work associated with these lock extensions will address most of the pending major rehabilitation needs of the site. Typical major rehabilitation work such as mechanical and electrical replacement, power and control cable system upgrades, lock miter gate repairs or replacement, emptying and filling valves repairs or replacement, and critical lock chamber concrete repairs will be accomplished by the construction work associated with extending the existing lock chambers. This situation results in the avoidance of one cycle of major rehabilitation at each of the respective sites. The cost for these avoided rehabilitation cycles results in benefits to the lock extension measures. The next subsequent cycle of major rehabilitation will likely need to occur in the 2035-2050 timeframe (roughly 20 to 25 years after construction for a 2R lock). Similar savings in rehab costs also can be obtained for other sites, if following the construction of a new lock at another location the existing lock is no longer maintained. Since similar savings can be obtained for other sites as well if the existing lock is not maintained, the screening analysis did not include consideration of major rehabilitation avoidance.

Operations Costs. Operations costs are for labor, materials, equipment, and supplies for any activity involved with operating the locks. Examples include labor for the lock crew,[7] utility costs (fuel, electricity, phone service, sewer, etc.), office supplies, radios, tools, and similar expenses. The same staff and generally the same materials and supplies are needed regardless of the type of lock construction or the size of the chamber (whether 600-foot or 1,200-foot). Therefore, the operations costs are expected to be uniform for each of the lock alternatives. An exception is for Location 2 locks that result in only a single lock rather than the other options, which result in two operational locks. The annual operations cost for a Location 2 lock is estimated to be $800,000.[8] The annual operations cost for a lock at any other location plus the existing lock is $1,050,000 ($800,000 and $250,000, respectively, for the two locks).[9] Since the operations costs do not differ greatly from alternative to alternative, this is not a significant screening factor, but it needs to be included in the total cost picture. As noted above under the maintenance costs, the Location 2 lock can be operated at essentially the same costs as the exiting lock at $800,000 annually. This cost is part of the without-project cost, and as a result only the incremental $250,000 annual cost associated with the addition of another facility must be accounted for as a with-project cost.

Economic Impacts to Navigation During Construction. In order for any of the lock alternatives to be economically viable, the construction of the lock cannot cause excessive delays or closures to navigation during the construction period. With the large overhead and amount of cargo hauled by tows, the cost of delaying transport climbs rapidly as delays mount. The system economic model will be used to determine the cost impact of navigation delays during construction. However, in developing the various lock options, the schedule and duration of delays and closures were identified. To do this, a construction sequence for each lock alternative was developed. Then the need for interrupting navigation was addressed for each step in a construction sequence. The delays to navigation would be greatest with construction of a lock at Location 2 (extending the existing lock using Type B or C) and second highest with construction at Location 3 (immediately adjacent to the existing lock in the auxiliary lock bay). These high impacts to navigation were one of the key reasons for the development of the Location 2 Type R lock (which provided an alternative to minimize these impacts). For Locations 1 and 4, the navigation delays are negligible since there is adequate separation from the existing tow maneuvering areas.

One way to reduce delays to navigation during construction is scheduling activities that impact navigation in the winter's slower navigation season.[10] This was done to the extent possible, however, some activities cannot be scheduled simultaneously due to sequencing constraints. Drawbacks to winter construction include a decline in construction quality and the additional costs associated with productivity loss from working in colder weather.

---

[7] The lock crew typically consists of 8 persons per lock site. They rotate in shifts to cover 24 hours per day, 7 days per week of lock operations during the navigation season (typically mid-February to mid-December; however, see next footnote). During the off season, a staff is also maintained at the locks for security, maintenance, and dam operation.

[8] The present worth estimate of 50 years of operations costs for a Location 2 lock is $10,500,000 based upon a 7.4 percent discount rate and the annual operations cost of $800,000 (Jan 96 price levels).

[9] The present worth estimate of 50 years of operations costs for a lock at any of the other locations plus the existing lock is $13,800,000 based upon a 7.4 percent discount rate and the annual operations cost of $1,050,000 (Jan 96 price levels).

[10] During the winter, navigation usually ceases on the Mississippi River upstream of Quincy, Illinois (Lock and Dam 21) and slows at Locks and Dams 22-25. However, the Illinois River traffic remains high all year, sometimes even peaking in the winter months. Traffic at Mel Price Lock and Dam and Lock and Dam 27 on the Mississippi River also stays high all year due in part to the traffic from the Illinois Waterway and in part to less severe ice conditions.

Another way of reducing delays to navigation during construction is by constructing large segments (lockwall monoliths, floor slab sections, gate sills, etc.) in an off-site precasting operation and then transporting them to the site for rapid placement by crane barge or float-in methods.

The Engineering Appendix describes the construction sequences and estimates the delays to navigation during construction for those lock locations and types that have the highest impacts. Where historical data were unavailable, elicitation was made of expert assessments for construction durations and navigation delays. Summaries of the delays to navigation for each lock concept are shown in Tables 15 and 17 (for pile-founded locks) and Tables 16 and 18 (for rock-founded locks).

Initial estimates of the costs of delays and closures were made to assess the economic impact to the navigation industry. These initial analyses indicated that these costs are a potentially significant screening factor. Some of the alternatives that are favored due to low first costs may drop in rank compared to other alternatives when the economic impacts to navigation during construction are considered. However, the magnitude of the economic impacts to navigation varies depending upon the economic assumptions and level of congestion at the time construction is undertaken. Subsequent analyses using the system economic models have shown somewhat lower impacts due to changes in economic assumptions and methodology. Assuming that traffic continues to grow with time, then the later the initiation of construction the greater congestion and larger the economic impacts would be to the navigation industry. Construction before traffic levels reach high levels of congestion could reduce the economic impacts during the navigation season.

TABLE 15: SUMMARY OF DELAYS TO NAVIGATION DURING CONSTRUCTION OF 1,200-FOOT LOCKS (PILE-FOUNDED LOCKS)

Lock Location and Type	Duration of Delays
Pile-Founded Locks	
Location 1	
Type C	Negligible
Location 2	
Type B	3 winter continuous closures (90, 90, and 113 days); 550 days of 9-minute delays to upbound exchange tow approaches; and 72 weeks of 8 hr/day x 5 days/week closures
Type C	Same as Location 2, Type B, *plus* the third winter closure would be about 17 days longer
Type R	3 winter continuous closures (97, 96, and 96 days); one 14-day closure during the navigation season; one 8-day closure during the navigation season; and 515 days of 9.4-minute delays to upbound exchange tow approaches
Location 3	
Type B	See note 2.
Type C	4 winter continuous closures (90, 90, 107, and 75 days); 808 days of 9-minute delays to upbound exchange tow approaches; 533 days of 11-min. delays to downbound exchange approaches; one 7-day continuous closure; and 51 weeks of 8-hr./day x 5 days/week closures
Location 4	
Type B	Negligible
Type C	Negligible

Notes:
1. The timing of the closures is important in addition to their duration. Addendum C shows the timing for the alternatives that have the greatest impacts.
2. Not only does the Location 3, Type B lock cost more than the Location 3, Type C lock, but it has greater impacts to navigation to construct the permanent guidewall. Therefore, the Type B lock was screened out as noted previously.

TABLE 16: SUMMARY OF DELAYS TO NAVIGATION DURING CONSTRUCTION OF 1,200-FOOT LOCKS (ROCK-FOUNDED LOCKS)	
Lock Location and Type	Duration of Delays
Rock-Founded Locks	
Location 2	
Type B	3 winter continuous closures (90, 90, and 80 days); 550 days of 9-minute delays to upbound exchange tow approaches; and 51 weeks of 8 hr/day x 5 days/week closures
Type C	3 winter continuous closures (90, 129, and 90 days); 504 days of 9-minute delays to upbound exchange tow approaches; one 7-day continuous closure; and 52 weeks of 8 hr/day x 5 days/week closures
Type R	3 winter continuous closures (90, 94, and 96 days); 12 two-day closures during the navigation season and 546 days of 9.4-minute delays to upbound exchange tow approaches
Location 3	
Type B	3 winter continuous closures (90, 90, and 100 days); 610 days of 9-minute delays to upbound exchange tow approaches; 610 days of 11-min. delays to downbound exchange approaches; 21 weeks of 8 hr/day x 5 days/week closures; and 9 weeks of double filling/emptying times
Type C	3 winter continuous closures (90 days each); 640 days of 9-minute delays to upbound exchange tow approaches; 640 days of 11-min. delays to downbound exchange approaches; 28 weeks of 8 hr/day x 5 days/week closures; and 12 weeks of double filling/emptying times
Location 4	
Type B	See note 2.
Type C	See note 2.

Notes:

1. The timing of the closures is important in addition to their duration. Addendum C shows the timing for the alternatives that have the greatest impacts.
2. A Location 4 lock could be placed where there are negligible delays to navigation during construction. The Location 4 rock-founded concept lock (developed for Lock and Dam 22 conditions) was placed where it would only remove one dam gate to minimize first costs. With this placement, a Location 4 lock would have similar impacts to a Location 3 lock. To avoid these impacts, the lock could be placed farther from the existing lock, thereby displacing an additional tainter gate that would have to be replaced. The additional cost for this is approximately $18 million plus cost adjustments for any quantity increases (that would be determined on a site-specific basis) for constructing in deeper water.

TABLE 17: SUMMARY OF DELAYS TO NAVIGATION DURING CONSTRUCTION OF 600-FOOT LOCKS (PILE-FOUNDED LOCKS)	
Lock Location and Type	Duration of Delays
Pile-Founded Locks	
Location 1	
Type C	Negligible
Location 3	
Type B	See note 1.
Type C	4 winter continuous closures (90, 90, 107, and 75 days); 550 days of 9-minute delays to upbound exchange tow approaches; 533 days of 11-minute delays to downbound exchange approaches; one 7-day continuous closure; and 18 weeks of 8 hr/day x 5 days/week closures
Location 4	
Type B	Negligible
Type C	Negligible

Notes:
1. Not only does the Location 3, Type B lock cost more than the Location 3, Type C lock, but it has greater impacts to navigation to construct the permanent guidewall. Therefore, the Type B lock was screened out as noted previously.

