CHAPTER 3

PROJECT PARAMETERS

Section I. Hydrology

3-1. General. Watershed hydrology is one of the first needs in developing a navigable waterway. The hydrologic conditions along the full waterway length will impact on the possible need for dams to establish reliable navigation. For instance, coastal regions, the Great Lakes, and the lower reaches of such major rivers as the Mississippi and Missouri are the only locations in the United States where existing depths or flows are adequate to maintain reliable navigation without dams. Hydrologic parameters also determine if the natural flows of the basin are adequate for continuous lock operations, or if supplemental supplies or special storage facilities will be required. Some navigation systems will traverse more than one river basin and require a hydrologic analysis of each basin. Basic hydrologic parameters for the design of all navigation dams are presented.

3-2. Basin Description. An understanding of certain physical features of a basin are necessary to properly evaluate the hydrologic and hydraulic functions. These physical features, as outlined below, are needed to determine the rainfall-runoff and the discharge-stage relationships of the basin.

a. The location, size, shape, and general topographic nature of basins.

b. The names, drainage patterns, and longitudinal slopes of the main-stem and major tributaries.

c. The stream geometry including meandering patterns, channel widths, bank-line heights, cross-section shapes, bed slopes, and information on the historic changes to these features.

d. The density of vegetation cover over the basin and the soil types with respect to porosity and erodibility. An indication of water table levels in that portion of the basin that could be affected by establishing permanent navigation pools.

e. The density of vegetation within the floodplain of the stream and the type and erodibility of materials compromising the bed and banks of the streams.

f. All lake, reservoir, flood control, water supply, levee, irrigation, or other water resource projects that have caused modifications to streamflow discharges or durations. The dates when these modifications began affecting the natural flows need to be identified for proper correlation with streamflow records.

3-3. Hydrologic Data. The hydrologic studies for a river basin identify the discharges which a dam structure-- located at any particular point within the basin--must be designed to control. Minimum, normal, and maximum discharges are all significant to the dam design. Furthermore, discharges must be determined that reflect not only existing basin conditions but also future basin conditions covering the economic life of the navigation system. For design purposes, stream discharges and stages at any site are commonly identified with respect to flow duration and exceedence frequency. The impacts of various flows on dam design are indicated.

a. Minimum Flows. These flows are essential to evaluate the quantity of water available for lock operations and for other potential project purposes such as water supply, low flow, hydropower, etc. Minimum available flows will also identify the possible need for water storage or water import facilities to meet project purposes. At sites with limited water supplies, special seals may be proposed on spillway gates or other dam features to minimize water leakage.

b. Normal Flows. Moderate or commonly recurring flood flows are needed to establish the elevation of various project features such as access roads, lock walls, operating decks, etc., and also project-related relocations and real estate requirements. Typical discharges used to determine the elevations include: the two percent duration flow, the 2-, 10-, 50- and 100-year interval flood flows, and the standard project flood (SPF).

c. Maximum Flows. The maximum experienced flood of record is determined for each project, but the dam should generally be designed with adequate capacity to pass the probable maximum flood (PMF). Passage of this discharge may be exclusively through a gated spillway, but a portion could pass over the lock, the esplanade, and overflow weirs or embankments extending across the waterway overbanks.

Chouteau Lock and Dam is a typical navigation structure located on the McClellan-Kerr Arkansas River Navigation System. The pertinent discharge and stage data for this project is presented in Figure 3-1.

