Chapter 3
Project Engineering Considerations

3-1. General

In previous decades, many inland and coastal rivers and waterways were developed for navigation with channelization or navigation lock and dam projects. However, the emphasis in this era is on the modernization, addition, or replacement of the components of the existing inland waterway system for increased efficiency and/or major rehabilitation of deteriorating parts of this infrastructure. Many of the lock and dam projects are approaching or have exceeded 50 years in age, and may require improvement or rehabilitation. The engineering considerations for navigation lock development or improvement identified in this chapter should be studied and presented in the feasibility report. More detailed engineering analysis should be provided in subsequent design memoranda.

3-2. Information Investigations

After a waterway or navigation project is proposed for navigation improvements, the first step in engineering is the information gathering stage. This stage should start during the reconnaissance stage, with the information presented in the feasibility report.

a. Characteristics and history. All available information should be collected and evaluated concerning the project such as existing characteristics, physical setting, surrounding infrastructure, social context, environmental resources, transportation modes, economic base, and past performance. An engineering assessment of a waterway for improvements should focus on existing and projected data for the following items:

(1) The natural characteristics of the river, including its stability in a defined channel, the character of the riverbed, scouring or depository, slope of river valley, the riverbed soil profile, the underlying geology, and seismic zone activity.

(2) The river basin hydrographic data, including project storms, rainfall, and runoff factors.

(3) Hydraulic data with river hydrographs, including stage duration, stage velocities and stage discharge curves, low-water and flood-stage levels with their slopes, seasons, length of time each stage is prevalent, the regularity of streamflow cycle, and magnitude of sudden rises.

(4) The normal channel dimensions, including overbank areas, location of dikes, revetments, and natural or artificial barriers.

(5) Climate, weather, and ice conditions.

(6) Existing navigation upstream or downstream (typical tow size).

b. Maps and topography. Information needed for engineering a lock project should be obtained or developed on the topographical features, land use, and river developments of the immediate site and entire project area. If the required information cannot be easily located, surveys and mapping should be performed to show the data required for planning and design of the project. This information should include the following:

(1) Topographic and hydrographic mapping of the site land and water areas with the appropriate scale for the level of study.

(2) Location, elevation, and other information concerning cities and industrial developments.

(3) Railroads, highways, power lines, pipelines, flood protection, levee districts, sewer outlets, power plants and water supply, and pumping stations.

(4) Fishing and hunting preserves, channel soundings, high- and low-water marks, agricultural land use, and river gages.

(5) Harbors, bridges, dams, dikes, wharves, pleasure resorts, and all other features that might be affected by the proposed project.

c. Real estate considerations. Numerous real estate considerations are associated with a navigation facility and those concerning the lock site itself may form only a small part of the picture. In the investigation phases, the government may need temporary access to private property to perform surveys and foundation exploration; to assess possible requirements for highway, railroad, and utility relocations; to determine access road alternatives; and for other reasons. In the site selection stage, temporary access will be needed at a number of locations to obtain adequate data for determining the best site for the structure. Project construction and/or operation purposes will require real estate for staging construction activities and for project-induced flooding of lands adjacent to the upstream channel, channel work, navigation structures, access roads, and support facilities. Surveys should be performed to identify the need to mitigate damages from levee underseepage from changed pool conditions. Mitigation may involve compensating a landowner for estimated damages for changed industrial and agricultural land use over the project life. An alternative to mitigation may be the need for levees, pumping stations, and drainage structures to handle increased water levels and induced underseepage from changed pool conditions. Other considerations which may pose major concerns include the following:

(1) Determining the types of right-of-way required (including easements and fee title properties).

(2) Establishing the entity responsible for obtaining real estate and performing relocations.

(3) Estimating the lead-times required to obtain rights-of-way and perform relocations.

(4) Identifying lands for mitigation of changed environmental conditions.

3-3. Site Selection

Selection of alternative site locations is the next step in the project formulation.

a. General layout. Locks and the associated dam are integral parts, and the relation of both has to be considered when selecting lock site alternatives for a navigation project. The location of a navigation lock is determined by identifying and evaluating all feasible locations within the project area. In identifying the location, the following criteria should be evaluated: lock capacity, location of existing navigation structures (modification of existing structures or complete replacement at an alternate site), navigation efficiency and safety, visibility and straight approaches for vessels, foundation conditions, relative cost of structure, existence of public utilities, required relocations, lands available and suitable for construction staging, esplanade and general operations, and any other advantages for a particular site. An engineering determination should be made to confirm that the alternative site locations selected are feasible for navigation conditions and foundation qualities. Locks should be located in straight stretches of river with approaches aligned with the currents. For example, a location which produces crosscurrents in the approaches or shoaling would be undesirable unless modified by dike work or channel relocation. On the other hand, when conditions warrant, there may be an advantage in locating the lock in a side canal or cutoff to take advantage of natural river formations, reduce cofferdam staging, or bypass undesirable features. Specific guidance regarding hydraulic considerations is provided in EM 1110-2-1601 and in EM 1110-2-1604.

b. Lock capacity and layout. For input into the site selection evaluation, an integrated engineering and economic planning study needs to be performed to determine the number, size, capacity, and layout of the various lock alternatives.