TABLE 18: SUMMARY OF DELAYS TO NAVIGATION DURING CONSTRUCTION OF 600-FOOT LOCKS (ROCK-FOUNDED LOCKS)	
Lock Location and Type	Duration of Delays
Rock-Founded Locks	
Location 3	
Type B	3 winter continuous closures (90, 90, and 100 days); 610 days of 9-minute delays to upbound exchange tow approaches; 610 days of 11-minute delays to downbound exchange approaches; 6 weeks of 8 hr/day x 5 days/week closures; and 9 weeks of double filling/emptying times.
Type C	3 winter continuous closures (90 days each); 606 days of 9-minute delays to upbound exchange tow approaches; 606 days of 11-minute delays to downbound exchange approaches; 13 weeks of 8 hr/day x 5 days/week closures; and 12 weeks of double filling/emptying times.
Location 4	
Type B	See note 2.
Type C	See note 2.

Notes:
1. The timing of the closures is important in addition to their duration. Addendum C shows the timing for the alternatives that have the greatest impacts.
2. A Location 4 lock could be placed where there are negligible delays to navigation during construction. The Location 4 rock-founded concept lock (developed for Lock and Dam 22 conditions) was placed where it would only remove one dam gate to minimize first costs. With this placement, a Location 4 lock would have similar impacts to a Location 3 lock. To avoid these impacts, the lock could be placed farther from the existing lock, thereby displacing an additional tainter gate that would have to be replaced. The additional cost for this is approximately $18 million plus cost adjustments for any quantity increases (that would be determined on a site-specific basis) for constructing in deeper water.

Environmental Resource Impacts. The environmental resource impacts are being determined for both site-specific and systemic impacts. The site-specific impacts include the effects of construction such as impacts to particular species, disturbance to or loss of various habitats, increased turbidity, and redirection of normal flow patterns. In general, the locations with the most extreme environmental impacts were eliminated during the initial screening of lock locations. The remaining locations typically make use of the existing navigation channel or require only slight to moderate channel modifications.

A detailed discussion of the site-specific environmental analysis and development of costs is covered in the *Site Specific Habitat Assessment* report (September 1998). Costs vary rather widely depending on the lock site, location, type, and resources at and around particular locks. For example, at Location 2, average site-specific environmental costs are estimated to range from $530,000 at Lock 24 to $5.3 million at Lock 22 (see Table 19 for information on the other lower lock sites and locations). These costs represent habitat replacement and are only an average of a range identified in the *Site Specific* report. These costs could change significantly during formal mitigation planning. In addition, they do not include costs necessary to address any endangered species or mussel bed impacts. While these cost estimates are specific to the locks and dams shown, they may give a general sense of the site-specific costs at upstream sites (Locks and Dams 11-18).

In contrast with the site-specific costs that are related to the specific location of construction, system environmental costs are instead primarily based on the increase in system traffic and related impacts that any improvements allow over the without-project condition. The system environmental impacts and costs will not be determined until potential changes in system traffic levels are identified by evaluating various alternative plans using the system economic model. However, system environmental impacts are not anticipated to provide deciding information on lock location or types since all of these options provide for similar increases in tow traffic. Both the site-specific and system impacts will be identified in the Environmental Impact Statement (EIS) for the study.

TABLE 19: AVERAGE SITE-SPECIFIC COSTS BY LOCK SITE AND LOCATION

Lock Site	Location 1	Location 2	Location 3	Location 4
Lock 20		$1,643,175	$1,106,815	$450,000
Lock 21		$4,065,750	$3,995,750	$2,239,500
Lock 22		$5,333,344	$5,333,344	$5,453,344
Lock 24		$527,940	$597,940	$702,940
Lock 25	$3,123,750	$633,360	$1,058,400	$988,400
La Grange	$5,245,266	$4,834,141		
Peoria	$576,000	$646,000		
Average	$2,981,672	$2,526,244	$2,418,450	$1,966,837

Note: Costs shown above represent average costs based on the ranges identified in the *Site Specific Habitat Assessment* report.

Cultural and Historic Resource Impacts. The Mississippi and Illinois River valleys are known to contain valuable cultural resource sites, primarily early Native American settlements and historic structures of various origins. These cultural resources could potentially be encountered with the construction of new locks. The Historic Properties Work Group, a component of the EIS effort, is investigating the cultural and historical resources that could potentially be impacted by lock construction. Efforts conducted as part of the system study indicate that similar impacts are anticipated regardless of the lock location or type implemented. However, because the study area is so large, additional investigations would be required during site-specific studies should any new locks be recommended. Therefore, the extent of these impacts was not quantified at the time of this analysis but will be included in the EIS.

PERFORMANCE BENEFITS

Lockage Time. The lock performance has been defined as the lock's ability to lock tows efficiently. The lower the lockage time is for tows, the higher the efficiency. For the majority of lockages on the current system, a double lockage is required. The steps of a double lockage were shown in Figure 1.

If lock chambers were as large as the maximum tow size, double lockages would no longer be required. For the Mississippi River and Illinois Waterway, the maximum tow size is also the prevailing tow size, i.e., about 1,200 feet long by 105 feet wide. Constructing a 1,200-foot-long lock at a site would eliminate a number of the lockage steps currently required, resulting in a very large reduction in lock transit time. The resulting lockage would then be a single lockage, having the steps indicated in Figure 2. In addition, constructing a new lock at Locations 1, 3, or 4 would result in the site having two locks available. This would not only allow for improvement in the individual lockage times, but also would provide some potential for multiple lockages to occur simultaneously. An additional benefit of multiple chambers is the ability to still have one working chamber if accidents occur or repairs are needed. However, considerable limitations are anticipated in operating two chambers simultaneously. This would likely require actions such as traffic staggering and size limitations.

Table 20 gives an overview of the existing lockage times and estimated new lockage times for 1,200-foot tows at new or extended chambers. The savings represent the potential reduction in time associated with eliminating the need to conduct double lockages and the steps discussed earlier. In general, eliminating the double lockage steps saves a tow approximately 60 minutes (eliminates the need to extract first cut, turn back chamber, enter and lock a second cut, and remake; see time differences in Figures 1 and 2). However, due to the extra time needed to enter and exit a longer chamber and the longer filling and emptying times associated with the greater water volumes, somewhat smaller savings are anticipated as shown below. In contrast with existing double lockages, existing single lockages (tows less than 600 feet) would actually experience a minor increase in lockage time because they would be transiting an additional 600 feet of chamber and because the filling and emptying of the large volume of water requires some additional time. This increased time is likely to be offset by the greater ability to lock multiple small tows, recreational craft, and combinations of vessels together. In contrast, a new 600-foot chamber is not expected to provide much faster lockages per tow. The principal improvement is simply having an additional chamber available. The small time differences shown in Table 20 are generally related to filling and emptying times and approach and exit conditions. Filling and emptying times and approaches and exits are anticipated to be somewhat worse at Location 1 and 2 locks.

The Type 2R lock was included to provide a more complete set of alternatives. The Type 2R lock time savings assumes some channel improvement work will be done above the lock but that the upstream guidewall will not be extended. However, due to slower filling and emptying associated with not extending the culverts, the 2R lock option is 2 to 4 minutes slower than other Location 2 lock types.

TABLE 20: AVERAGE LOCKAGE TIME AND SAVINGS OF 1,200-FOOT AND 600-FOOT LOCKS			
Location/Type	**Avg Lockage Time[1,3] (Min)**	**Avg Savings[1,3] (Min)**	**Number of Sites[2]**
Existing 600'	103	-	15
1,200 ft Locks			
1C	59	43	4
2B	54	49	15
2C	57	46	5
2R[4]	57	46	15
3B	59	44	4
3C	53	49	12
4B	52	50	11
4C	52	50	11
600 ft Locks			
1C	107	-4	4
Loc 2	N/A	N/A	N/A
3B	106	-3	4
3C	100	3	12
4B	99	4	11
4C	99	4	11

Notes:
[1] The average values assume equal numbers of fly, exchange, and turnback lockages. However, in actuality these are not equal. The time savings shown are from tows currently needing double lockages (e.g., greater than 600 feet total length). Smaller tows can lock in significantly less time. For numbers shown, turnback approaches are assumed to take place during lockage of the previous tow.
[2] Number of sites evaluated is shown out of a possible 15. While Lock 19 was also evaluated, it already has a 1,200-foot chamber and as a result would skew the results.
[3] There is no difference in the performance between Type B and C at any location; differences shown only relate to the fact that averages are for different numbers of sites.
[4] Taking into consideration only the same locations, Type 2R locks are anticipated to be 2 minutes slower for fly and exchange lockages, and 4 minutes slower for turnback lockages than other Type 2 locks.

In comparing lock alternatives of the same lock length at the same site, most of the lockage steps are of equal duration among alternatives. The times for entering the chamber, gate operation, and exit are essentially constant for all alternatives. There could be differences in the durations of two of the remaining lockage steps: approach times and filling and emptying times. There are different influences on these two lockage components. The approach time varies from one site to another and could be different at different lock locations at a given site. In addition, the cost of the required channel work will vary by lock location, and this is accounted for in the lock cost estimates. The filling and emptying time depends on lock size and lock type (especially the design of the filling and emptying system). The filling and emptying times also vary by the lock lift (or head differential); however, this is equal among the lock alternatives at a given site. The quantification task for evaluating lockage time distinctions between large-scale alternatives was therefore focused on the approach times and filling and emptying times for the remaining lock alternatives. These estimates follow.

Approach Time Estimation. The approach times for the new lock alternatives were developed based upon the navigation modeling results for Lock and Dam 22 and the approach time improvements estimated in analyzing small-scale measures. The focus of approach analysis efforts was on downbound approaches, since upbound approaches tend to be less variable and less troublesome. It was determined that the maximum approach time improvement that could be attained at the existing Lock 22 is about a 35 percent timesaving. Since Lock and Dam 22 has the worst existing downbound approach times of the locks in the study, the 35 percent improvement experienced in the model study for Lock and Dam 22 is thought to be the maximum improvement achievable at other lock sites. At the opposite extreme from Lock and Dam 22 it is unlikely that any improvement could be made to the approach at Lock and Dam 13. The magnitude of the approach time improvements applied at each site as part of these large-scale improvements is very similar to the channel improvements used in the small-scale analysis that was used as a reference.

Table 21 summarizes the approach savings by lock location. Savings are the same for all lock types at each location. The one exception is Location 2R; this type has less savings than 2B and 2C, as shown in the following tables. This difference is due to the fact that the 2R lock does not include approach improvements unless required. However, there are differences based on the approach type (fly or exchanges). Turnback approaches are not shown since it is assumed that they can make their approach during the locking of the previous tow. While some upbound time savings were identified for the various locations, they averaged roughly 1 minute, with most locations having essentially the same benefits.