3-4. Hydrologic Data Sources. The records resulting from field measurements of both streamflows and climatological parameters such as rainfall, snowfall, evaporation rates, humidity, wind, and temperature are the basic source of needed hydrologic data. Streamflow records provide the simplest and most direct means of determining needed discharge data. However, streamflow recording stations are limited in number, often cover too short a time period, and occasionally are not reliable enough to provide all the flow information required for dam design. The normal procedure for obtaining the required supplemental data is to simulate flows from climatological data. In the United States, the sources of basic hydrologic data are as follows:

a. Streamflow Records. Most streamflow data within the United States are measured and recorded by the United States Geologic Survey (USGS) of the Department of the Interior. Occasionally, records are maintained by other agencies such as the Corps of Engineers, Soil Conservation Service, National Forest Service, various state agencies, and local municipalities. USGS records are published in convenient annual reports covering all gages maintained within a specified state.

b. Climatological Records. In the United States, climatological data

McClellan-Kerr Arkansas River Navigation System
CHOUTEAU LOCK AND DAM, VERDIGRIS RIVER, OKLAHOMA

From Design Memorandum No. 1, General Design

PERTINENT DATA

GENERAL

Purpose of project	Navigation
Location of lock	3,400 feet east river mile 8.5
Location of dam, river mile	9.6
Upper pool elevation, feet	511.0
Normal lower pool elevation, feet	490.0
Minimum lower pool elevation, feet	487.0

STREAMFLOW AT DAM SITE, cfs

Estimated maximum flood of record (1943)	224,000
Maximum modified flood of record	122,200
5-year recurrence interval flood, modified	50,000
10-year recurrence interval flood, modified	65,000
50-year recurrence interval flood, modified	126,000
Modified standard project flood	155,000
Discharge, 50 percent of time	620
Average flow	4,096
Minimum modified flow	230
Navigation design flood	65,000
Project design flood	155,000
Discharge, 2 percent of time	34,000

FLOOD DATA AT DAM SITE (TAILWATER ELEVATION, FEET)

Estimated maximum river stage (1943)	529
Maximum modified flood of record	526.3
5-year recurrence interval stage, modified	515.8
10-year recurrence interval stage, modified	519.0
50-year recurrence interval stage, modified	526.6
Modified standard project flood	529.3
Discharge, 2 percent of time	510.7
Discharge, 50 percent of time	491.4
Average flow	496.0
Minimum modified flow	490.5
Navigation design flood	518.5
Project design flood	529.3

Figure 3-1. Pertinent hydrologic data for a typical navigation dam project

such as precipitation, evaporation, wind speed, temperature, etc., are archived in various formats by the National Oceanic and Atmospheric Administration (NOAA), a unit of the US Department of Commerce. These data can be retrieved from annual reports or by magnetic tape from the NOAA data base. Most studies that have limited streamflow records utilize synthetic single storm events to determine flood frequencies. The general depth-area-duration rainfall data required for these computations are published by NOAA.

3-5. Hydrologic Model. For effective use in dam design, climatological data must be converted into streamflow data. This is normally accomplished by developing a math model to simulate the hydrologic response of the proposed project basin. A number of effective models have been developed, but the one most commonly used is Computer Program 723-X6-L2010, "Flood Hydrograph Package." This model, commonly called HEC-1, was developed and is maintained by the Hydrologic Engineering Center (HEC) located in Davis, California. The three main steps in developing an HEC-1 model for a specific project site are summarized.

a. Rainfall-Runoff. The HEC-1 model needs to represent the rainfall-runoff relationship at any particular location in the basin. This relationship is based on developing one or more unit hydrographs for that location within the basin. EM 1110-2-1405 provides guidance in unit hydrograph development.

b. Routing and Combining. The HEC-1 model is then used to route runoff from the various parts of the basin and combine them to establish flow conditions at the project location. General guidance for flood routing is contained in EM 1110-2-1408.