(1) Lock size and location.

(a) The number of locks and lock sizes for the desired capacity depends on the challenges involved in selecting the most efficient lock site. Different sites and configuration of locks may have different capacities because of differing site conditions such as navigation approaches, lock separation, incorporation into an existing structure, complete replacement, location in a canal or open river, and associated economic costs of the structures. The determination of commercial tonnage capacity required for a lock project is developed through economic studies of present and future commodity movement projections. Once the desired lock capacity is determined, then various lock sizes can be configured at the alternative sites to determine the costs of the navigation improvements. This integrated procedure is an iterative process between planners performing economic analysis, and project engineers conducting design and cost studies, in order to optimize the proposed navigation improvements.

(b) In most cases, the lock project will also require (unless it is located in a canal) a consideration of gated dam, ungated overflow dam, or navigable pass structure alternatives. These considerations involve complex design relationships that should be accounted for in the economic costs and alternative site selection process. The determination of pool and tailwater elevations for navigation will also impact the capacity and economic cost of the system as well as other requirements such as the need to control flowage damages. These requirements can make it a challenge to identify the most economical structures for a particular site.

(2) Traffic requirements. A comprehensive study of present and projected future traffic requirements, with particular emphasis upon lock size and time required for lockage, can indicate that one lock is sufficient to satisfy the 50-year economic capacity requirement. However, any cause for closure, such as emergency shut-down,

accident, or maintenance, for this one lock may make this project the head of navigation for as long as the lock is closed. If this condition is not acceptable, then two locks might be justified for the project to provide alternate access. Flights of two or more locks (locks in tandem) are sometimes used for unusually high lifts in excess of 100 ft, for water conservation, or for foundation conditions which are not adequate for a single lift. However, where site conditions permit, it will be more economical to provide the total lift in one chamber. In addition, single lifts will certainly be less expensive for the users because of decreased transit time and entail less maintenance and operating costs. However, the design of a single lock with over 110-ft lift is unprecedented and will require careful hydraulic, structural, and foundation design to ensure satisfactory performance.

c. Navigation requirements. For a canalized waterway to be developed for maximum use, operating restrictions and hazardous reaches should be eliminated by river regulating works, channel relocations, and selection of pool elevations. To ensure continuous use of the waterway, the locks should be located and operated for continuous navigation. The following factors should be considered during the economic, capacity, and design studies for lock configuration:

(1) Visibility.

(2) Ease of approach.

(3) Few lockage restrictions, such as double lockages.

(4) Provisions for prompt lockage.

(5) Adequate approach channel with low velocities.

(6) Elimination of crosscurrents which would tend to draw vessels away from lock entrance.

(7) Duplicate gates or closure to prevent downtime due to emergency and accident.

(8) Elimination of lockage in congested traffic areas.

(9) Adequate horizontal and vertical navigational clearances for bridges at or near locks.

(10) Adequate mooring facilities and maneuvering areas.

d. Planning criteria for navigation requirements. The most important considerations involve the effects of stream characteristics, streamflow, and visibility on navigation.

(1) Effects of stream characteristics on navigation. The characteristic of the river should be taken into account for the design of the navigation project. Straight stretches of rivers are usually less difficult to navigate for approaches to locks; thus, straight stretches one or two miles above and below are desirable locations for locks (if all other requirements are satisfied). The locks are usually located at one end of a dam to provide access to operation, increase the area available for flood discharges, and use the natural protection to navigation offered by a shoreline. If dual locks are considered, then there may be an operational advantage in separating the locks with a spillway in between. The depth of the channel lessens toward the banks on a straight reach or inside of curve but deepens on the outside of a curve. If the lock is located in a reach that has a tendency to shoal, the necessity to dredge may add unacceptable maintenance costs over the life of the project to provide the project depth during low-water stages. Because continual maintenance dredging in the approaches to a lock is expensive, this tendency should be eliminated with addition of river training structures during the site selection and design process. Shoaling and scour characteristics of the stream both naturally and with addition of the improvements should be determined using hydraulic theoretical analysis procedures verified by hydraulic navigation model testing.