TABLE 21: DOWNBOUND APPROACH TIMES AND SAVINGS BY LOCK LOCATION (MINUTES)

	Fly		Exchange	
	Time Estimate[2]	Savings[2]	Time Estimate[2]	Savings[2]
Existing[1]	27.9		21.8	
Loc 1	18.3	9.6	16.8	5.0
Loc 2[3] (w/approach)	25.1	2.8	19.7	2.1
Loc 2[4] (wo/approach)	27.2	0.7	21.1	0.7
Loc 3	20.8	7.0	15.8	6.0
Loc 4	20.7	7.1	15.2	6.6

[1] Existing times represent averages for 1990 at UMR Locks 11-25 and IWW Locks Peoria and La Grange.
[2] New Location 1-4 estimated times and savings based on engineering study efforts. Approach savings are the same for each location regardless of chamber size (600 or 1,200 feet). No differences in turnback approach times are anticipated.
[3] Location 2 savings are associated with the 2R alternative, including minor channel improvements at most sites.
[4] Location 2R savings assuming only minimal/required channel improvements are made. The limited savings shown are related to improvements at Locks 14, 15, and 25 which are anticipated to be required.

Filling and Emptying Time Estimation. Lock filling and emptying times were computed for each location and design alternative under consideration using the Tennessee Valley Authority (TVA) program TFSIM, as discussed in the Engineering Appendix. Existing filling and emptying times are on the order of 4 to 5 minutes each. These times are anticipated to increase by 3 to 7 minutes due to the greater volume of water. The slowest times are associated with Location 1 which uses a center fill system that must empty into the lower approach due to the lock location and thereby reduce performance. Location 2 times are also somewhat slower because a Type 2R lock would not include an extension of the filling and emptying system.

TABLE 22: FILLING AND EMPTYING TIMES AND DIFFERENCES BY LOCK LOCATION (MINUTES)

	Filling		Emptying	
	Time Estimate[2]	Additional Time	Time Estimate[2]	Additional Time
Existing[1]	4.1		4.5	
Loc 1[3]	10.6	6.5	11.5	7.0
Loc 2[4]	9.0	4.9	11.1	6.6
Loc 3	7.4	3.3	10.0	5.5
Loc 4	7.1	3.0	9.1	4.6

[1] Times represent 1990 averages for UMR Locks 11-25 and IWW Locks Peoria and La Grange at 600-foot chambers.
[2] New Location 1-4 estimated times and savings based on engineering study efforts and 1,200-foot chambers.
[3] Location 1 has slower times due to the design and use of a center fill system that empties into the lower approach.
[4] Location 2 refers to 2 R and slower times associated with not extending the filling and emptying system.

Disposition of the Existing Lock. Another aspect of with-project lock performance concerns the disposition of the existing 600-foot-long lock after a new lock is constructed at another location at the same lock and dam site. For a 1,200-foot Location 2 lock, the existing lock is incorporated into the new lock and there is no second lock. However, for construction at each of the other lock locations, several outcomes are possible concerning the existing lock:

1. Unobstructed approaches - lock remains functional for both recreational and commercial traffic with tows up to 1,200 feet long.
2. Partially obstructed approach - lock available only to recreational traffic (and possibly tows with size restrictions).
3. Hazardous approach conditions - lock unusable for either commercial or recreational craft.

The above scenarios are over simplified, but they present a few of the possibilities. The necessary provisions to ensure navigation safety must be determined on a site-specific basis and would probably require navigation modeling. However, subjective assessments were made of the with-project functioning of the existing lock after a second lock is constructed. These assessments are presented in Table 23.

TABLE 23: USE OF EXISTING LOCK AFTER NEW LOCK CONSTRUCTION

	With Location 1 Lock		With Location 3 Lock		With Location 4 Lock	
Lock Site	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
L/D 11	N/A	N/A	Full size tows	Full size tows	N/A	N/A
L/D 12	N/A	N/A	(No restrict.)	Recr./Single	(No restrict.)	Recr./Single
L/D 13	N/A	N/A	Full size tows	Full size tows	Full size tows	Full size tows
L/D 14	N/A	N/A	N/A	N/A	Recr./Single	Recr./Single
L/D 15	N/A	N/A	Recr./Single	Recr./Single	N/A	N/A
L/D 16	N/A	N/A	(No restrict.)	Recr./Single	(No restrict.)	Recr./Single
L/D 17	Full size tows	Full size tows	(No restrict.)	Recr./Single	(No restrict.)	Recr./Single
L/D 18	N/A	N/A	(No restrict.)	Recr./Single	Full size tows	Full size tows
L/D 19	N/A	N/A	Full size tows	Full size tows	N/A	N/A
L/D 20	N/A	N/A	(No restrict.)	Recr./Single	(No restrict.)	Recr./Single
L/D 21	N/A	N/A	Full size tows	Full size tows	Full size tows	Full size tows
L/D 22	N/A	N/A	Full size tows	Full size tows	Full size tows	Full size tows
L/D 24	N/A	N/A	Full size tows	Full size tows	Full size tows	Full size tows
L/D 25	Recr./Single	(No restrict.)	Recr./Single	Recr./Single	Recr./Single	Recr./Single
Peoria	Full size tows	Full size tows	N/A	N/A	N/A	N/A
La Grange	Full size tows	Full size tows	N/A	N/A	N/A	N/A

Notes:
1. "N/A" is used where the new lock location has been screened out and is not applicable.
2. "Full size tows" means that 1,200-foot-long tows could safely make an approach to the existing lock. However, traffic would have to be staggered between the two locks to avoid interference in the approaches and exits.
3. "Recr./Single" means that, after construction of a new lock, the existing lock could only be used by recreational craft and tows smaller than 600 feet long (i.e., tow size that pass in a single lockage).
4. "(No restrict.) is used to indicate that there are no restrictions on tow size on either the upstream or downstream side (as indicated); however, the approach on the other side of the lock limits the maximum tow size that will be able to use the existing lock (for transit in both directions).

An approach could be "obstructed" by the placement of the upstream or downstream guidewalls (or guardwalls) of the new lock, or even by a lockwall of the new lock. In some cases, this can be overcome by opening up the approach by cutting back the riverbank. Another way in which the approach could be obstructed is by having conflicting approaches for the existing and new locks.

In this condition, tows could only approach one lock at a time from the same direction. In fact, this would be the case for each of the new locks due to their close proximity to the existing locks. Delays to either lock could be minimized by sequencing measures that would be more flexible with two locks than with one. Causes of "hazardous" approach conditions include severe obstruction, adverse currents, or inadequate water depths. Some of the approaches were severely obstructed, but channel improvement measures were included in the cost estimates to allow access for tows up to 600 feet long to use each of the existing locks.

For each of the lock concepts at Location 3 (except at Lock 19), the existing intermediate lockwall filling and emptying culvert would be dedicated to the new lock. This would mean that the existing lock would be filled and emptied only from the landside, with resultant slower filling and emptying times for the existing lock. These slower times would occur because the flow area is cut in half and because filling from one side of a lock tends to shove tows over to one wall. Valve opening and closing times would have to be lengthened to keep hawser forces at an acceptable level and to minimize turbulence.

SECTION 4 - SECONDARY SCREENING

This section takes the quantitative numbers developed and discussed in the previous section and combines them with additional information learned from preliminary system model runs to conduct a secondary screening. This screening was based primarily on quantitative factors and cost effectiveness comparisons. However, the expertise of the various technical disciplines and results of the other economic and environmental study efforts were drawn on as well. The secondary screening was necessary to focus the detailed system modeling efforts on the most promising measures to optimize in the NED analysis and to maximize net benefits to the Nation. It was especially necessary since without it there were simply too many potential combinations to model all the possible options within the study schedule and scope.

APPLICATION OF COST AND PERFORMANCE INFORMATION

This section builds on the new lockage times and costs of the various remaining 1,200-foot and 600-foot lock options, as described in the previous section. Additional efforts were taken to include estimates of impacts to navigation and site-specific environmental costs for inclusion prior to a secondary screening. While system environmental and cultural impact costs were not included at this point, the magnitude of these costs was not anticipated to provide deciding information as to the selection of the most economically efficient location or type. This is because the system environmental impacts are closely related to future traffic levels, which are likely to be very similar for most of the measures. These impacts will be discussed and considered as part of the alternative plan analysis before a study recommendation is made.

The analysis then extended the new lockage time of the new or extended lock plus the value of the existing lock, if available, to obtain a total potential ability to lock boats. This number can then be compared with the existing locks' ability to lock boats and an incremental benefit identified. The following paragraphs discuss how these numbers were developed and their limitations.

Impacts to Navigation Cost Estimates

Estimates of the impacts to navigation were included, in addition to the first costs of construction and the present worth of increased operations and maintenance and rehabilitation needs discussed in the previous section. To determine the impacts to navigation cost of implementing various options, system economic model runs are needed using the Spatial Equilibrium Model (SEM).

The SEM preliminary runs, conducted in November 1998, showed that impacts to navigation for Type 2R locks averaged roughly $12 million per lock site for the five lower locks on the UMR (a combination of three rock-founded and two pile-founded sites). While the impact costs vary based on the economic assumptions and timing of implementation, including this approximate cost generally indicates the impacts to navigation. From this value, an estimate of the impacts to navigation for the other lock options was calculated based on relative hours of delay caused by construction of the other locations and types. Total delay hours were calculated using the information from Tables 15 through 18 in the previous section. For example, Location 2B has roughly twice the delay hours as a Location 2R at rock-founded sites and as a result is anticipated to cause approximately twice the delay costs.