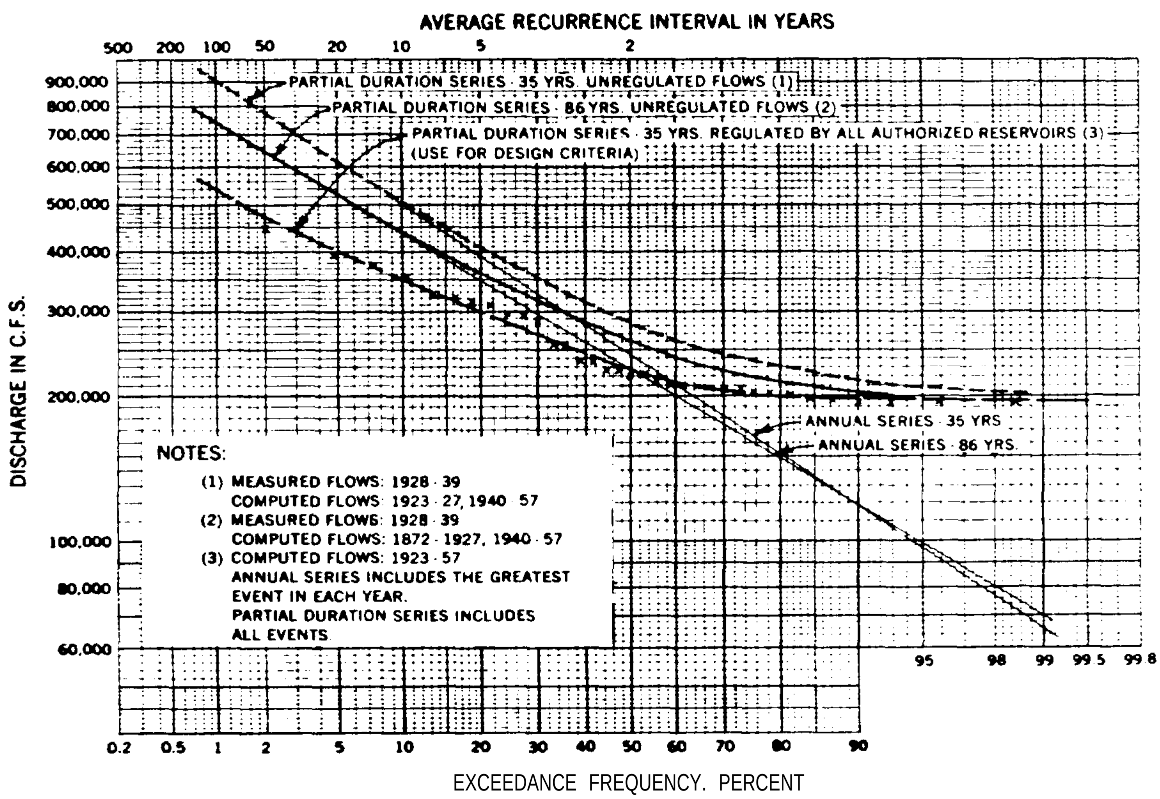
c. Calibration. Verification of the HEC-1 model requires an analysis of most of the experienced storms on the basin for which resulting flood hydrographs are known. Experienced rainfalls are applied to the model and the computed flood flows are compared with the experienced flood hydrographs. From several such tests, adjustments are made to the unit hydrographs, routing criteria, rainfall, and infiltration data within the model until a reasonable reproduction of all experienced flood hydrographs is obtained.

3-6. Flow Computations. Establishing a navigation system through a basin will usually affect the hydrology of the basin. Consequently, both existing and postproject conditions must be determined. Basic hydrologic computations required for all studies include the following.

a. Probable Maximum Flood (PMF). This hypothetical event represents the flood resulting from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible to occur in a region. The National Weather Service has identified the Probable Maximum Storm (PMS) upon which the PMF is based for all regions of the US. The precipitation data for these storms are contained in a series of regionally oriented Hydrometeorological Reports (HMR's). For any particular project, the PMF discharges are determined by inputting the PMS rainfall data into the adopted HEC-1 model for the project.

b. Standard Project Flood (SPF). As identified in EM 1110-2-1411, the SPF is runoff resulting from the Standard Project Storm (SPS)--the rainfall representing the most severe storm that is considered reasonably characteristic of the region in which the drainage basin is located. The EM provides the necessary guidance for developing this storm. For very large watersheds which are beyond the scope of EM 1110-2-1411, the SPS is frequently estimated to be half of the PMS as determined above.

c. Flood Frequencies. The designs of many dam features are based on the frequency of floods at the project site. Flood frequencies are identified as the time in years between which a particular flood discharge is likely to recur. For instance, a 50-year recurrence interval flood discharge would have an average time interval of 50 years between occurrence of a given or greater magnitude discharge. It would have a 2 percent chance of being equaled or exceeded in any one year. A typical discharge-frequency curve is shown in Figure 3-2.