(2) Effects of streamflow on navigation. The flow characteristics of the stream in the vicinity of a lock should be evaluated during the site selection to select a feasible location of the lock from a navigation and maintenance standpoint. Crosscurrents are set up where the thalweg crosses from one side of the river to the other; this action is caused by an unstable riverbed. Therefore, the thalweg will change positions frequently in some reaches each time there is a flood discharge. This condition also occurs where sizable tributaries enter the stream. Feasible site locations with necessary river training works should be included in the project plan to eliminate these flow characteristics. If locks are constructed at either the head or tail of a river crossing, or immediately below the mouth of a tributary, crosscurrents will occur at the approach channel leading to the lock. These currents, along with the prevailing winds, may force the tow off course and over the dam or force it against the bank or

the lock. If the tributary immediately above the site is a navigable waterway, and the lock's size does not permit a tow to pass in a single lockage, traffic congestion in the vicinity of the lock may cause additional difficulties. These problems may be caused by the need for extra space where broken tows can stand by and maneuver while regrouping. These undesirable characteristics that may affect the efficiency and safety of navigation should be eliminated by alternative siting or addition of river training works and protective structures. The selected alternatives should also consider what, if any, obstructive effects the lock structures will have on existing natural conditions such as the effects on the river currents. A pair of locks located on the riverside of the shoreline, on the deep side of the stream, may deflect enough streamflow from its natural course to cause appreciable crosscurrents. Engineering works should be included in the project plan to eliminate the undesirable navigational attributes. Otherwise, failure to eliminate these deficiencies during design may result in difficult navigation conditions after the project has been completed and in the need for expensive maintenance and modification after the project is placed in operation.

(3) Visibility. From the towboat pilot's standpoint, adequate visibility and ease of approach must be incorporated in the lock design. Pilots often have difficultly checking the momentum of a long and heavily loaded tow using rudder and prop control because of the inertia and relatively low power-mass ratio of the vessel. Pilots have described this problem as "like trying to balance a broom upright on your finger." To maintain control of the tow, pilots should have a clear view of the lock entrances for a sufficient distance both from the upstream and downstream directions. The distance will vary with the characteristics of each site and will depend upon the velocities of the stream and the power of the vessels, but a clear site distance upstream and downstream of one to two miles is preferable. Usually, because the tow is floating along with the current and cannot exercise full propeller steerage power, the upstream approach is more difficult to navigate than the downstream approach where the tow is pushing against the current. However, these risks can be reduced by providing downbound approaches aligned with the current, with adequate sight distance, and with the downbound lock placed close to the bank for the tows to align on the approach to the lock.

(4) Lock location with respect to riverbanks and streambed.

(a) The location for a lock with respect to channel alignment, river currents, riverbanks, and damming structures directly affects the time required for a tow to approach and transit a lock. For lock and dam construction in open rivers, the lock is usually located against one bank of the stream adjacent to the end of the dam, while in canal construction the lock often forms the damming surface to maintain pool.

(b) Since the locks located adjacent to a spillway dam in the river will block a significant amount of natural flow area, compensating flow area needs to be provided in the spillway area. This procedure will pass flood discharges without producing swellhead effects that could cause appreciably greater damage to the land and industries upstream than would have occurred without the lock. On main stem rivers, enough gated spillway area has been provided to hold the swellhead to 2 ft or less at the project location. Minimizing the swellhead effect will also reduce outdraft conditions from the lock approach into the dam at open river conditions. On the other hand, for rivers that carry a heavy silt load, too much spillway area could cause silt to build up in the lock approaches. If the tentative site does not furnish adequate width for the desired spillway area, the project will incur increased cost because of either the increase in flood damages or the lock having to be placed outside the banklines to obtain additional area. Increased excavation for foundations and approach channels needs to be compared with possible savings in cofferdam costs for constructing the locks in overbank areas. When such conditions exist or if the stream meanders with short radius curves of large central angle, it may be possible to construct a cutoff canal with a lock near the downstream end of the cutoff. This configuration may produce increased navigational efficiency rather than relying on a program for maintenance of the project depth in the natural channel. A general hydraulic river model should be used to verify the alternate lock locations. If shoaling or scour is expected, then a movable bed hydraulic model should be used to test the lock and dam configurations.

e. Nonnavigation considerations.

(1) Existing facilities. Alternative locks site studies should consider the impacts and disturbances to existing public and private installations such as bridges, utilities, and pipelines. The evaluation of these potential sites should also consider the political, social, and economic costs for modification or relocation of these facilities.

(2) Use of lock as supplemental spillway. During times of high or flood discharges, the lock structure may be used as an auxiliary controlled spillway. However, this auxiliary use functions only if the lock is designed so

that the upper gates or other closure structure can be closed under head with flowing water conditions. In this case, the lock chamber and floor should be designed for the expected scouring velocities. Miter gates are not suitable to be closed under this condition; therefore, special gates such as lift gates or emergency type closures need to be provided to make closure after the lock is opened for flow. This design should only be considered in situations where a narrow waterway at the lock site so restricts the flow that potential flood damage would greatly exceed the amount expected in open river conditions.