TABLE 24: ESTIMATED IMPACT TO NAVIGATION HOURS, PERCENT AVAILABLE AND COST

Lock Location and Type[1]	Total Hours of Availability Lost [2,3]	Percent Reduction over 3-Year Const.[4]	Percent Lock Available[4]	Ratio of Delays to 2R Const.[6]	Estimated Cost Based on 2R Lock ($Mil)
Rock-founded 1,200 ft locks					
2B	2205	11%	89%	2.10	$25
2C	3335	17%	83%	3.18	$38
2R	987	5%	95%	0.94	$11
3B	1571	8%	92%	1.50	$18
3C	1715	9%	91%	1.63	$20
4B[5]	1571	8%	92%	1.50	$18
4C[5]	1715	9%	91%	1.63	$20
Pile-founded 1,200 ft locks					
2B	3597	18%	82%	3.42	$41
2C	4005	20%	80%	3.81	$46
2R	1145	6%	94%	1.09	$13
3C	3054	15%	85%	2.91	$35
Rock-founded 600 ft locks					
3B	971	5%	95%	0.92	$11
3C	924	5%	95%	0.88	$11
4B[5]	971	5%	95%	0.92	$11
4C[5]	924	5%	95%	0.88	$11
Pile-founded 600 ft locks					
3C	1656	8%	92%	1.58	$19

[1] Locations and types not shown have essentially 100 percent availability of the existing lock during construction (Location 1 and Location 4 at pile-founded sites). Construction occurring during the 90-day winter closure or away from the lock approaches was not assumed to impact navigation (except at Peoria and La Grange on the IWW, which do not have a winter closure period).
[2] For calculating delays in approaches, assumed 5 tows traveling each way per day (10 tows per day), 2 of which are upbound exchanges and 2 downbound exchanges. The other 6 lockages are anticipated to be turnback lockages. Even with greater numbers of tows, it is unlikely that the number of exchanges would increase above 4 total per day.
[3] Impacts to filling and emptying assumes 4 minutes per cycle (doubling would add 4 additional minutes) times the average of 2 cycles per lockage, times 10 lockages per day.
[4] The percentage reductions and available are based on delays occurring during a 275-day/year navigation season and 3-year construction schedule. This assumes no impacts associated with lock closures during the 90-day winter. This understates costs at some of the lower UMR lock sites where limited navigation occurs year round. Peoria and La Grange costs were estimated separately based on 365 days and inability to avoid impacts to navigation during the winter. This results in an increase of impacts to navigation of 6,480 hours (90 days x 24 hours x 3 years). Increasing costs by $74 million over UMR pile-founded 2B and 2R locks.
[5] At rock-founded Location 4 locks, the impacts depend on the placement of the lock in the gated section of the dam. These impacts could be eliminated by locating the lock farther out in the gated section of the dam, at an additional first cost of $18 million. In instances where the impacts to navigation are greater than $18 million, the location would be moved to eliminate the impacts and the additional first cost incurred.
[6] The ratios are compared to a weighted average of 3 rock-founded and 2 pile-founded 2R locks, which is equivalent to roughly 1,050 hours of lost lock time and $12 million in impact costs per lock based on initial system economic model runs.

The delays associated with having just 600-foot chambers versus a 1,200-foot chamber also impact navigation cost. Even without a queue, the process of using the 600-foot chamber takes roughly 45 to 50 minutes longer, which is in essence an impact to navigation. As a result, there is an added cost of using 600-foot chambers. However, rather than a system delay associated with a total lock shut down, the delay cost averages roughly $300 per hour per tow. This still results in a significant annual cost. For example, assuming 2,500 double lockage tows per year and an additional 45 minutes of time required to lock each double lockage tow, shows an increase of 1,875 hours of delay time annually. This equals roughly $560,000 in delays to navigation, even without considering the cumulative delays that occur if other tows are waiting in queue during these slower lockages. This cost is an annual cost that will be incurred each year and will increase as the number of boats increases. In contrast, the costs shown above are one-time delay costs associated with the 3-year construction period. However, one benefit of having two locks is that impacts to navigation could be reduced during a closure of one lock since boats could still utilize the other lock.

Site-Specific Environmental Cost Estimates

The section on the quantification of costs summarized the environmental costs developed in the *Site-Specific Habitat Assessment* for the lower seven lock sites. A brief evaluation of these costs, compared with the other lock costs, reveals that from a strictly monetary standpoint these environmental costs are not of sufficient magnitude to represent a significant screening factor between the various locations and types. However, these costs were included in order to understand better the approximate total costs of the various large-scale options. To provide costs for all 16 sites, rough estimates were made of the costs at Locks 11-19, the sites not monetized in the *Site-Specific Habitat Assessment* report. These costs were developed using the qualitative analysis of these sites completed as part of the site-specific effort and then estimating habitat replacement costs relative to the values developed for the lower seven sites. In addition, the site-specific environmental costs of 600-foot chambers were estimated at 75 percent of the 1,200-foot locks for the same location at the same lock site. While further site-specific cost refinements would be necessary as part of the site-specific design process if improvements are recommended, the method used is considered to be a reasonably accurate estimate of cost.

The costs shown in the following tables indicate the habitat replacement costs, but they do not fully include other factors such as endangered species, mussel beds, or socio-economic impacts that could potentially impact environmental costs or lock placement decisions. These factors were considered qualitatively and were considered in the screening. At these additional sites, some of the more significant issues are listed below. These factors were taken into account to the extent possible in developing the site-specific costs:

Lock 20: Socio-economic impacts related to development along the Canton, Missouri, riverfront.

Lock 17: A new lock at Location 1 would result in extensive loss of bottomland hardwood forest habitat that should be avoided or minimized to the extent possible.

Lock 16: Proposed realignment of the upstream approach channel with 2B and Locations 3 and 4 locks would result in considerable impact to the side channel and diverse backwater aquatic habitats.

Lock 14: New lock construction presents considerable concern over the potential to degrade channel border and wetland habitat and damage the historic side channel area through lock construction.

Lock 12: Any new or extended lock construction presents significant potential for socio-economic impacts by impairing the view of the river from historic downtown Bellevue, Iowa, and eliminating access to a public boat ramp, as well as potentially impacting a locally important sport fishing area.

Performance of New Facility

In order to compare the various options, the performance of the locks was stated in comparable terms by starting with the average lockage time at each site. The average lockage times were based on equal portions of fly, turnback, and exchange lockages. While this is not likely to occur, a sensitivity analysis that examined higher percentages of turnback and exchanges did not reveal significant differences in average lockage times or differences in the relative merits of the various lock options. As a result, the simplified assumption of equal distribution of the various lockage types was used for this analysis.

Using the new lockage times and resulting presence of either one or two chambers, an estimate was made of the approximate ability to process double lockage tows (e.g., tows longer than 600 feet; these will become singles with 1,200-foot locks). This number is only hypothetical since it does not look at various tow sizes or take into account the numerous limitations in locking efficiency due to flow conditions, adverse weather conditions, equipment failure, etc. It does not take into account the limitations of jointly using two chambers (e.g., the existing lock in combination with Locations 1, 3, and 4 locks were not shown as limited in their ability to lock boats due to outdraft and conflicts in the approach and exits, which are likely to occur). The analysis also did not include the value of having two chambers operating during the limited periods of periodic closure. The focus of this evaluation was to summarize the performance benefits in comparable terms.

For example, to compare the relative efficiency of having one 1,200-foot chamber versus two chambers, an estimation of the ability to lock boats per day was calculated. For example, if a new 1,200-foot lock extension has an average lockage time of 57 minutes, then roughly 25 boats could be locked per day (1,440 minutes per day/57 minutes per lockage = 25.3 lockages per day). Similar calculations were made for locations that would result in two chambers at a lock site. However, when two locks would be available, the total number of tows per day would be the total of the two individual locks. For example, if the same 1,200-foot chamber were available in combination with an existing lock, which could lock 14 boats, then together they could lock roughly 40 boats per day (assuming no conflicts, which are likely to occur).

From this information, a percentage increase in capacity could be approximated by dividing the new boats per day by the former ability to lock boats. For example, if the new facility has one extended 1,200-foot lock allowing approximately 25 boats to lock per day while the former facility could only lock 14, then the new facility would have approximately 181 percent of the former lock's ability to process tows, representing an incremental increase of 81 percent. Again, as stated above, this method likely overstates the actual lock capacity, but it does provide a uniform method to compare the various alternatives.

Cost Effectiveness Category

One additional category was developed using the cost and performance information discussed above. The final column in Table 25 shows the percentage increase in efficiency per million dollars of improvement cost. This column in essence allows an incremental cost comparison of the various measures. Continuing with the example above, the 181 percent increase in capacity was divided by the cost of the improvement in millions, $134. This creates a cost effectiveness category, percent increase in the ability to lock tows per million dollars of expenditure, that allows a comparison between the relative effectiveness of the various measures.

While the summary table provides a good indication of the relative cost, performance, and cost effectiveness, the screening was conducted looking at each lock site individually due to site-specific differences and the variation in number of sites included in the averages.

TABLE 25: SUMMARY OF NEW LOCK COSTS, PERFORMANCE, AND COST EFFECTIVENESS

Lock Type	New Lockage Time[1]	Costs w/o Impacts to Nav or Env ($1,000)	Estimated Impacts to Nav ($1,000)[2]	Site-Specific Env. Cost ($1,000)[3]	Total Cost ($1000)	No. of Sites	Tow/Day New Lock[4]	Tow/Day Existing Lock[4]	Total Tow/Day Facility[4]	Percent Increase Tow/Day	Percent Increase/ $1 mil
1,200-Foot Locks											
1C	59	$176,150	$0	$4,111	$180,261	4	24	14	38	275	1.53
2B	54	$138,309	$45,533	$2,679	$186,521	15	27	0	27	192	1.08
2C	57	$114,664	$38,000	$2,621	$155,285	5	25	0	25	189	1.22
2R	57	$110,105	$22,200	$1,819	$134,124	15	25	0	25	181	1.41
3B	59	$157,798	$18,000	$1,910	$177,707	4	25	13	38	286	1.63
3C	53	$188,869	$30,000	$2,466	$221,335	12	27	14	41	293	1.34
4B	52	$261,273	$6,545	$2,830	$270,649	11	28	14	42	294	1.10
4C	52	$257,791	$6,545	$2,830	$267,167	11	28	14	42	294	1.12
600-Foot Locks											
1C	107	$164,425	$0	$3,083	$167,508	4	13	14	27	197	1.18
3B	106	$132,798	$11,000	$1,432	$145,230	4	14	13	27	203	1.42
3C	100	$155,111	$16,333	$1,985	$173,429	12	14	14	29	202	1.19
4B	99	$221,727	$4,000	$2,270	$227,997	11	15	14	29	202	0.89
4C	99	$229,182	$4,000	$2,270	$235,452	11	15	14	29	202	0.87

Notes:

[1] Average lockage time is based on equal percentages of fly, exchange, and turnback lockages. The numbers shown assume turnback approaches occur during the lockage of the previous tow, this may understate overall lockage time slightly.

