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	Engineering and Design HYDRAULIC DESIGN OF SHALLOW DRAFT NAVIGATION PROJECTS	
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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
CECW-EH Washington, DC 20314-1000

Regulation
No. 1110-2-1458

30 April 1998

Engineering and Design
HYDRAULIC DESIGN OF SHALLOW DRAFT NAVIGATION PROJECTS

1. Purpose

This regulation prescribes the policy and design procedures for development of a new or replacement of an existing shallow draft navigation project. Shallow draft navigation refers to commercial barge traffic. Detailed design guidance is contained in the references listed in paragraph 3.

2. Application

This regulation applies to all USACE Commands having civil works responsibilities.

3. References

a. ER 1105-2-100, Guidance for Conducting Civil Works Planning Studies.

b. ER 1110-2-1403, Studies by Corps Hydraulics and Hydrologic Facilities and Others.

c. EM 1110-2-1003, Hydrographic Surveying

d. EM 1110-2-1604, Hydraulic Design of Navigation Locks.

e. EM 1110-2-1605, Hydraulic Design of Navigation Dams.

f. EM 1110-2-1611, Layout and Design of Shallow-Draft Waterways.

g. EM 1110-2-1612, Ice Engineering.

h. EM 1110-2-5025, Dredging and Dredged Material Disposal.

4. Distribution Statement

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5. Policy

The hydraulic design of a shallow draft navigation project must result in a safe, efficient, reliable, and cost-effective project with appropriate consideration of environmental and social aspects. A satisfactory design must cover portions and/or extensions of the following elements to the degree appropriate as the design progresses through the various stages of project development:

a. Safety - minimize potential hazards to humans and property, avoid creation of a false sense of security, and identify consequences of storm intensities, river stages, etc., exceeding selected design conditions.

b. Efficiency - select channel dimensions and alignment and lock and dam configuration to optimize degree of protection, operation, and maintenance.

This regulation supersedes ER 1110-2-1458, dated 5 Aug 85.

c. Reliability - provide the ability to achieve project purposes throughout the project economic life and the proper functioning of features such as channels, river training structures, and locks and dams.

d. Cost effectiveness - minimize initial, operational, maintenance, and replacement cost on an annual cost basis.

e. Environmental aspects - avoid or minimize adverse ecological impacts, provide initial beautification efforts, and mitigate significant adverse impacts.

f. Social aspects - provide low cost shipping rates, increase recreational opportunities, maintain community cohesion, preserve historic and cultural sites, and improve aesthetics.

6. Project Elements

The major elements of a shallow draft navigation project and the responsible agency are listed as follows:

• Locks	CE
• Dams	CE
• Powerhouse	CE or LG
• Channels	CE
• River training structures	CE
• Special features (ice control, bridge pier protection, etc.)	CE
• Turning basins	CE
• Aids to navigation	USCG
• Recreation	CE or LG
• Fleeting areas	LG
• Port facilities	LG

where:

CE = U.S. Army Corps of Engineers

LG = Local Government

USCG = U.S. Coast Guard

7. Project Design Process

a. Study plan. The initial step in the hydraulic design process is to develop a study plan in support of the design effort. This plan will indicate the time, manpower, cost, and scheduled completion of the various design studies to be performed as the design progresses through the various stages of project development. Careful consideration of the type and complexity of the hydraulic design studies, data acquisition, and phasing of this effort with other ongoing project development efforts is necessary (see Appendix A). Coordination with other disciplines to ensure the timely availability, format, and adequacy of the hydraulic design technical information inputs to and outputs from the hydraulic design studies is essential. Physical and mathematical model studies (ER 1110-2-1403) should be provided for early in the study plan, when they are needed. The hydraulic design study plan must be flexible and be able to adjust to changes in the project development and other circumstances.

b. Alternative designs. Alternative design comparisons should be made on an annual cost basis. Alternative designs are to be studied and presented in sufficient detail to provide a valid basis for plan comparison and plan selection. Cost and benefit estimates should be appropriate to the stage of project development.

c. Environmental studies. Environmental studies are needed early in the design process so adverse impacts can be identified and avoided or minimized. In some instances, environmental benefits may warrant including an environmental restoration feature in the project.