(3) Cofferdam considerations. Because the cost of cofferdam construction could prove expensive, careful evaluation of the cofferdam scheme and of alternatives should be made. In fact, the costs of cellular cofferdams and dewatering necessary to construct a lock and dam in stages within the river channel can amount to 20 to 30 percent of the total construction costs. Therefore, it is important to determine the optimum cofferdam scheme, sequence of construction, and number of stages during the alternative site selection process. Potential sites where locks and dam can be constructed in a cutoff outside the river channel can be more economical, if lands are available and navigation conditions are suitable. All feasible cofferdam alternatives should be evaluated for costs, construction sequence, construction schedules, effects on navigation, sediment transport, scour, and passage of flows. The evaluation should address the following alternatives: sequence of construction (locks first or dams first), number of cofferdam stages, type of cofferdam, and cofferdam heights. A risk analysis should be performed to determine the optimum cofferdam height based on probability of river stage occurrence. The probability of overtopping the cofferdam at a certain elevation (cost of structure) can be compared to the damages associated with the frequency of flooding the cofferdam (cost of damages) to provide data for the selection of top of cofferdam. For design of cofferdams on main stem rivers, a 10-year frequency is a reasonable criteria that generally meets the optimum criteria. The risk analysis procedure is outlined in ETL 1110-2-532. A three-stage cofferdam layout is shown on Plate 1.[1] Cofferdam details are shown on Plates 2 through 4 and a temporary river closure is shown on Plate 5.

f. Accessibility. The accessibility of the project site with respect to initial construction, maintenance, and operation must be considered. Adequate staging areas should be provided and protected against flooding. In addition, site access under normal conditions and during flooding should be available for construction and operation. Land access should be provided to construction areas as well as to the various cofferdam stages. During the planning and estimating stages, the availability of construction materials should be determined. Facilities must be accessible for the transport of construction materials such as suitable coarse and fine aggregates, protection stones, structural and prefabricated items, and machinery and equipment. Electric power also should be available for project construction and operation.

3-4. Lock Size and Configuration

a. Size. The number, length, and width of lock chambers should be determined from the previously discussed economic and cost alternative studies. Criteria for the proposed physical dimensions for a lock must also include the requirements established by existing legislation and other official restrictions. For example, navigation depths on existing waterways are often dictated by existing laws, such as the authorized 9-ft channel on portions of the inland waterway. The plan dimensions for the new projects should be at least as large as the dimensions for other locks on that waterway, otherwise unnecessary traffic bottlenecks may occur. Larger plan dimensions should be considered, if other locks on the waterway are to be enlarged or if larger dimensions will serve to increase the navigational efficiency of the waterway. The widths of most locks in the inland waterway system will be controlled by the number of barges abreast that are in general use for that stretch of the system. Usually, the lengths of most locks will be related to the number of barges placed end-to-end that are to be accommodated in a lockage.

(1) Controlling factors. Determining the size of lock to be used in the plan of improvement involves numerous factors including type and quantity of traffic, lockage time, and waterway features. For example, the ease with which a tow of barges can be dispatched through the lock depends upon the type of barges used on the waterway, the arrangement of the tow, the inclusion of haulage units, and the prevailing type and size of the towboat in relation to the usable size of the lock chamber. Locks that are utilized above 80 percent of capacity will have queues form at heavy traffic periods with significant backup for the tows. The lock should be long enough to accommodate the standard tow using the waterway in one lockage without having to split the tow into a double lockage. In addition, the lock size should be large enough to accommodate the traffic which can reasonably be anticipated

[1] Plates mentioned in this chapter and succeeding chapters are included at the end of the main text.

during the life of the structure. If the waterway has features such as treacherous reaches, sharp bends, narrow channels, and shallow depths which restrict the size of tows and cannot be corrected, then lock sizes should be determined by the normal size barge tows that can navigate the restricted stretches of the waterway. The design of lockage facilities should also account for connecting waterway systems. The dimensions of a lock chamber (width and length) are determined by a balance between economy in construction and the average or probable size of tow likely to use the lock. (Chapter 5 provides more specific information about lock dimensions.)

(2) Transit time. The time required for tows to transit the locks may constitute a significant part of the total trip time for a tow. The objective is to develop an overall design that reduces transit time. The optimum transit time should be determined by economic studies to balance costs and capacity. Transit time can be separated into seven components:

(a) Time required for a tow to move from an arrival point to the lock chamber.

(b) Time to enter the lock chamber.

(c) Time to close the gates.

(d) Time to fill or empty the lock.

(e) Time to open the gates.

(f) Time for tow to exit from the chamber.

(g) Time required for the tow to reach a clearance point so that another tow moving in the opposite direction can start toward the lock.

(3) Methods to reduce transit time. The seven components of time listed represent the total transit time for continuous lockages alternating in direction of movement. Two of the seven time components listed above (gate operating time and filling and emptying time) depend on design of the lock operating equipment. However, approach time, entry time, exit time, and departure time are dependent on pilot skill, towboat capability, design of the approach channels, guide walls, and lock wall appurtenances (line hooks, check posts, floating mooring bits, etc). Particular attention in the design needs to be given to laying out the upstream approach walls to reduce outdraft with flow through features to align the currents into the approach to the lock. For dual locks, transit time can be reduced by separating the locks a sufficient distance to allow simultaneous arrivals and departures. Every minute saved in transit is significant economically, especially when locks reach capacity and queues begin to form. For intermediate lift locks, filling and emptying systems can be designed for 6 to 8 minutes (min) to fill or empty; however, filling or emptying a high-lift lock requires up to 10 min. Miter gates can be designed for operating times of 1 to 2 min. Layout of the locks, guide walls, adjacent dam, and approaches can be model tested to minimize transit times.