[2] Costs for impacts to navigation are estimated based on initial model runs indicating costs of $12 million per lock associated with construction of 2R locks. Costs for other sites were estimated based on relative hours of unavailability compared to the 2R locks. The high average value shown above is skewed by the much higher costs of Location 2R locks at Peoria and La Grange Locks on the IWW.

[3] Environmental costs for Locks 20-25, Peoria, and La Grange are the average of the ranges provided in the *Site Specific Habitat Assessment* report. The values for the other sites were estimated based on qualitative analysis of the sites and relative impacts compared to the seven sites which had specific costs identified. The environmental costs associated with the 600-foot locks were estimated at 3/4 the cost of the 1,200-foot lock options, but were not looked at in detail.

[4] The tows per day are based on the average time to lock double lockage tows. The percentage increase in capacity is likely overstated for locations with 2 locks, since no reduction in efficiency of the existing lock was incorporated in the evaluation.

SECONDARY SCREENING PROCESS

Using the information summarized in the table above and presented for each lock site in Table 26, a secondary screening was conducted on a site-by-site basis. Due to the differences in cost effectiveness of the various measures, it is relatively easy to screen a number of the lock types, lengths, and locations. In addition to the cost effectiveness numbers, the study team utilized all other available engineering, economic, and environmental information and professional judgment in conducting the screening.

Cost effectiveness provides a valid technique to compare the relative benefits of various measures. However, it is best used to screen between measures that have either similar benefits or costs. For example, it is best used when measures provide similar increases in efficiency at differing costs. It is not as effective when the measures have greatly different costs and performance. In cases where a measure provides significantly greater benefits (ability to lock boats) at a greater cost, even if the efficiency is somewhat lower, the system economic model is needed to determine if the extra benefits are worth the cost.

As the above table shows, virtually all the large-scale improvement options would nearly double the ability to lock large tows (roughly a 200 percent increase). In the case of a new 1,200-foot lock that still allows the existing 600-foot lock to be used, the increase would be closer to a tripling (300 percent increase). As a result, two separate cost-effectiveness comparisons were made. First, measures providing approximately a doubling in total ability to lock tows per day were evaluated; then a separate comparison was made between the options that would more nearly triple the ability to lock tows per day.

Starting with the lowest cost option, a comparison shows that at Lock 24 a 2R lock would increase efficiency by roughly 189 percent over the existing lock alone (an incremental increase of 89 percent). This results in about a 1.44 percent increase in efficiency per million dollars of cost. Comparing this efficiency with the efficiency of other Location 2 locks (202 percent increase for both 2B and 2C at an increased efficiency of 1.27 and 1.18 per million dollars, respectively), it is possible to eliminate the Locations 2B and 2C lock options based on cost efficiency. These lock options provide very similar benefits to the 2R lock but do so at a higher cost. This same process was followed at each lock site with the same result.

Again using the 2R locks as a comparison, the analysis indicates that the addition of another 600-foot lock provides relatively comparable lockage ability (roughly double lockages per day). However, the overall ability to lock with two 600-foot chambers is potentially greatly overstated because there will be inefficiencies due to conflicts in the approach path. Despite this potential overstatement, it is clear that at virtually all sites a 2R lock would provide similar benefits more efficiently than any of the 600-foot lock options. In addition, it is likely that the most efficient of the 600-foot lock options, Location 3, would have the most significant reductions in efficiency because both chambers could not be used to full effectiveness at the same time. Implementing 600-foot locks also would result in the continuation of time-consuming and highly variable double lockages with associated greater operations, risks, and inefficiencies. A rough estimate of the impacts to navigation associated with these slower lockage times of $560,000 per year was discussed above but was not included in the cost-effectiveness calculations. The only offsetting benefit would be the redundancy in having two chambers to offset losses during closures of one of the chambers. However, unplanned closures are rare and typically do not result in lock closures of significant magnitude. Based on this information, the 600-foot lock options were eliminated from consideration. The only UMR site where the cost efficiency appears higher for the 600-foot locks over the 2R lock extension is at Lock 22. However, based on the additional qualitative factors discussed above, the 600-foot lock options were eliminated here as well.

The IWW sites are an exception to the above discussion due to the much higher impacts to navigation costs associated with extending the existing lock, Location 2. Year-round navigation on the IWW allows no regular winter closure period for construction with minimal impacts to navigation. One possible way to avoid these high impacts would be to construct all or part of the extension during periods of open pass (which occur 40 and 45 percent of the time, respectively, at Peoria and La Grange). During these periods, delays to tows potentially could be minimized or eliminated. If these high impacts to navigation are included (as shown in tables) for the 2R option, 600-foot or 1,200-foot Location 1C locks would dominate the 2R lock extension option. However, due to uncertainties in how to address impacts to navigation, both locations (1C and 2R 1,200-foot locks) will be carried forward for further consideration at Peoria and La Grange. In addition, due to the considerable limitation in operating two 600-foot locks and similarities in cost to the 1,200-foot 1C lock, the option of constructing a new 600-foot lock at Location 1C was eliminated.

Next, the various options that would yield a new 1,200-foot option while leaving the existing lock were compared. These options included the 1C, 3B, 3C, 4B, and 4C lock options. This evaluation revealed that where they are available (only four sites) Location 1C locks appear to be the most cost effective. Of the options available at virtually all sites, Location 3 locks dominate Location 4 locks. The Location 3 locks provide essentially the same benefits as Location 4 locks at an average cost of approximately $50 million lower, resulting in a higher cost effectiveness. This allowed Location 4 locks to be screened out in favor of Location 3. An exception is Lock 14 which does not have a Location 1 or 3 improvement option.

In most cases, the cost differences between the Type B and Type C lock options at specific lock sites is not significant to allow screening. The differences of a few million are on costs of well over $100 million, which include considerable contingencies. Given the uncertainties at this time, these costs are essentially equal. As a result, a single cost can be used for Location 3 in the system economic model runs, and the actual method of construction (B, C, or some hybrid) can be finalized during detailed design efforts if the system model runs show Location 3 locks are justified.

While distinctions could be made between the 2R locks and other survivors at each site based on cost effectiveness, due to the difference in the relative level of benefits (tows/day) it is more appropriate to compare these various options in the context of the system economic models. In cases where traffic growth is assumed to be relatively modest, a lower cost 2R lock extension may be preferable to other locations that would provide two locks. In contrast, if traffic and delays are considered to grow more significantly into the future, it may be desirable to implement locks at Locations 1, 3, or 4. Many of these items are best handled in the context of the system model and can not be adequately screened on a simple cost-effectiveness basis. The only exceptions are the IWW sites since at these locations the Type 1C lock presents lower total costs and as a result could be used to eliminate the Type 2R lock. However, as discussed previously, due to the potential associated with 2R locks to reduce impacts to navigation, both 1C and 2R 1,200-foot locks were carried forward for further consideration.

TABLE 26: SITE-SPECIFIC SUMMARY OF NEW LOCK COSTS, PERFORMANCE, AND COST EFFECTIVENESS

Lock Site	Lock Location Type		Lockage Time[1]	Costs w/o Impacts to Nav or Env ($1000)	Estimated Impacts to Nav ($1000)[2]	Site-Specific Env. Cost ($1000)[3]	Total Cost ($1000)	Tow/Day New Lock	Tow/Day Existing Lock	Total Tow/Day Facility	Percent Increase Tow/Day	Percent Increase/ $1 mil
LaGrg.	Ex. Lock		103									
1,200ft	Loc 1	1C	60	$169,400	$0	$5,245	$174,645	24	14	38	271	1.55
	Loc 2	2B	57	$152,050	$115,000	$4,834	$271,884	25		25	180	0.66
		2R	60	$114,250	$87,000	$4,834	$206,084	24		24	172	0.84
600 ft	Loc 1	1C	105	$155,100	$0	$3,934	$159,034	14	14	28	199	1.25
Peoria	Ex. Lock		107									
1,200ft	Loc 1	1C	64	$173,500	$0	$576	$174,076	23	14	36	267	1.53
	Loc 2	2B	59	$150,000	$115,000	$646	$265,646	24		24	181	0.68
		2R	62	$121,250	$87,000	$646	$208,896	23		23	173	0.83
600 ft	Loc 1	1C	112	$160,200	$0	$432	$160,632	13	14	26	195	1.22
25	Ex. Lock		101									
1,200ft	Loc 1	1C	56	$184,000	$0	$3,124	$187,124	26	14	40	279	1.49
	Loc 2	2B	51	$161,200	$41,000	$633	$202,833	28		28	198	0.97
		2R	54	$124,400	$13,000	$633	$138,033	27		27	188	1.36
	Loc 3	3C	50	$202,930	$35,000	$1,058	$238,988	29	14	43	301	1.26
	Loc 4	4B	50	$287,930	$0	$988	$288,918	29	14	43	302	1.04
		4C	50	$264,630	$0	$988	$265,618	29	14	43	302	1.14
600ft	Loc 1	1C	108	$173,400	$0	$2,343	$175,743	13	14	28	194	1.10
	Loc 3	3C	99	$167,630	$19,000	$794	$187,424	15	14	29	202	1.08
	Loc 4	4B	99	$236,930	$0	$741	$237,671	15	14	29	202	0.85
		4C	99	$229,930	$0	$741	$230,671	15	14	29	202	0.88
24	Ex. Lock		107									
1,200ft	Loc 2	2B	53	$133,830	$25,000	$528	$159,358	27		27	202	1.27
		2C	53	$132,830	$38,000	$528	$171,358	27		27	202	1.18
		2R	56	$120,230	$11,000	$528	$131,758	26		26	189	1.44
	Loc 3	3B	54	$201,730	$18,000	$598	$220,328	27	13	40	298	1.35
		3C	54	$198,730	$20,000	$598	$219,328	27	13	40	298	1.36
	Loc 4	4B	51	$259,730	$18,000	$703	$278,433	28	13	41	307	1.10
		4C	51	$268,430	$18,000	$703	$287,133	28	13	41	307	1.07
600ft	Loc 3	3B	105	$168,730	$11,000	$448	$180,178	14	13	27	201	1.12
		3C	105	$158,730	$11,000	$448	$170,178	14	13	27	201	1.18
	Loc 4	4B	105	$231,730	$11,000	$527	$243,257	14	13	27	201	0.83

TABLE 26 (Continued)