LOCK AND DAM NO. 7
FREQUENCY OF PEAK DISCHARGES AT LITTLE ROCK

Figure 3-2. Typical discharge-frequency curve used in the design of Murray Lock and Dam, Arkansas River, Arkansas

d. <u>Flow Duration.</u> Lesser project flows are commonly expressed with respect to their duration--the percent of time that a particular discharge is equaled or exceeded. Discharge-duration curves are determined from the total period of flow data records. These records are also used to determine existing minimum flow conditions. A typical stage-duration curve as derived from the discharge-duration and discharge rating curves for Murray Lock and Dam is shown in Figure 3-3.

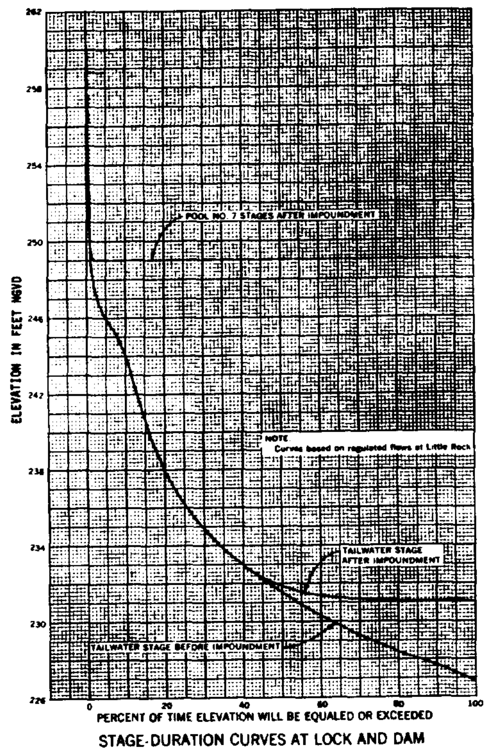


Figure 3-3. Typical stage-duration curve for Murray Lock and Dam, Arkansas River, Arkansas

Section II. Hydraulics

3-7. <u>General.</u> Hydraulic studies for navigation dam design generally cover two distinct phases. One phase is establishing the stage-discharge relationship over the entire area affected by the proposed project under both existing and postproject conditions. The studies in this phase coordinate closely with the hydrologic studies. They establish stage-discharge relationships both at specific sites and over extended river or channel reaches affected by the project. The second phase of hydraulic studies involves the design of dams and other structures--their type, shape, size, and siting to assure satisfactory hydraulic performance. These second phase studies are covered in CHAPTER 5. The required stage-discharge studies presented here cover channel discharge rating curves, water-surface profiles, and establishment of navigation pool elevations.

3-8. Channel Discharge Rating Curves. Stage-discharge relationships are required to initiate water-surface profile computations and also to establish the tailwater conditions for the hydraulic design of dams and their spillway structures. The basic source of discharge rating curves is stage-discharge records collected at stream-gaging stations. These stations are located at relatively fixed stream cross sections such as bridge openings or weir structures where the stage-discharge relationships will stay relatively fixed with time. Most existing stream-gaging stations are established and operated by the USGS. However, existing station locations are limited and establishing new stations for specific projects may be advisable.

a. Stream Changes. Existing rating curves can be determined directly from stream records. However, these curves are affected by project-related changes to the downstream channel alignments, cross sections, channel stabilization measures, and established navigation pools. Postproject or future condition rating curves must reflect these changes. The effects of these changes can only be estimated until the project design has been finalized, so the postproject rating curves are generally adjusted and refined throughout the project design process. See paragraph 5-7 for factors that can affect tailwater rating curves.