b. Sizes of existing locks. Historical information on lock sizes is contained in Bloor (1951). The paper not only contains valuable historical data but is also recommended reading for anyone participating in navigation lock planning and design. This reference also discusses the location, size, and date of construction of navigation locks on the inland waterways of the United States and establishes reasons for past lock size selection. In addition, this paper examines factors governing the selection of lock sizes, trends in barge and towboat sizes, and towing practices and states that lock sizes adopted in the past have frequently been too small to allow utilization for the full physical life of the structure. The most recent information on the location, size, lift, and date of construction of navigation locks on the inland waterways of the United States is contained in the IWR Report 88-R-7. In this report, an examination of the tabulation of lock sizes reveals the following trends in lock sizes:

(1) Most locks built since 1950 have chamber widths of either 84 or 110 ft with lengths varying to suit the particular waterway system.

(2) Approximately 32 locks with 56-ft-wide lock chambers and 360- to 747-ft lengths have been constructed. However, the last 56-ft-wide lock was opened in 1965. Replacement locks at the existing 56-ft-wide locks have been 84 ft wide. In the future, any 56-ft-wide locks will probably be constructed only in special situations.

(3) Other locks have been built that have widths varying from 18 to 86 ft.

(4) Locks on the Gulf Intracoastal Waterway and the Atlantic Intracoastal Waterway have been built with widths varying from 52 to 110 ft and lengths from 310 to 1206 ft.

c. Standard lock sizes. The selection for a lock size will be made from the following lock dimension table. Deviations from these lock dimensions will only be granted by HQUSACE with sufficient justification.

Lock width, ft	Lock length, ft
84	600
84	800
84	1200
110	600
110	800
110	1200

These lock dimensions are usable dimensions; these dimensions are not to be encroached upon by lock gates, sills, or other lock features. For the most common type of lock with mitering lock gates, the usable length is measured from the downstream side of the upper miter sill where it joins the lock wall to the upstream point of the lower gate when it is in the recessed position. Deviations from the above listed standard lock sizes are authorized for the following systems:

(1) Locks in the Great Lakes-St. Lawrence River waterway system, which are 80 ft wide by 800 ft long.

(2) Locks in the Columbia River-Snake River system, which are 86 ft wide by 675 ft long on the major portion of the waterway and either 86 by 500 ft or 86 by 360 ft on smaller streams in the system.

(3) Locks on the Intracoastal Waterways, which have special width requirements. (The Army Corps of Engineers New Orleans District is conducting a study to determine the feasibility of standardizing lock widths at 110 ft.)

(4) Locks to be used by small crafts, which do not require lock facilities as large as the established standards.

d. Barge and towboat size. Lock design and barge design have influenced each other to such an extent that the sizes of each generally correspond to the other. Before the lock size is determined, studies should be conducted of the prospective equipment which will use the waterway system. Data on the width, length, capacity, power, and number of barges and towboats, including the years in which they were built and operated on existing similar waterways, can be obtained from various Corps of Engineers offices and barge-line operators. These data can help to determine which group of barges and their tow formations are the prevalent configuration for the waterway system being studied. Tabulated data on barge and towboat sizes are contained in IWR Report 88-R-7 and in the ASCE paper by Bloor (1951). Figure 3-1 shows barge and towboat sizes.

e. Lift.

(1) The function of a lock is to transport vessels vertically from one level to the other whether the lock is connected to a spillway in the river, in a canal, or in a harbor. The maximum lift of a lock is defined as the vertical distance from the normal pool upstream of the lock to minimum tailwater surface downstream of the lock. Since the criteria for design of the lock structures, gates, filling and emptying systems, and operating equipment are determined by the lift, lift should be one of the first factors to be determined in the project formulation.

(2) Cost and time are two important factors that must be considered to determine lift. Currently, the trend in modernization of waterway systems is to replace several low-lift locks with one higher lift lock. Since lockages are time-consuming and expensive for waterway operators and from a waterway maintenance and operating standpoint, configuring a waterway of considerable reach with fewer higher lift locks instead of many low-head structures may improve the lockage time. Also, many low-lift locks along the waterway could limit the development and usefulness of the waterway. The overall cost for one high-lift lock is often lower than the combined cost of two low-lift locks which, together, would equal the lift of the high-lift lock; however, the design of the high-lift lock may be more complicated. The trade-off is that higher lift locks may cause more damages, involve environmental impacts, require relocations, and involve modification to flood control works along the waterway system to accommodate the higher pool levels. Since these considerations apply to new construction and to modification of existing projects, it may be important to make such decisions on a site-specific basis.

f. Single lock. Generally, a single lock on a waterway system with sufficient dimensions to handle the standard size tows without double lockage will have enough capacity to handle the 50-year tonnage capacity. In fact, a large lock may be more economical to construct and operate than two smaller locks. Providing two smaller locks of equivalent capacity may require that tows be broken and their barges be pushed through in two or more lockages, depending on how small the lock is and/or how many barges are in the tow. Obviously, breaking up tows and making up tows for lockages through small locks will cause delay and incur economic penalties for moving the tonnage through the lock.