8. Hydraulic Design Presentation

a. Hydraulic design studies. The hydraulic design presentation portion of all reports prepared for decision or information will contain sufficient detail to allow an independent assessment as to the soundness of the report conclusions and recommendations. The accuracy of hydraulic design studies (computations, physical and mathematical modeling, etc.) is dependent on the accuracy of input data and the degree to which the analytical procedure is representative of the hydraulic phenomena. The effects of uncertainty should be demonstrated by risk analysis procedures for the significant design elements involved. The hydraulic design presentation will normally discuss the following subjects. These conditions are used to optimize stilling basin length and downstream scour protection thickness, size, and length.

(1) Water levels. The range of water level stages is needed. Water level parameters are stage, frequency, duration, and short-term fluctuation amplitude (range of certainty). Water levels can be affected by storm surges, seiches, river discharges, natural lake fluctuations, reservoir storage limits, and ocean tides. High water levels are used for determining dam and lock wall heights. Low water levels are used to determine channel depth, lock floor and sill elevations, and lower limit for environmental impact studies. Intermediate levels are used to select normal operating conditions.

(2) Waves. The naturally occurring waves and vessel-generated waves require analysis and prediction. Wave height, period, direction, and duration are needed to design suitable bank protection works, set dam and lock wall heights, and provide design loads for gates.

(3) Currents. Currents can be density, tidal, river, or seiche induced. Prediction of current strength and duration is needed for selection of the design conditions.

(4) Channel shoaling. Channel shoaling estimates are needed to develop maintenance dredging volumes and costs. The river sediment budget will identify sediment sources, volumes moved, and sinks. This river budget will indicate the extremes and expected volumes of shoaling in channels and lock approaches. Movable bed physical models and/or mathematical models are usually needed to refine shoaling estimates (EM 1110-2-1611).

(5) Design vessels. The design vessels are selected from comprehensive studies of the fleet expected to use the project during its design life. The design vessels are identified by their dimensions and maneuverability. EM 1110-2-1611 lists barge and towboat sizes used in U.S. waterways. Consultation with the Corps' Institute for Water Resources is recommended for estimating the future fleet composition. Historic fleet composition may be obtained from the Corps' Navigation Data Center.

(6) Channel width. A rational design is needed to allow safe and efficient transit of the vessels expected to use the project (EM 1110-2-1611). Factors to be considered are:

- Vessel size.
- Vessel maneuverability.
- Traffic congestion.
- Effects of wind, waves, and currents.
- Bend and approach configurations.

(7) Channel depth. Channels in existing rivers must be consistent with connecting channel depths. Normal water depth in confined canals is to be at least 25 percent greater than the design vessel draft. Additional depth can be provided for advanced maintenance dredging, which includes an allowance for inaccuracies in depth measurements during dredging operations (EM 1110-2-1611).

(8) Channel alignment. Channels will usually follow the natural river course. This

alignment usually requires the least initial construction dredging. Movable bed physical models and/or mathematical models will estimate shoaling rates for various channel alignments. Fixed bed physical models with radio-controlled vessels or ship simulator studies will assess the transit safety of alternative alignments (EM 1110-2-1611).

(9) Lock and dam layout. The lock and dam layout will provide safe vessel transit through the range of river conditions expected during the navigation season. The design should allow a down bound tow to lose power in the upper approach and have the river currents float the tow safely behind the upstream lock guard wall. A general physical model or ship simulator study will be used to optimize the lock and dam layout (EM 1110-2-1611).

(10) Lock design. Locks are to be designed for safe and rapid filling and emptying. Locks for barges are to have hawser loads at 4536 kg (5 tons) or less. Hawser loads for ships can exceed this 4536-kg (5-ton) limit; however, they must remain in a safe range for the lock mooring facilities. Physical model studies are needed to determine hawser loads. Standard lock sizes listed in EM 1110-2-1611 will be used. Lock floor elevations are set for safe and rapid filling with acceptable hawser loads. Lower lock sills will be as low as possible (0 to 0.9 m (0 to 3 ft) above floor) to allow safe and rapid tow entry and exit. The upper sill will have the same or greater clearance as the lower sill (EM 1110-2-1604 and EM 1110-2-1611).

(11) Dam design. Navigation dams are designed to maintain a constant upper pool as long as conditions will permit and to pass flows with an acceptable backwater effect. The magnitude of backwater is determined through a cost-effectiveness analysis. This analysis considers several spillway lengths and overflow weir lengths with the shorter lengths causing higher upstream backwater elevations. The minimum cost layout including upstream costs and damages from higher backwater, will be the most cost effective. A restriction on the least cost layout is to provide a minimum number of spillway gates based on operational flexibility, particularly when one or more gates are non-operational for maintenance or repair. The minimum number of gates will be determined by economic analysis, experience, and engineering judgment (EM 1110-2-1605 and EM 1110-2-1611). Stilling basins and downstream scour protection will be designed for the following conditions:

- Uniform discharge through all spillway gates for a range of headwaters and tailwaters expected during project life.