b. Backwater Effects. Occasionally, channel rating curves under both existing and postproject conditions are affected by backwater effects from downstream receiving rivers, major tributaries, lakes, or bays. In such instances, channel stages cannot be related to a specific stream discharge. For any specific channel discharge, the water level would vary over a range of stages depending on the downstream backwater stages. The specific rating curve application will determine if a low, high, or average backwater stage should be considered. A study of experienced coincident discharge and stage conditions can be helpful in selecting appropriate backwater conditions.

3-9. Water-Surface Profiles. A key tool in the development of a navigation system through a drainage basin is the model used to calculate water-surface profiles for both existing and postproject conditions. By comparing the two profiles over a wide range of the discharges, the hydraulic impacts of establishing various dam locations and navigation pool elevations can be evaluated. The preproject and postproject profiles are also needed to evaluate the effects on flood heights, relocation requirements within the pool length, and flooding effects on adjacent real estate.

a. Computation Procedures. Navigation projects are located on or along streams that flow within the subcritical range. Development of a basin specific computer model for calculating standard backwater computations is the normal method for determining water-surface profiles. The most common computer program for conducting water-surface profiles is HEC-2. Information on the theoretical basis, latest version, and operating instructions for HEC-2 can be obtained from HEC, the model developer. Basic guidance for operating HEC-2 is provided in EM 1110-2-1409. Other satisfactory backwater programs have been developed for specific projects. For instance, the Arkansas River profiles were computed with the LRD-1 program. This program was developed for handling flood flows that spread over broad overbank areas containing both cleared and heavily wooded areas. However, the HEC-2 program is the most common one used to compute water-surface profiles.

b. Multiple Computations. During floods when water levels are well over the riverbanks, flow patterns can become very complex. Man-made obstructions such as transportation embankments, levees, building developments, dams, etc., or even natural features such as swales, cutoffs, or divided channels can require multiple backwater runs through the study reach to properly identify water profiles. In some complex study reaches, development of a hydrodynamic (unsteady or multidimensional) math model as an alternative to standard backwater computations may be advisable. WES or HEC personnel can advise users on available hydrodynamic models.

c. Profile Plots. Plotting existing and postproject water-surface profiles over a complete navigation system can be a major undertaking. Many HEC-2 users have developed computer graphics programs for accomplishing this task. Information on many of these programs, both locally available and remotely accessible, can be obtained from HEC.

3-10. Specific Profile Uses. Following are descriptions of some of the most common uses of water-surface profiles in navigation dam design.

a. Real Estate. The extent of lands acquired under fee-simple purchase or under easement rights purchase are based on envelope curves which directly compare preproject with postproject water-surface profiles.

b. Relocations. Highway and railroad embankments, bridges, overhead utility crossings, flood protection levees, drainage structures, and a multitude of riverside facilities such as water and sewage treatment plants, pumping stations, parks, and industrial and residential areas are all affected by floodwaters when a navigation pool is established. Alteration, protection, or relocation of all these facilities are based on the water-surface profiles.

c. Lock and Dam Features. The elevations of a number of structural features are determined from water-surface profiles. For example, on the Arkansas River navigation system the channel was anticipated to be navigable for flows up to the lo-year recurrence interval flood. Flow velocities at larger floods were expected to be too high for safe or efficient operation of most tows. Consequently, the top of lock walls and the esplanade areas were set at the higher of 10 feet above the navigation pool or two feet above the IO-year recurrence interval flood. Access roads were set at the lo-year recurrence interval flood. Other feature elevations were similarly dependent on the profiles.

d. Groundwater Table. Permanently establishing navigation pools at elevations near the top of riverbanks may cause significant changes to the water table levels on adjacent lands. Saturated soils can adversely affect or destroy the productivity of farmlands. Established land drainage facilities can loose their efficiency by reduction of the hydraulic heads between the fields or ditches and the river. A special study of water table changes resulting from proposed navigation pools may be necessary. Such a study was conducted by the USGS along reaches of the Arkansas River. The study included an inventory of over 1,500 existing wells, installing and periodic reading of an additional 1,500 wells, 27 pumping tests, numerous aquifer sample tests, and geologic mapping. The study covered the affected lands in each proposed pool. It led to shifting of some project sites to minimize adverse drainage problems. Study results are summarized in item 29.