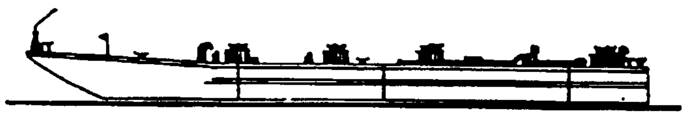
g. Dual locks.

OPEN HOPPER BARGES

TYPE	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
STANDARD	175	26	9	1000
JUMBO	195	35	9	1500
SUPER JUMBO	250-290	40-52		2500-3000

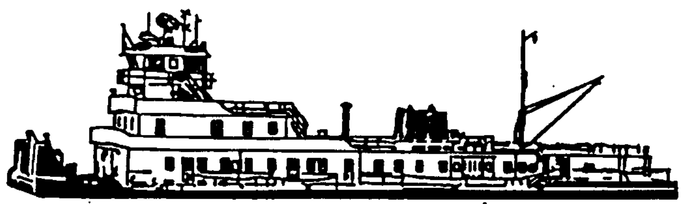
COVERED HOPPER BARGES

TYPE	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
STANDARD	175	26	9	1000
JUMBO	195	35	9	1500



INTEGRATED CHEMICAL AND PETROLEUM BARGES

LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
150-300	50-54	9	1900-3000



TOWBOATS

LENGTH FEET	BREADTH FEET	DRAFT FEET	HORSEPOWER
65-160	24-50	5-9	300-7000

Figure 3-1. Barge and towboat dimensions

(1) On the other hand, 50-year traffic projections may require dual locks to handle the projected tonnage. If an auxiliary lock with smaller capacity (shorter length) than the main lock is provided, the auxiliary lock should have the same width as the main lock. This will allow the interchange of spare gates, emergency closures, maintenance bulkheads, and operating equipment between the two locks. In addition, the same width will handle the standard width tow configurations on the waterway but composed of fewer barges. As a further consideration, the smaller auxiliary lock can be used to handle most smaller tows and recreational craft, and the main lock can be used to handle the larger tows which should maximize the tonnage capacity of the lock project.

(2) If a navigation project is configured for dual locks of equal size, the alternatives for unseparated locks (sharing a common intermediate wall) and separated locks should be studied for operational efficiency, capacity, cost, and safety. The separated locks will allow placement of one or two spillway gates between the locks to provide flow between the locks to align navigation flows and to pass ice. Separated locks can provide improved traffic handling efficiency and greater capacity, since the tows can make simultaneous approaches and departures. The separated locks can provide for construction staging of cofferdams which could place one lock in operation at an earlier time. The disadvantages of separated locks are higher first cost and the requirement for site conditions

that will allow space in the river to site the wider structures. Nonseparated lock configurations that usually have a lower first cost may exhibit problems with crosswinds, crosscurrents, and other factors which can inhibit the simultaneous approach of tows headed in the same direction. This impairment can be improved by using approach walls of appropriate length and orientation, standby areas for tows, and various traffic control procedures (three up and three down procedures). If the site conditions warrant, then a study should be performed and reported for these alternatives.

h. Tandem locks. Tandem locks (locks or lock chambers placed in series) at a given facility will probably not be feasible for low lifts since much more time will be required for multiple lockages than for a single lockage. However, where the overall lift is extremely large (over 100 ft), tandem locks may be the feasible engineering alternative or the most economical choice. Engineering feasibility and cost studies for these alternatives should be performed to justify the installation of tandem locks.

i. Approach walls. The design of the lock approaches can have a significant impact on lock capacity, depending on the volume and bunching of traffic to be handled within a given time period. The purpose of approach walls is to align the approach currents parallel to the lock and to provide a smooth surface for the tows to land and guide on in order to make a parallel approach into the lock chamber. To achieve optimum lock approach conditions, measures must be provided such as controlling direction of current in the approach channel and providing maneuver room to allow for strong crosswinds. Without proper approach conditions, a tow, such as a string of empty barges affected by crosswinds, could take up to an hour to make a safe entrance from just a few hundred feet upstream of the lock.

3-5. Project Engineering Alternative Studies

a. Alternate studies. During the feasibility stage, alternate studies need to be performed and supplemented, if necessary, by more detailed analysis, design, verification, testing, and research and development during the feature design stage. Resources, budgets, and schedules for the alternative study plan need to be identified and included in the Project Management Plan. Examples of alternate studies may consist of the following considerations.