Lock Site	Lock Location	Type	Lockage Time[1]	Costs w/o Impacts to Nav or Env ($1000)	Estimated Impacts to Nav ($1000)[2]	Site-Specific Env. Cost ($1000)[3]	Total Cost ($1000)	Tow/Day New Lock	Tow/Day Existing Lock	Total Tow/Day Facility	Percent Increase Tow/Day	Percent Increase/ $1 mil
		4C	105	$246,730	$11,000	$527	$258,257	14	13	27	201	0.78
22	Ex. Lock		112									
1,200ft	Loc 2	2B	63	$121,830	$25,000	$5,333	$152,163	23		23	177	1.17
		2C	63	$115,830	$38,000	$5,333	$159,163	23		23	177	1.11
		2R	68	$101,230	$11,000	$3,083	$115,313	21		21	165	1.43
	Loc 3	3B	64	$142,030	$18,000	$5,333	$165,363	22	13	35	274	1.66
		3C	64	$138,030	$20,000	$5,333	$163,363	22	13	35	274	1.68
	Loc 4	4B	63	$206,830	$18,000	$5,453	$230,283	23	13	36	278	1.21
		4C	63	$200,030	$18,000	$5,453	$223,483	23	13	36	278	1.24
600ft	Loc 3	3B	107	$120,030	$11,000	$4,000	$135,030	13	13	26	204	1.51
		3C	107	$109,030	$11,000	$4,000	$124,030	13	13	26	204	1.65
	Loc 4	4B	107	$194,830	$11,000	$4,090	$209,920	13	13	26	204	0.97
		4C	107	$189,330	$11,000	$4,090	$204,420	13	13	26	204	1.00
21	Ex. Lock		98									
1,200ft	Loc 2	2B	51	$151,060	$41,000	$4,066	$196,126	28		28	192	0.98
		2R	55	$112,260	$13,000	$2,716	$127,976	26		26	179	1.40
	Loc 3	3C	57	$197,160	$35,000	$3,996	$236,156	25	15	40	272	1.15
	Loc 4	4B	54	$288,430	$0	$2,240	$290,670	27	15	42	282	0.97
		4C	54	$289,130	$0	$2,240	$291,370	27	15	42	282	0.97
600ft	Loc 3	3C	95	$162,860	$19,000	$2,997	$184,857	15	15	30	203	1.10
	Loc 4	4B	95	$238,430	$0	$1,680	$240,110	15	15	30	203	0.84
		4C	95	$253,430	$0	$1,680	$255,110	15	15	30	203	0.80
20	Ex. Lock		104									
1,200ft	Loc 2	2B	54	$119,900	$25,000	$1,643	$146,543	27		27	193	1.32
		2C	54	$119,900	$38,000	$1,643	$159,543	27		27	193	1.21
		2R	58	$99,200	$11,000	$843	$111,043	25		25	181	1.63
	Loc 3	3B	54	$151,100	$18,000	$1,107	$170,207	26	14	40	291	1.71
		3C	54	$156,100	$20,000	$1,107	$177,207	26	14	40	291	1.64
	Loc 4	4B	53	$201,230	$18,000	$450	$219,680	27	14	41	296	1.35
		4C	53	$197,930	$18,000	$450	$216,380	27	14	41	296	1.37
600ft	Loc 3	3B	101	$129,100	$11,000	$830	$140,930	14	14	28	203	1.44
		3C	101	$127,100	$11,000	$830	$138,930	14	14	28	203	1.46
	Loc 4	4B	101	$170,230	$11,000	$338	$181,568	14	14	28	203	1.12
		4C	101	$175,230	$11,000	$338	$186,568	14	14	28	203	1.09
19	Ex. Lock		58									
1,200ft	Loc 3	3B	68	$277,050	$18,000	$1,600	$296,650	21	25	46	186	0.63
18	Ex. Lock		99									
1,200ft	Loc 2	2B	52	$146,400	$41,000	$600	$188,000	28		28	192	1.02
		2R	55	$110,400	$13,000	$500	$123,900	26		26	181	1.46
	Loc 3	3C	52	$197,250	$35,000	$600	$232,850	28	15	42	290	1.25
	Loc 4	4B	50	$280,050	$0	$600	$280,650	29	15	43	297	1.06
		4C	50	$272,750	$0	$600	$273,350	29	15	43	297	1.09
600ft	Loc 3	3C	98	$162,950	$19,000	$450	$182,400	15	15	29	201	1.10
	Loc 4	4B	97	$231,050	$0	$450	$231,500	15	15	29	202	0.87
		4C	97	$238,050	$0	$450	$238,500	15	15	29	202	0.85
17	Ex. Lock		105									
1,200ft	Loc 1	1C	57	$177,700	$0	$7,500	$185,200	25	14	39	284	1.53
	Loc 2	2B	55	$157,100	$41,000	$3,500	$201,600	26		26	192	0.95
		2R	59	$117,600	$13,000	$2,700	$133,300	25		25	179	1.34
	Loc 3	3C	53	$205,000	$35,000	$3,500	$243,500	27	14	41	298	1.22
	Loc 4	4B	54	$293,000	$0	$3,500	$296,500	27	14	40	296	1.00
		4C	54	$295,700	$0	$3,500	$299,200	27	14	40	296	0.99
600ft	Loc 1	1C	104	$169,000	$0	$5,625	$174,625	14	14	27	201	1.15
	Loc 3	3C	101	$171,700	$19,000	$2,625	$193,325	14	14	28	204	1.06
	Loc 4	4B	101	$244,000	$0	$2,625	$246,625	14	14	28	204	0.83
		4C	101	$260,000	$0	$2,625	$262,625	14	14	28	204	0.78

TABLE 26 (Continued)

Lock Site	Lock Location Type		Lockage Time[1]	Costs w/o Impacts to Nav or Env ($1000)	Estimated Impacts to Nav ($1000)[2]	Site-Specific Env. Cost ($1000)[3]	Total Cost ($1000)	Tow/Day New Lock	Tow/Day Existing Lock	Total Tow/Day Facility	Percent Increase Tow/Day	Percent Increase/ $1 mil
16	Ex. Lock		100									
1,200ft	Loc 2	2B	51	$162,900	$41,000	$8,100	$212,000	28		28	198	0.93
		2R	55	$124,500	$13,000	$600	$138,100	26		26	182	1.32
	Loc 3	3C	50	$211,700	$35,000	$8,100	$254,800	29	14	43	299	1.17
	Loc 4	4B	50	$289,200	$0	$8,100	$297,300	29	14	43	300	1.01
		4C	50	$297,900	$0	$8,100	$306,000	29	14	43	300	0.98
600ft	Loc 3	3C	98	$177,400	$19,000	$7,695	$204,095	15	14	29	203	0.99
	Loc 4	4B	98	$241,200	$0	$7,695	$248,895	15	14	29	203	0.81
		4C	98	$262,200	$0	$7,695	$269,895	15	14	29	203	0.75
15	Ex. Lock		111									
1,200ft	Loc 2	2B	59	$105,430	$25,000	$600	$131,030	24		24	187	1.43
		2C	59	$98,430	$38,000	$600	$137,030	24		24	187	1.37
		2R	62	$90,630	$11,000	$600	$102,230	23		23	179	1.75
	Loc 3	3B	62	$136,330	$18,000	$600	$154,930	23	13	36	280	1.81
		3C	62	$161,330	$20,000	$600	$181,930	23	13	36	280	1.54
600ft	Loc 3	3B	109	$113,330	$11,000	$450	$124,780	13	13	26	202	1.62
		3C	109	$128,330	$11,000	$450	$139,780	13	13	26	202	1.44
14	Ex. Lock		104									
1,200ft	Loc 2	2B	56	$110,330	$25,000	$5,000	$140,330	26		26	186	1.32
		2C	56	$106,330	$38,000	$5,000	$149,330	26		26	186	1.24
		2R	59	$102,530	$11,000	$5,000	$118,530	25		25	177	1.49
	Loc 4	4B	57	$208,200	$18,000	$5,000	$231,200	25	14	39	281	1.22
		4C	57	$203,400	$18,000	$5,000	$226,400	25	14	39	281	1.24
600ft	Loc 4	4B	103	$188,200	$11,000	$3,750	$202,950	14	14	28	201	0.99
		4C	103	$189,700	$11,000	$3,750	$204,450	14	14	28	201	0.98
13	Ex. Lock		92									
1,200ft	Loc 2	2B	46	$146,400	$41,000	$1,600	$189,000	31		31	200	1.06
		2R	49	$110,600	$13,000	$1,600	$125,200	29		29	189	1.51
	Loc 3	3C	47	$196,300	$35,000	$1,600	$232,900	30	16	46	296	1.27
	Loc 4	4B	47	$280,800	$0	$1,600	$282,400	31	16	46	296	1.05
		4C	47	$270,500	$0	$1,600	$272,100	31	16	46	296	1.09
600ft	Loc 3	3C	93	$162,300	$19,000	$1,200	$182,500	15	16	31	199	1.09
	Loc 4	4B	93	$231,800	$0	$1,200	$233,000	15	16	31	199	0.86
		4C	93	$235,800	$0	$1,200	$237,000	15	16	31	199	0.84
12	Ex. Lock		95									
1,200ft	Loc 2	2B	47	$146,100	$41,000	$2,500	$189,600	30		30	200	1.05
		2R	50	$121,300	$13,000	$2,500	$136,800	29		29	189	1.38
	Loc 3	3C	47	$198,900	$35,000	$2,500	$236,400	31	15	46	303	1.28
	Loc 4	4B	46	$278,600	$0	$2,500	$281,100	31	15	46	304	1.08
		4C	46	$275,300	$0	$2,500	$277,800	31	15	46	304	1.09
600ft	Loc 3	3C	93	$164,600	$19,000	$1,875	$185,475	15	15	31	202	1.09
	Loc 4	4B	93	$230,600	$0	$1,875	$232,475	15	15	31	202	0.87
		4C	93	$240,600	$0	$1,875	$242,475	15	15	31	202	0.83
11	Ex. Lock		102									
1,200ft	Loc 2	2B	49	$110,100	$41,000	$600	$151,700	29		29	208	1.37
		2R	53	$81,200	$13,000	$500	$94,700	27		27	193	2.04
	Loc 3	3C	49	$203,000	$35,000	$600	$238,600	30	14	44	309	1.29
600ft	Loc 3	3C	100	$168,700	$19,000	$450	$188,150	14	14	29	201	1.07

Notes:

[1]Average lockage times shown are based on equal percentages of fly, exchange, and turnback lockages. The numbers shown assume turnback approaches occur during the lockage of the previous tow; this may understate overall lockage time slightly.