3-11. Navigation Pool Level Stability. In addition to the flooding impacts of an established navigation pool elevation, consideration should be given to the operational stability of the selected pool. A navigation dam should provide a fixed pool elevation with as little stage variation as possible. Attainment of this goal best promotes reliability and growth in waterway traffic and also simplifies development of port facilities. A number of factors that have an effect on pool stability need to be considered.

a. Project Purposes. Pool stability for any navigation dam can best be maintained by eliminating or minimizing those project purposes that require water storage within navigation pools. To the extent possible, project purposes requiring storage should be located in headwater or tributary projects to the navigation channel. If included in navigation dams, the water requirements should be restricted to amounts less than the minimum inflows into each pool minus that amount required for navigation lockage and dam leakage. Recreation purposes normally are enhanced by stable pools. Many navigation pools do include hydroelectric power plants. To minimize pool fluctuations, they should be operated as run-of-river plants with allowable pool fluctuations limited to three feet or less. Allowable tailwater fluctuations should be established. Rates of change in pool and tailwater elevations should also be considered.

b. Dam Head. Stable navigation pools are more easily maintained with high-head rather than low-head dams. This is because high pools are less frequently affected by flood stages--particularly in the downstream portion of the pools. However, existing developments are so extensive in many reaches of those rivers which can economically justify navigation projects that low-head dams with pool levels contained within the riverbanks are usually mandated. In such instances, stable pools can best be maintained with dams that have high capacity spillways which minimize upper and lower pool head differentials during flood conditions. Both high- and low-head dams are common on navigation projects located throughout the United States.

Section III. Sedimentation

3-12. General, Sedimentation problems should be grouped into two main categories: (a) local scour and deposition problems and (b) general degradation and aggradation problems. The first is controlled or influenced primarily by the hydraulic design of the project structures. The second is the result of the stream's response to changes in the discharge hydrograph and sediment transport caused by the proposed navigation projects. Each of these problem areas should be reported separately. State the refinements, if any, for subsequent sedimentation studies and the impact of either more or less sediment on project performance. General information and guidance about sedimentation is obtained in EM 1110-2-4000.

3-13. Problems.

a. Alluvial rivers tend to establish an equilibrium between the water and sediment loads imposed upon them. Any significant modifications to the system (realignments, lock and dams, etc.) will disrupt this balance and a period of adjustment will occur as the stream attempts to reestablish a new state of equilibrium. During this period of adjustment, sediment-related problems are increased. Development of a river system for navigation involves the construction of several major work components such as locks and dams, bank stabilization, reservoirs, and realignments. The impacts of each of these components of work can be assessed individually. However, the ultimate response depends on how the system integrates these individual impacts in an effort to attain a new equilibrium state. Because of this complexity it is difficult and sometimes dangerous to develop definite rules or trends that apply to all navigation projects. Design criteria and techniques that have been successful on one river system may not be feasible on another system which has different hydrologic or geomorphic characteristics.

b. Sediment problems are generally more difficult to predict for low-head navigation dams than for high-head dams. Common problems associated with high-head dams are aggradation in the upper pool followed by degradation of the downstream channel. Low-head dams generally follow somewhat different trends, since they are designed to allow open-river conditions during the high-flow periods when the majority of sediment is transported. Special care must be taken to ensure that open-river flows occur frequently enough so that the existing sediment transport regime is not significantly altered.