(1) Site selection studies. All feasible sites should be examined for addition of lock structures (or lock and dam structures). These alternative sites could consist of the addition of a lock to an existing project with rehabilitation of the remaining structure, complete replacement of the lock and dam at an alternate site, lock located landward of the existing lock, lock placed on the opposite dam abutment from the existing lock, or any other feasible alternative. Supporting documentation should consist of engineering feasibility studies, cost studies, and economic analysis.

(2) Cofferdam and diversion alternative studies. These studies should include type of cofferdam (earth, sheet pile, etc.), number of cofferdam stages, cofferdam heights, sequence of construction (locks first or dam first), river training works, effects on navigation, river diversion, by-pass canals, scour, deposition, lands, and damages.

(3) Lock configuration studies. These studies consider feasible alternatives for lock offset, location with respect to dam, and separation.

(4) Lock structure type and geometry studies. These studies include types of emergency and maintenance closure, high-level (over both lock and dam) or low-level (over dam only) service bridges, scour protection, type of filling and emptying system (side port, bottom longitudinal), ice management features, and type of lock structure (gravity, semigravity, U-Frame, W-Frame).

(5) Alternate lock foundation studies. These studies should determine the type of foundation for the locks, which include pile founded, soil founded, rock founded, and type of piles (steel H, pipe, concrete, reinforced concrete slurry walls, and others).

(6) Innovative construction. Designers should study innovative construction methods which may reduce project costs. These innovations may include use of precast components, float-in elements, and in-the-wet construction to eliminate cofferdams.

b. Cofferdam and diversion alternatives. Usually, a lock construction site is either located in an existing waterway channel, or it is exposed to flooding because of its proximity to the channel. Therefore, the waterway must be diverted away from or around the construction site either by an auxiliary waterway passage or through use of a cofferdam or by combining the two methods. The two principal considerations then are the method of diversion and the degree of protection against unplanned flooding of the site. Ideally, the chosen diversion method will be the most economical one that will satisfy the necessary engineering, environmental, and social considerations. The principal reference for cofferdam and diversion planning is ER 1110-2-8152. This reference attempts to address all of the concerns of the various disciplines and entities which have an interest in the cofferdam and diversion requirements. Also, this regulation has been supplemented by subordinate commanders to accommodate requirements unique to work in their divisions and/or districts.

(1) Diversion methods.

(a) Lock construction outside the waterway channel. Lock construction in a bendway out of the waterway channel is preferred over most other types of construction sites, particularly if the site under consideration is not in urban or environmentally sensitive areas. Since this type of site is not within the channel, diversion during construction is not required. With this site, the cofferdam requirements are basically those needed to protect the lock construction site from flooding when the waterway stages are above top bank. For lock construction outside of a waterway channel, a top bank site outside the channel is normally preferred. This preference applies particularly to locks on waterways that are made navigable for the first time and also applies to many replacement locks.

(b) Lock construction within the waterway channel. Despite the preference for lock construction outside the channel, conditions may dictate that the lock be constructed within the permanent waterway channel. For example, when the lock under construction is replacing an existing lock, when channel realignment is not feasible, or when relocation costs associated with alternative construction sites are prohibitive, then the channel site may become the recommended site. For this type of site, a cofferdam is required to protect the construction work through a wide range of possible waterway stages.

(c) Temporary flow and navigation diversion. In many instances, flow and navigation during construction can be handled within the existing channel. In the case where lock construction takes place within a cofferdam(s) located in the channel section, staged construction may be required. Staged construction does not restrict flow to such extent as to induce flooding upstream of the construction site or to create significant swellhead at the construction site; thus, it will maintain existing navigation on the lock. For example, in the case of Melvin Price Locks and Dam, a major portion of the dam was built in an early stage of construction so that the dam could be used to divert a portion of the Mississippi River flow during lock construction. Conceivably, a variation of the above-mentioned diversion schemes would be a temporary rerouting of flow (or portion of the flow) through another existing waterway or through a new channel excavated for the purpose of diverting flow. This scheme would allow the new lock to be generally oriented in the existing channel alignment and reduce the possible incidents of tow damage to the cofferdam that is constructed in the existing navigation channel.

(2) Cofferdam designs. Generally, if the lock can be built outside the waterway channel where a cofferdam of earthfill construction can be used, this type of design will achieve the greatest economy. Also, this location usually allows more of the lock construction work to be done in the dry and at a greater degree of economy than if at a location where a sheet-piling cell cofferdam is required. With a cellular cofferdam, phased construction may be used advantageously. In phased construction (see Plate 1), plans should be made to reuse sheet piling when the cells are to be relocated between phases and/or when the sheet piling can be used in other applications such as for approach wall support piers. Principles for cofferdam layout and design are included in ER 1110-2-8152 and EM 1110-2-2503.