[2]Cost estimates prepared for these conceptual designs were prepared to the same level of detail as those presented in the *Conceptual Lock Designs Report*. The project element costs are based on 1996 prices and include 25 percent contingencies.

[3]The operations and maintenance costs and the major rehab costs reflect only the incremental life cycle costs for each alternative. Total O&M costs would be $13,100 million for Location 2 locks and $19,000 million for other locations leading to the existence of two locks. However, this $13,100 million is associated with the existence of the existing lock and as such does not represent a with-project cost.

[4]Costs for impacts to navigation are estimated based on preliminary system economic model runs, which indicated impact to navigation costs of $12 million per lock associated with the construction of a 2R lock. The costs for the other lock types where then estimated based on relative hours of unavailability. This is at best a rough estimate to provide a general indication of relative level of impacts. However, as part of the actual evaluation of alternative plans, the Economic Work Group used the system economic model will convert the days of impacts to navigation to economic costs.

[5]Environmental costs for Locks 20-25, Peoria, and La Grange are the average of the ranges provided in the *Site Specific Habitat Assessment* report. The values for the other sites were estimated based on qualitative analysis of the sites and relative impacts compared to the seven sites which had specific costs identified. The environmental costs associated with the 600-foot locks were estimated at 3/4 the cost of the 1,200-foot lock options but were not looked at in detail.

[6]The total costs shown are not all inclusive. They do not include the costs related to system environmental impacts, cultural impacts, and only include rough estimates of impacts to navigation during construction.

RESULTS OF SECONDARY SCREENING

The results of this screening are summarized in Table 27. This secondary screening greatly reduced the number of potential lock locations and types. The development of the lower cost 2R lock allowed all other Location 2 lock extensions and 600-foot lock options to be screened out. The IWW sites were the exceptions, where impacts to navigation associated with extending the existing lock lower it in relative performance to Location 1 locks, which can be constructed with minimal impacts to navigation. However, the numerous qualitative limitations lead to the screening of a 600-foot lock option at these sites as well.

Regarding options that would result in the construction of a new 1,200-foot lock in addition to the existing 600-foot lock, Location 1 locks dominated at the four sites where they can be constructed. At all sites, Location 3 locks dominated Location 4 locks. As a result, Location 4 locks were screened out, except at Lock 14 where it is the only option other than extending the existing lock. At Locks 17 and 25, both 1C and 3C locks were carried forward due to considerable unquantified concerns over the environmental impacts associated with Location 1 locks. For the remaining Location 3 and 4 locks, due to similarities in the cost of Type B and C locks, the lowest cost will be used in further system economic evaluations, but both design types will be considered during the detailed design efforts at those lock sites that show justification.

TABLE 27: REMAINING LOCK LOCATIONS AND TYPES FOLLOWING THE SECONDARY SCREENING

	Location Number and Viable Types					
Lock and Dam Site	1	2	3[3]	4[3]	5	6
L/D 11		R	C			
L/D 12		R	C			
L/D 13		R	C			
L/D 14[1]		R		C		
L/D 15[1]		R	B			
L/D 16		R	C			
L/D 17	C	R	C			
L/D 18		R	C			
L/D 19[1]			B			
L/D 20[2]		R	B			
L/D 21		R	C			
L/D 22[1]		R	C			
L/D 24[2]		R	C			
L/D 25	C	R	C			
Peoria	C	R				
La Grange	C	R				

[1] These sites have rock foundations. All others (except for note 2) are sand-founded sites (requiring piles).
[2] These sites have mixed foundations; some locations would be rock-founded and some pile-founded.
[3] While only a Type B or C lock is shown, costs and performance evaluations to date have shown these lock options to be essentially equal. As a result, only the lower cost option is shown in the table, but if the system economic analysis shows justification for Location 3 or 4 locks, Type B, C, and possible hybrids of the two will be considered during the site-specific detailed design efforts.

OTHER CONSIDERATIONS

Despite screening out a number of lock locations and types based on cost effectiveness using available cost and performance information, some issues remain that could lead to the eventual recommendation to implement a different location of lock other than the remaining lock options shown above. For example, Location 4 locks were generally rated as a good to best location from a navigation perspective. The main reasons are that it resulted in two locks, presents minimal impacts to existing traffic during construction, and afforded the best opportunity for the optimum approach conditions, especially for downbound tows. There are also similar reasons why a Location 3 lock may be preferred over a lower cost lock extension. A more complete list of potential reasons to select other types includes:

- Ease of Approach and Exit: Locations 3 and 4 in many cases provide significant approach improvement benefits, while some time savings are anticipated for downbound fly and exchange approaches, there is a potential for unquantified safety improvements as well.
- Redundancy of Two Locks: Prevents system shut-downs during necessary repairs and rehabilitation. This also allows for greater increases in traffic growth without the need for further capital infrastructure improvements in the near future.
- Corps Design Criteria/Policy/Standards: Type 2R represents that greatest deviation from current Corps design criteria.
- Uncertainties: Focusing on a location 2 lock extensions present some risks for unanticipated delays during construction and the resulting higher impacts to navigation. Delays due to weather also present greater risks for lock extensions due to reliance on winter closure periods for construction.
- Impacts to Navigation During Construction: The further a new lock location is from the existing lock, the greater the opportunity for virtually continuous, mostly uninterrupted use of the existing lock during construction of the new facility.
- Recreational Craft: Improvement options that provide two locks would allow better accommodation of recreational and other non-commercial vessels. This also improves safety since two chambers would allow various vessels to more easily stay out of each other's way.
- Site-Specific: Some site-specific factors or limitations not fully identified to date may influence the ultimate location (geotechnical, environmental, etc.).

For NED analysis purposes, only the remaining locations and types will be considered using the system economic models. However, in addition to the cost effectiveness evaluation and NED evaluation it may be necessary to further consider other alternatives, such as Location 3 and 4, as part of the recommended plan process if any of the above issues become more important.

COST EXTRAPOLATION (BASIC LOCK COST)							
				$ 1000s			
ROCK FOUNDED							
				EST	EST	EST	PER 200'
LOCATION 1		600'	1200'	800'	1000'	400'	
TYPE A		168000	188000	175000	181000	161000	7000
TYPE B		152000	176000	160000	168000	144000	8000
TYPE C		147000	171000	155000	163000	139000	8000
LOCATION 2							
TYPE B			115000				
TYPE C			110000				
LOCATION 3							
TYPE B		109000	131000	116000	124000	102000	7000
TYPE C		96000	122000	105000	113000	87000	9000
LOCATION 4							
TYPE A		176000	206000	186000	196000	166000	10000
TYPE B		163000	184000	170000	177000	156000	7000
TYPE C		154000	165000	158000	161000	150000	4000
LOCATION 5							
TYPE A		195000	234000	208000	221000	182000	13000
TYPE B		159000	186000	168000	177000	150000	9000
TYPE C		146000	161000	151000	156000	141000	5000
COST EXTRAPOLATION (BASIC LOCK COST)							
				$ 1000s			
PILE FOUNDED							
				EST	EST	EST	PER 200'
LOCATION 1		600'	1200'	800'	1000'	400'	
TYPE A		273000	326000	291000	308000	255000	18000
TYPE B		191000	219000	200000	210000	182000	9000
TYPE C		149000	163000	154000	158000	144000	5000
LOCATION 2							
TYPE B			160000				
TYPE C			151000				
LOCATION 3							
TYPE B		172000	200000	181000	191000	163000	9000
TYPE C		160000	194000	171000	183000	149000	11000
LOCATION 4							
TYPE A		339000	373000	350000	362000	328000	11000
TYPE B		232000	283000	249000	266000	215000	17000
TYPE C		217000	248000	227000	238000	207000	10000
LOCATION 5							
TYPE A		287000	342000	305000	324000	269000	18000
TYPE B		205000	246000	219000	232000	191000	14000
TYPE C		181000	227000	196000	212000	166000	15000

ATTACHMENT 1

LOCATION 1
LOCK AND DAM 25 -- CHAMBER SIZE COMPARISON MATRIX ($000)

	NON-COM CHAMBER	200 FOOT CHAMBER	400 FOOT CHAMBER	600 FOOT CHAMBER	800 FOOT CHAMBER	1000 FOOT CHAMBER	1200 FOOT CHAMBER
NON-COM	0	104295	158270	179054	194824	200393	220329
200 FOOT	-104295	0	53975	74759	90529	96098	116034
400 FOOT	-158270	-53975	0	20784	36554	42123	62059
600 FOOT	-179054	-74759	-20784	0	15770	21339	41275
800 FOOT	-194824	-90529	-36554	-15770	0	5569	25505
1000 FOOT	-200393	-96098	-42123	-21339	-5569	0	19936
1200 FOOT	-220329	-116034	-62059	-41275	-25505	-19936	0
PROJECT LIFE	5 YEARS	23 YEARS	37 YEARS	46 YEARS	50 YEARS	50 YEARS	50 YEARS

ATTACHMENT 2

LOCATION 2 -- CHAMBER EXTENSIONS

LOCK AND DAM 25 -- CHAMBER SIZE COMPARISON MATRIX ($000)

	800 FOOT EXTENSION	1000 FOOT EXTENSION	1200 FOOT EXTENSION
800 EXT.	0	4475	208524
1000 EXT	-4475	0	204049
1200 EXT	-208524	-204049	0
PROJECT LIFE	3 YEAR	3 YEARS	41 YEARS

LOCK AND DAM 25 -- 1200 FOOT CHAMBER COMPARISON MATRIX ($000)

	1200 FOOT EXTENSION	1200 FOOT LOCATION 3	1200 FOOT LOCATION 1
1200 EXT	0	29297	29592
1200 LOC 3	-29297	0	295
1200 LOC 1	-29592	-295	0
PROJECT LIFE	~~33~~ 41 YEARS	50 YEARS	50 YEARS

LOCATION 3

LOCK AND DAM 25 -- CHAMBER SIZE COMPARISON MATRIX ($000)