- Single gate (each gate studied separately) full open with normal headwater and minimum tailwater. This condition would assume incorrect gate operation. Minor damage to the downstream scour protection is acceptable as long as the integrity of the structure is not jeopardized. Single gate full open with above normal pool should also be considered. This would simulate several gates blocked by loose barges.

- Single gate (each gate studied separately) open sufficiently wide to pass floating ice or drift at normal headwaters and minimum tailwater. No damage is acceptable for this condition.

b. Physical model studies. Physical model studies are needed to verify the final design.

(1) Powerhouse. Hydropower installations at new or existing navigation dams must be sited and operated so that adverse impact on navigation is minimized. Physical model studies are usually needed to select optimum powerhouse location and operation and determine necessary flow control structures (EM 1110-2-1611).

(2) River training structures. River training structures are usually needed in erodible rivers to maintain channel dimensions and alignment.

Movable bed physical models are needed to verify layouts (EM 1110-2-1611).

(3) Relocations. Most shallow draft navigation projects will require some relocations. These relocations can be roads, towns, bridges, railroads, utilities, pipeline crossings, etc. These relocations must be identified and costs estimated for various lock and dam layouts and channel alignments.

(4) Ice control measures. Ice control measures are to be used to optimize use of shallow draft waterways (EM 1110-2-1611 and EM 1110-2-1612).

(5) Dredging and disposal. When dredging is required, a study is needed to identify the dredging and disposal methods and short- and long-term disposal effects. Beneficial uses of dredged material need to be evaluated. The type of dredge equipment is to be assessed to ensure it is capable of operating in the shallow project dimensions usually selected for shallow-draft projects (EM 1110-2-1611 and EM 1110-2-5025).

(6) Environmental and social impact. The project designers should strive to create an environmentally and socially compatible project that eliminates or minimizes adverse impacts. This requires early determination of potential impacts and close coordination between the designer and environmental specialists during assessment of alternative designs. In some cases the opportunity to generate substantial environmental benefit may warrant the inclusion of an environmental restoration feature in the project. Determination of environmental and social impacts is needed to justify mitigation measures (EM 1110-2-1611).

(7) Physical model and tow simulator studies. These studies (ER 1110-2-1403 and EM 1110-2-1611) are to:

- Optimize spillway and stilling basin designs for operation under the various conditions listed in paragraph 8*a*(11) (fixed bed physical model).
- Optimize the navigation conditions in lock approaches: best arrangement of locks, dam and training structures; movement of ice and debris; and conditions during construction (comprehensive fixed bed physical model).
- Determine the effects of structures on movement of sediment, channel development in lock approaches and in critical reaches, and scour considerations with various cofferdam plans (comprehensive movable bed physical model).
- Determine conditions at other locations as needed such as harbor entrances, docking and assembly areas, and at bridges (fixed or movable bed physical model or vessel simulator).
- Optimize channel dimensions (vessel simulators or fixed bed physical models with remote-controlled model tows).

(8) Vessel captains and Coast Guard views. Local towboat captains which will use the waterway and the Coast Guard are requested to provide opinions on safety of the proposed channel dimensions and lock layout.

(9) Datum. Navigation projects will refer to an established reference datum. In accordance with Section 224 of WRDA 1992, coastal navigation projects shall be referenced to the Mean Lower Low Water (MLLW) datum based on local tidal parameters. Inland navigation systems shall be referred to hydraulically derived low water reference planes (LWRP) or regulated pool levels in controlled areas. Great Lakes projects shall be referenced to the International Great Lakes Datum of 1985 (IGLD 85). The relationship of the reference datum/plane to the National Geodetic Vertical Datum of 1929 (NGVD 29) and/or the North American Vertical

Datum of 1988 (NAVD 88) shall be established for use during construction (EM 1110-2-1003).

(10) Aids to navigation. Shallow draft navigation projects usually require marking lights and channel buoys. The Coast Guard will provide information on type and location of suitable aids (EM 1110-2-1611).