3-6. Engineering Considerations

a. Hydrologic and hydraulic studies. To perform the structural layout and design of the navigation lock, hydrologic, hydraulic, and potomology data are needed to determine the hydraulic dimensions, elevations, scour protection, and river training works. Before the types and sizes of structures can be determined, detailed hydrologic and hydraulic data must be obtained. This information includes the following: records of maximum, minimum discharge volumes, stages, velocities, and continuous stage hydrographs; stage duration and stage frequency relationships; pool and tailwater stages, and pool regulation procedures; precipitation and runoff; and temperature and ice conditions. In addition, potomology information for scour, deposition, bed load, silt carrying characteristics, and water quality is needed. Other hydraulic information on surrounding infrastructure should encompass such details as banklines, railroad and highway profiles, bridge heights, sewer outlets, water intakes, and river regulating works. This information should be compiled in a usable manner through drawings, charts, and graphs by hydraulic engineers for use of the project team to determine the top of lock walls, sill, and chamber depths. The methods used to procure and process such information for hydrologic analysis are contained in the EM 1110-2-1400 series; the methods for hydraulic analysis are contained in the EM 1110-2-1600 series. Information for the hydraulic layout and design of navigation locks is contained in a

U.S. Army Engineer Waterways Experiment Station (WES) paper by Davis (1989).

b. Model studies. Physical model studies of the hydraulic and/or navigational characteristics of channels and dams, lock approaches, and lock filling and emptying systems are a traditional and necessary part of the planning and design for most navigation facilities. As more experience is gained and more accurate techniques are developed, mathematical models may be used more extensively than physical models in the future since mathematical model results are likely to be more economical and more quickly determined. Model studies are usually conducted in the planning and feasibility phases of project design. These studies should continue, if necessary, through the design phases to test design and construction alternatives. To limit the scope of model testing, the plan should use the model testing information covered in numerous WES publications and in design memoranda for many existing navigation projects to develop approximate project layouts and structure configurations. In addition to the more traditional model tests, model testing may need to be done for sediment transport in the channel and through the lock and for scour testing. Model testing is particularly important if the lock is to be constructed in a river that has a history of transporting large volumes of sediment and/or if the riverbanks have not been stabilized by revetment and other forms of canalization. Dredging requirements can be extensive and costly if the channel bed is not stable or if sediment transport cannot be managed by rock dikes and other types of channel structures. The cost of model studies varies depending on the area under study, characteristics of the streams, nature of the problem, and number of plans and alternate plans to be tested before an acceptable solution is developed. The cost of model studies has usually been less than 0.10 percent of the project cost.

c. Subsurface investigations.

(1) Comprehensive geological studies of the area should be conducted, and these studies should address the topography and geology of the area, the location and description of sites, the foundation conditions, and the foundation and seepage problems and their proposed treatment. As a part of these studies, geologic maps should be prepared to help uncover any subsurface conditions that may render a site unsuitable for a lock or any subsurface conditions that may require special considerations. EM 1110-1-1804 outlines the methods of exploration, their limitations, and the general procedure for subsurface investigations.

(2) Geophysical methods of subsurface exploration are a useful tool in the study of subsurface conditions. When applied properly with a full understanding of the limitations, such methods can be used to obtain accurate and reliable information for use in preliminary or reconnaissance studies. Detailed instructions, methods, and references are included in EM 1110-1-1802.

(3) In the planning and design of navigation locks, a geotechnical investigation is an essential step. A detailed discussion of investigation phases, exploratory methods, laboratory procedure, presentation of data, and similar requirements relating to geotechnical design is presented in the EM 1110-2-1900 series.

d. Foundation considerations. Before a project site is selected, the characteristics of the foundation materials should be studied at the possible lock locations. Usually, during the early stages of an investigation, the information should indicate the feasibility of project construction using ordinary design standards. After several possible sites are selected, the choice can be narrowed further through a foundation and navigation study. These studies should be followed by investigations of each remaining location to determine the final site.

e. Sediment transport. Most locks should be equipped with recesses to trap sediment; these recesses will prevent sediment accumulation from interfering with gate operations. In addition, the volume and distribution of sediment that may move through each waterway should be determined. If the waterway is rich in sediment, a number of permanent measures may be required to keep the sediment moving through the lock. These measures will prevent the necessity for frequent sediment removal by dredge or dragline. Usually, these measures will involve various procedures which make use of water jetting and air bubbler systems to dislodge and move the sediment. Experience gained from the Red River navigation project has shown that the channel cross section at the lock should be approximately the same as that of the natural river to facilitate sediment transport. Lock approaches in canals connected to rivers may have difficult sediment problems if a dam is not placed adjacent to the lock to assist in sediment transport.

f. Future expansion provision. Future expansion is usually limited to construction of an adjacent (or dual) lock. If studies indicate that traffic will increase sufficiently to warrant expanding locking capacity, a study should be conducted to determine if the "expanded" capacity can be justified in the initial construction. This study is necessary because the second lock will be less costly in the initial construction phase than at a later date. However, if only one lock will be constructed initially and if provisions for future construction are desired, the feasibility of such expansion should be verified within the framework of hydraulic and navigation model studies for the initial lock. Structural features which are subject to a high rate of deterioration, such as steel lock gates, are not normally included in the minimum provisions for future expansion.