3-14. Sediment Data Needs. Knowledge of sediment transport, in terms of both quantity and quality, is essential for design of river engineering works on alluvial streams. The primary sediment problems associated with navigation systems are related to deposition in navigation pools, degradation below dams, and streambank erosion. In order to assess these problems, certain basic data must be available. These basic data should include suspended sediment samples, bed-load samples (if possible), bed material samples, and borings in the streambed and banks. Sampling stations should not be restricted to the limits of the navigation project but should include upstream and downstream reaches, as well as major tributaries.

3-15. Sedimentation Study. Potential sediment problems may be minimized and in some cases eliminated by conducting a detailed sedimentation study of the entire stream system. As one component of a comprehensive geomorphic analysis the sedimentation study is aimed at developing an improved understanding of the significant sedimentation processes within the basin. The major emphasis of this type study should be on analyzing the channel morphology and sedimentation phenomenon during the historic period, although long-term system changes are also considered. As a minimum the sedimentation study should document the variations in sediment transport (size and quantity), identify all major sources of sediments (bed and banks, tributaries, etc.), locate degrading, aggrading, and stable reaches, and establish the range of flows transporting the majority of sediments. Correlating the results of the sedimentation study with historical changes in the basin (channel improvements, land use, reservoirs, etc.) enables the engineer to develop a firm understanding of past and present sedimentation processes. With this information the effects of anticipated project features can be analyzed qualitatively. A qualitative analysis of this nature is essential for the development of and interpretation of results from sediment transport models.

3-16. Analysis Tools. A number of methods are available to design engineers to analyze sedimentation problems associated with the design and operation of navigation projects. These tools include numerical models, physical models, and analysis of prototype data. Prior to use of any of these tools, the designer should have developed an understanding of the existing sediment regime of the planned navigation system. The methods for establishing baseline sediment study were discussed in paragraph 3-15 of this section. Also prior to the development of either numerical or physical models, the designer should have a knowledge of the expected sedimentation changes as a result of altering the river system. This knowledge should help the design engineer in selection of model to be used, study limits for the model, and estimating the cost of the model study. The first analysis tool used by the engineer designing the navigation projects should be review of sedimentation control methods that have been used on other navigation projects. Sediment control measures have been used on a number of rivers in the US including the Missouri, Ohio, Mississippi, Arkansas, Ouachita, Red, and Black Warrior Rivers. A review of what has worked and more important what has not worked as a means of controlling and reducing sediment problems on these rivers will provide the designer of a new navigation system with a basis for developing solutions to sediment problems that develop during the model studies. The following tools are available for the detailed studies. It should be emphasized that tools listed below, whether they be numerical or physical in character, have all been successfully applied to navigation sedimentation problems and if correctly applied using good engineering judgment will provide reliable guidance in selections of sediment control measures.

a. The first model the engineer should consider for analyzing sedimentation problems is "Scour and Deposition in Rivers and Reservoirs," (HEC-6) developed by the HEC (item 28). HEC-6 is a one-dimensional flow model that can be used to analyze scour and deposition in both rivers and reservoirs. The program is very useful in determining long-term trends of scour and deposition in a stream channel and can be used to determine degradation that can be expected downstream of dams. Downstream degradation of the channel bed can be a significant problem in areas downstream of high-lift locks and dams. Deposition in navigation channels and lock approaches is usually a problem in low-lift and run of river projects. HEC-6 is useful in the initial studies associated with navigation project because of its ability to provide the location and volumes of deposition that can be expected with a navigation project. Locations and volumes of deposition can be used to estimate the amount of maintenance dredging that can be expected. Although one-dimensional models will point out locations and volumes of deposition, more detailed physical models and/or two-dimensional numerical model studies will most likely be needed to develop alternative methods of reducing or eliminating maintenance dredging. HEC-6 can also be used to study sedimentation problems that can be expected during floods and the effect dredging depth has on the rate of deposition. Detailed discussion of the input data for HEC-6 can be found in the user manual for HEC-6 and can be obtained from the HEC; briefly the data needs are geometric, sediment, hydrologic, and operational data. Of the models to be discussed in this section, HEC-6 will usually be most useful in the initial studies of the proposed system and are the only models that can address the entire system at one time, HEC-6 is not designed to model hydraulic structures in great detail and the user should not try to use HEC-6 in areas where the one-dimensional flow assumptions do not apply.