(11) Baseline surveys. Physical and environmental surveys are needed during preconstruction design phases. These surveys provide the data necessary for the studies listed below. Hydrographic and hydraulic survey data are also to be used for physical and/or mathematical models and vessel simulator calibration and verification. The following surveys are usually needed for the design of navigation projects:

- Hydrographic (EM 1110-2-1003).
- Hydrologic.
- Current: velocity, direction, and duration.
- Sediment: suspended and bedload.
- Geologic.
- Ice (thickness, duration, and frequency of occurrence).
- Biological population (type, density, distribution, and migration).
- Water quality.
- Cultural resources.

(12) Period of analysis and design conditions. The period of analysis of shallow draft navigation projects is 50 years. The design conditions during the 50-year period must be selected by an optimization process which determines the frequency and extent of damages when various design conditions (river stage, waves, currents, ice, etc.) are exceeded. These damages are included in the life cycle project cost for each design condition (EM 1110-2-1611). The project design condition selected by this comparison of costs will maximize net benefits. The economic determinations must comply with the requirements of ER 1105-2-100. Life cycle costs include:

- Construction cost.
- Operation and maintenance (O&M) cost.
- Replacement cost.

(13) O&M plan. A comprehensive plan of how the project will be operated and maintained is required. This plan is presented in support of O&M costs. The following elements are normally included in the O&M plan:

- Predicted project costs and physical changes. Include the postconstruction predictions of physical changes and anticipated O&M costs.
- Surveillance plan. Describe the type and location of instrumentation needed and the types and frequency of surveys. The plan covers minimum monitoring of project performance to verify safety, efficiency, and environmental impacts. Cost information is used for O&M budgetary purposes.
- Analysis of survey data. Comparative studies of the survey data are needed. These comparative studies verify design information such as rates of erosion and shoaling.
- Periodic inspection and project performance assessment. Present a tentative periodic inspection schedule. Inspections include a site assessment and comparisons of survey data to project changes predicted during the design effort. Compare actual project O&M costs to predicted costs.

(14) Repair and rehabilitation. Repair (normal maintenance) of structures can be expected during the project economic life. These repairs may be necessary because of floods which exceed design conditions or by long-term deteriorations. Normal repair costs are to be included in the O&M budget. A review of the accident history is needed to identify hazards and justify modifications to improve safety. Rehabilitation design will consider all features that would be included in a modern project. Rehabilitation of structures can be used to extend the project economic life in lieu of complete replacement or abandonment. Rehabilitation and replacement options are to be evaluated when normal maintenance becomes excessive or when the project stops functioning properly.

9. Summary

The design of shallow draft navigation projects requires an understanding of the problem, assembly and evaluation of all pertinent facts, and the development of a rational plan with identified risks and uncertainties. The design engineer is responsible for developing the design rationale and sufficient alternative plans so the economic optimum plan is evident and the recommended plan is substantiated. Applicable Corps of Engineers guidance and pertinent textbooks, research reports, or expertise from other agencies may be used as source information. The usual necessary steps leading to a sound plan are outlined below:

a. Review appropriate ERs, EMs, ETLs, etc.

b. Assemble and analyze pertinent factors and environmental data.

c. Conduct baseline studies to identify uncertainties.

d. Select rational set of design conditions.

e. Develop trial layouts with annual costs.

f. Model test.

g. Obtain views of vessel captains and Coast Guard.

h. Develop O&M plans.

I. Select economic optimum plan.

j. Assess environmental and other impacts.

k. Develop recommended plan.

FOR THE COMMANDER:

1 Appendix
APP A - Principal Factors
Affecting Hydraulic Design

ALBERT J. GENETTI, JR.
Major General, USA
Chief of Staff

Appendix A
Principal Factors Affecting Hydraulic Design

A1. Climate-weather

a. Wind (speed and direction).

b. Waves (height, period, and direction).

c. Visibility (rain, smog, fog, snow, etc.).

d. Ice (thickness, duration, and frequency of occurrence).

e. Temperature (air and water).

A2. Site characteristics

a. Water levels (river, tidal, etc.).

b. Currents (tidal and/or river).

c. Sediment movements.

d. Type of bottom (soft or hard).

e. Water depth (bathymetry).

f. Obstructions (sunken vessels, abandoned structures, etc.).

g. Bridge crossing (location and clearances).

A3. Tow characteristics

a. Geometry (length, width, and draft).

b. Maneuverability (speed, turning radius, reverse capability, etc.).

A4. Environmental

a. Esthetics.

b. Culture.

c. Ecology.

d. Archaeology.

A5. Social

a. Recreation.

b. Access.

c. Safety

d. Displacement of homes or businesses.