	NON-COM CHAMBER	200 FOOT CHAMBER	400 FOOT CHAMBER	600 FOOT CHAMBER	800 FOOT CHAMBER	1000 FOOT CHAMBER	1200 FOOT CHAMBER
NON-COM	0	59014	137677	167341	177877	192973	220254
200 FOOT	-59014	0	78663	108327	118863	133959	161240
400 FOOT	-137677	-78663	0	29664	40200	55296	82577
600 FOOT	-167341	-108327	-29664	0	10536	25632	52913
800 FOOT	-177877	-118863	-40200	-10536	0	15096	42377
1000 FOOT	-192973	-133959	-55296	-25632	-15096	0	27281
1200 FOOT	-220254	-161240	-82577	-52913	-42377	-27281	0
PROJECT LIFE	5 YEARS	15 YEARS	31 YEARS	40 YEARS	45 YEARS	50 YEARS	50 YEARS

ATTACHMENT 4

LOCATION 2 -- CHAMBER EXTENSIONS

LOCK AND DAM 22 -- CHAMBER SIZE COMPARISON MATRIX ($000)

	800 FOOT EXTENSION	1000 FOOT EXTENSION	1200 FOOT EXTENSION
800 EXT.	0	1904	103583
1000 EXT	-1904	0	101679
1200 EXT	-103583	-101679	0
PROJECT LIFE	1 YEAR	2 YEARS	40 YEARS

LOCK AND DAM 22 -- 1200 FOOT CHAMBER COMPARISON MATRIX ($000)

	1200 FOOT EXTENSION	1200 FOOT LOCATION 3	1200 FOOT LOCATION 4
1200 EXT	0	20419	20690
1200 LOC 3	-20419	0	271
1200 LOC 4	-20690	-271	0
PROJECT LIFE	40 YEARS	50 YEARS	50 YEARS

LOCATION 3

LOCK AND DAM 22 -- CHAMBER SIZE COMPARISON MATRIX ($000)

	NON-COM CHAMBER	200 FOOT CHAMBER	400 FOOT CHAMBER	600 FOOT CHAMBER	800 FOOT CHAMBER	1000 FOOT CHAMBER	1200 FOOT CHAMBER
NON-COM	0	38544	88937	108710	116015	123395	162705
200 FOOT	-38544	0	50393	70166	77471	84851	124161
400 FOOT	-88937	-50393	0	19773	27078	34458	73768
600 FOOT	-108710	-70166	-19773	0	7305	14685	53995
800 FOOT	-116015	-77471	-27078	-7305	0	7380	46690
1000 FOOT	-123395	-84851	-34458	-14685	-7380	0	39310
1200 FOOT	-162705	-124161	-73768	-53995	-46690	-39310	0
PROJECT LIFE	3 YEARS	14 YEARS	29 YEARS	37 YEARS	41 YEARS	46 YEARS	50 YEARS

ATTACHMENT 6

LOCATION 4

LOCK AND DAM 22 -- CHAMBER SIZE COMPARISON MATRIX ($000)

	NON-COM CHAMBER	200 FOOT CHAMBER	400 FOOT CHAMBER	600 FOOT CHAMBER	800 FOOT CHAMBER	1000 FOOT CHAMBER	1200 FOOT CHAMBER
NON-COM	0	70592	110232	125813	131967	142713	161402
200 FOOT	-70592	0	39640	55221	61375	72121	90810
400 FOOT	-110232	-39640	0	15581	21735	32481	51170
600 FOOT	-125813	-55221	-15581	0	6154	16900	35589
800 FOOT	-131967	-61375	-21735	-6154	0	10746	29435
1000 FOOT	-142713	-72121	-32481	-16900	-10746	0	18689
1200 FOOT	-161402	-90810	-51170	-35589	-29435	-18689	0
PROJECT LIFE	3 YEARS	21 YEARS	35 YEARS	42 YEARS	46 YEARS	50 YEARS	50 YEARS

ATTACHMENT 7

LOCATION 1

LAGRANGE LOCK AND DAM -- CHAMBER SIZE COMPARISON MATRIX ($000)

	NON-COM CHAMBER	200 FOOT CHAMBER	400 FOOT CHAMBER	600 FOOT CHAMBER	800 FOOT CHAMBER	1000 FOOT CHAMBER	1200 FOOT CHAMBER
NON-COM	0	297027	364154	384677	410305	418049	425237
200 FOOT	-297027	0	67127	87650	113278	121022	128210
400 FOOT	-364154	-67127	0	20523	46151	53895	61083
600 FOOT	-384677	-87650	-20523	0	25628	33372	40560
800 FOOT	-410305	-113278	-46151	-25628	0	7744	14932
1000 FOOT	-418049	-121022	-53895	-33372	-7744	0	7188
1200 FOOT	-425237	-128210	-61083	-40560	-14932	-7188	0
PROJECT LIFE	4 YEARS	29 YEARS	42 YEARS	49 YEARS	50 YEARS	50 YEARS	50 YEARS

ATTACHMENT 8

LOCATION 2 -- CHAMBER EXTENSIONS					
LAGRANGE LOCK AND DAM -- CHAMBER SIZE COMPARISON MATRIX ($000)					
	800 FOOT	1000 FOOT	1200 FOOT		
	EXTENSION	EXTENSION	EXTENSION		
800 EXT.	0	56512	139787		
1000 EXT	-56512	0	83275		
1200 EXT	-139787	-83275	0		
PROJECT					
LIFE	4 YEAR	14 YEARS	40 YEARS		
LAGRANGE LOCK AND DAM -- 1200 FOOT CHAMBER COMPARISON MATRIX ($000)					
	1200 FOOT	1200 FOOT			
	EXTENSION	LOCATION 1			
1200 EXT	0	18928			
1200 LOC 3	-18928	0			
PROJECT					
LIFE	40 YEARS	50 YEARS			

ATTACHMENT 9

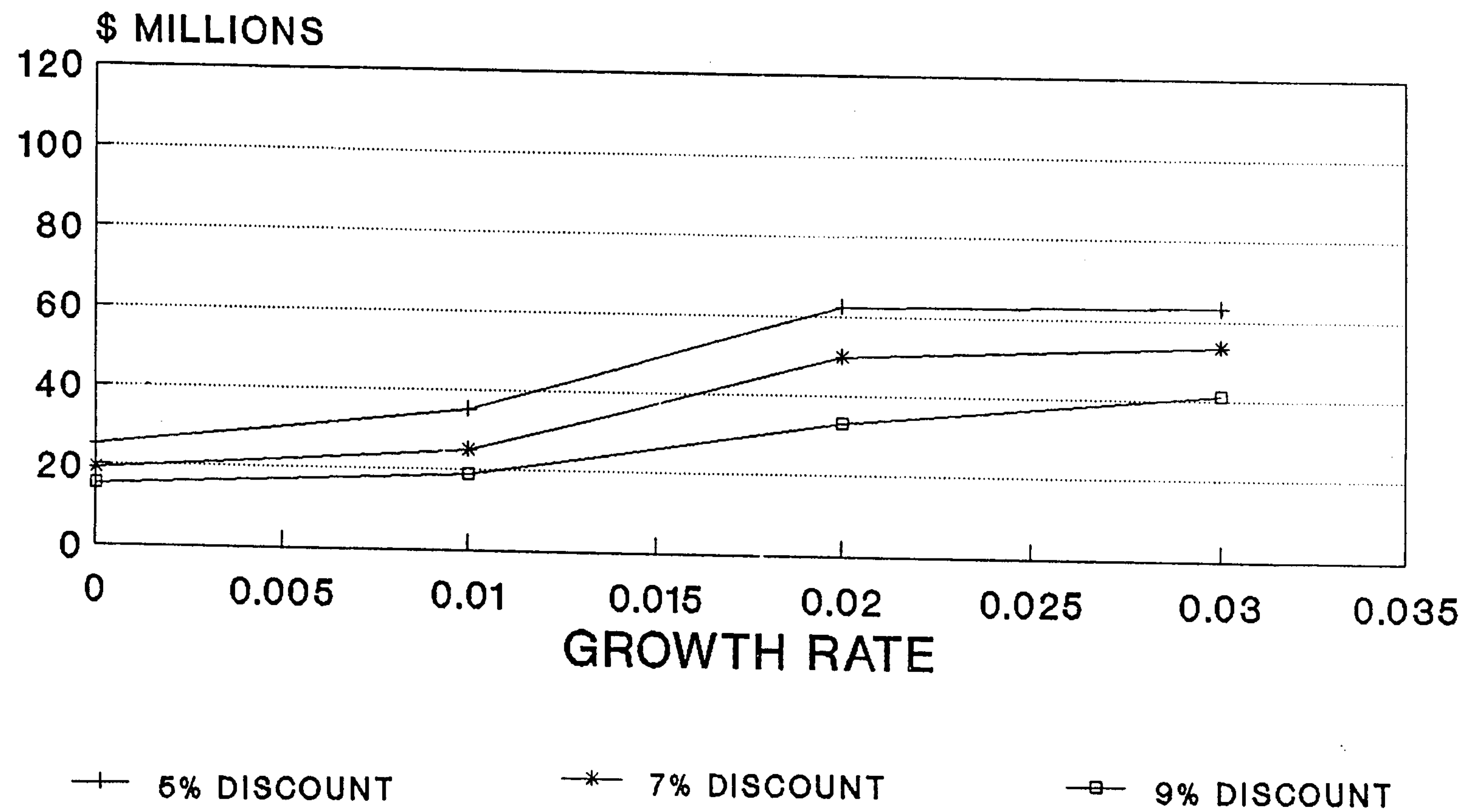
LOCATION 3

LOCK AND DAM 19 -- CHAMBER SIZE COMPARISON MATRIX ($000)

	NON-COM CHAMBER	200 FOOT CHAMBER	400 FOOT CHAMBER	600 FOOT CHAMBER	800 FOOT CHAMBER	1000 FOOT CHAMBER	1200 FOOT CHAMBER
NON-COM	0	206542	261052	290421	304935	326829	361428
200 FOOT	-206542	0	54510	83879	98393	120287	154886
400 FOOT	-261052	-54510	0	29369	43883	65777	100376
600 FOOT	-290421	-83879	-29369	0	14514	36408	71007
800 FOOT	-304935	-98393	-43883	-14514	0	21894	56493
1000 FOOT	-326829	-120287	-65777	-36408	-21894	0	34599
1200 FOOT	-361428	-154886	-100376	-71007	-56493	-34599	0
PROJECT LIFE	7 YEARS	24 YEARS	31 YEARS	36 YEARS	39 YEARS	44 YEARS	50 YEARS

ATTACHMENT 10

Incremental Benefits
600' vs 1200' Chamber



Based on Lock 22 - Location 4

ATTACHMENT 11