b. If it is determined that HEC-6 cannot adequately provide solutions to sediment problems, the TABS-2 modeling system can be used (item 25). A word of caution at this time is necessary in that when you decide to apply the TABS-2 system, everything involved gets bigger. The data required to do the modeling increase, the computer cost increases, and the level of expertise required to apply the model increases. TABS-2 is a generalized numerical modeling system for open-channel flows, sedimentation, and constituent transport. It consists of more than 40 computer programs to perform modeling and related tasks. The major modeling components--RMA-2V, STUDH, and RMA-4--calculate two-dimensional, depth-averaged flows; sedimentation; and dispersive transport, respectively. The other programs in the system perform digitizing, mesh generation, data management, graphical display, output analysis, and model interfacing tasks. Utilities include file management and automatic generation of computer job control instructions. TABS-2 has been applied to a variety of waterways, including rivers, estuaries, bays, and marshes. The TABS-2 model can be used to analyze scour and deposition problems associated with navigation structures, locks and dams, dikes, and approach and exit channels. TABS-2 is also a useful tool in lock site studies. If there are a number of possible sites to place a proposed lock and dam, the TABS-2 system can be used to determine the possible scour and deposition problems associated with each site and to evaluate preventive measures necessary to prevent sediment problems. Because of cost and data requirements, the TABS-2 model limits should be limited to area of concern and not used to model long reaches of river. Long reaches of river can be modeled more efficiently using HEC-6. The TABS-2 model is also a useful tool in the initial analysis of alternative methods of reducing sediment problems before construction and testing of physical models. Other sediment models are available, one of which is a stream tube model used to determine scour and fill trends in an alluvial stream. St. Louis District has applied the model to navigation dams, cofferdams, and other related structures,

c. Before beginning the detailed design of a proposed navigation project, a movable-bed physical model study should be considered. The cost of the model study is small when compared with the total engineering design and construction cost of a navigation project, and results of physical model study are often useful in verifying the design developed in numerical model studies and in providing guidance for design of the overall project. Each lock and dam should be physically modeled with a movable-bed prior to detailed design; if the project requires major channel realignment a typical reach model should also be considered.

3-17. Sediment Control Measures. A number of methods for controlling sediment problems are associated with navigation projects. These methods of sediment control involve the management of sediment problems at an isolated location, and source reduction of sediment either by bank stabilization or an upstream reservoir. Control of sediment problems at isolated locations involve such things as dikes, bank stabilization, and structural modifications to the lock and dam. Controlling the source of sediment must be carefully analyzed to ensure that the control does not have adverse impacts upstream or downstream of the project. The reduction of upstream sediment source does not in itself imply overall reduction of sediment problems. In areas where no sediment source is obvious, measures such as covering the sediment source with polyethylene filter cloth should be considered. Bank stabilization methods can be found in numerous reports and design documents for the Arkansas and Red Rivers and good literary review can be found in Section 32 Bank Stabilization Report (Item 26). When considering an upstream reservoir as a method for reducing sediment inflows, the need for grade control in the channel downstream of the reservoir should also be considered. This review of grade control structures should also include tributaries to main channels that might be subject to degradation resulting from the construction of upstream reservoirs.

Section IV. Ice Conditions

3-18. General. The prediction of extent and duration of ice conditions at navigation dams is necessary to allow development of ice control methods. The extent of ice problems can be determined by review of historical records and monitoring the site conditions during the study. EM 1110-2-1612 provides methods of estimating ice growth and duration using winter air temperatures.