OFFICE OF BRIDGE DEVELOPMENT
MANUAL ON HYDROLOGIC AND HYDRAULIC DESIGN

CHAPTER 3
POLICY AND PROCEDURES

SEPTEMBER 2007

TABLE OF CONTENTS

3.1 INTRODUCTION

3.1.1 Purpose of Chapter 3

Safety, traffic service, waterway adequacy, environmental compatibility and structural stability are important aspects of bridge design and construction. The purpose of this chapter is to outline, identify and reference policies and procedures which will provide an appropriate level of consideration in the hydraulic design of bridges and other structures.

3.1.2 Policy vs Design Criteria

Policy and Design Criteria statements are frequently closely related, criteria being the specific guidance which is needed to interpret and implement broad policy statements. For this manual, the following definitions of policy and criteria will be used:

Policy - a definite course of action or method of action, selected to guide and determine present and future decisions.

Design Criteria - the standards by which a policy is carried out or placed in action.

An example of a policy statement might be: "The designer will size the drainage structure to accommodate a flood compatible with the classification of the highway." An example of a design criterion (from Chapter 10, Hydraulic Design of Bridges might be: “Drainage structures located on highways classified as Major and Minor Collectors shall be designed for a 25-year flood."

3.1.3 Chapter Outline

The following sections of this chapter will present information concerning hydraulic design of drainage structures and related Federal, State, and local policies. Some sections will be limited to outlining the relevant policies (with references indicating where details can be obtained) while other sections will state the policies and give detailed information

3.2 BASIC CONCEPTS

3.2.1 State-of-Practice

The policies, criteria and procedures set forth in this Manual establish a design process that is representative of the present "State of Practice" as defined in publications of the Maryland State Highway Administration, AASHTO, the Federal Highway Administration, the National Highway Institute, The U.S. Geological Survey, the Corps of Engineers, the Transportation Research Board and others. In addition, the State Highway Agency conducts its own research and implementation program, often in cooperation with the University of Maryland and the Maryland Department of the Environment to address specific issues of primary interest to the State of Maryland. The "State of Practice" in the fields of Hydrology and Hydraulics continues to undergo rapid changes. New advances regularly are made in developing more accurate and sophisticated mathematical and computer models for hydraulic analysis, in improving procedures for evaluation of stream stability and bridge scour, in methods to restore and enhance distressed stream channels and in methods for predicting the magnitude and duration of peak flood flows. To the extent feasible, the Manual will be periodically up-dated to reflect new technology adopted by the SHA to keep current with the "State of Practice".

3.2.2 Adequate Drainage Structure

Because of State regulations controlling work in flood plains, the need to provide for the safety of the traveling public and to minimize environmental impacts to streams, wetlands and other natural resources, the SHA conducts detailed hydrologic and hydraulic location and design studies. The objective of such studies is to use a process that would be followed by a reasonably competent and prudent engineer in evaluating, selecting and approving a final design for an adequate drainage structure.

An adequate drainage structure may be defined as one, which meets the following criteria:

- The design of the structure meets or exceeds normal engineering practice,
- The design provides for practical measures to limit environmental impacts and to provide for environmental benefits
- The design is consistent with what a reasonably competent and prudent designer would do under similar circumstances.

3.2.3 Design Process

The Design Process of the Office of Bridge Development has significantly evolved during the past several years to place greater emphasis on the evaluation of stream morphology and on environmental impacts and benefits. For the project development process to be efficient and successful, it is essential that each step be coordinated with offices within SHA, such as the Office of Environmental Design, and the various State and Federal agencies responsible for the review and approval of the project. It is important that managers and team leaders within the Office of Bridge Development accomplish this coordination on an ongoing basis as a routine aspect of the project development process.

In 2003, the project development process was modified to encompass the steps listed below.

1) Establish design objectives and priorities.
2) Hydrologic analysis (includes bankfull discharge obtained from Step 4).
3) Existing condition hydraulics.
4) Geomorphology and Environmental Studies
5) Conceptual design for channel stability, and stream restoration and enhancement,
6) Assessment of structure/stream channel alternatives
7) Proposed condition hydraulics including final bridge/culvert scour evaluations and FEMA study revisions, when required):
   - pre-TS&L for structures
   - semi-final stream channel design
8) Design plans (including temporary measures during construction)

These studies are discussed further in the following sections. A detailed checklist regarding information to be considered in conducting the various studies is presented in Appendix A of this chapter.

3.2.3.1 Design Objectives and Priorities

Objectives and priorities may change from project to project. The project team leader has the task of getting all interested parties involved in the project, including the designers and design reviewers, to reach essential agreement on objectives and priorities at an early stage of design.

3.2.3.2 Hydrologic Analysis

Detailed procedures for hydrologic analysis are set forth in the publication entitled "Application of Hydrologic methods in Maryland".. This report was prepared by a panel of national experts and has been adopted by both the SHA and the Maryland Department of the Environment or MDE. The basic steps in the hydrologic analysis are computed using the software of the Maryland GIS Hydro Program.

<u>Existing Condition Hydrology</u>

- Compute estimates of peak flows using TR-20
- Compute estimates of peak flows using regression equations based on stream flow records of Maryland watersheds.
- Compare the values obtained from these two methods and select the design flow values following the methodology set forth in the panel report.

Peak flow values of the two, ten and 100-year floods are needed for hydraulic analysis for compliance with State flood plain regulations. Peak flow values of the 100-year, 500-year and overtopping flows are needed for scour analyses. Other peak flood events (25-year or 50-year) may be needed to meet the design standards set forth in Chapter 10 for the particular classification of the highway on which the structure under design is located. Finally, bankfull flow discharges and other characteristics are needed to evaluate the morphology of the stream under study. A flood-frequency curve for existing conditions should be developed to present the overall relationship of the various flood peaks.

Condition of Ultimate Development

Once the flood frequency curve is developed for existing conditions, it is modified to estimate runoff from the watershed for conditions of ultimate development in the watershed. These ultimate development discharges are used for design. Flood frequency plots are prepared, comparing flood peaks for existing conditions with conditions of ultimate development.

3.2.3.3 Existing Condition Hydraulics

Cross-sections are taken and field studies made so as to prepare water surface profiles for existing conditions. This step sets up base conditions for evaluating the proposed design alternatives. The Appendix A checklist itemizes the many factors to be taken into consideration in developing the water surface profile model for the site.

3.2.3.4 Geomorphology and Environmental Studies

This fourth step in the design process involves the evaluation of the existing stream system, the effects that a proposed structure will have on this system and the effect of the stream on the proposed structure. Detailed guidance on stream morphology studies is set forth in Chapter 14. The objective of these studies is to determine if the existing stream system is stable, and if so, how to design the bridge structures to maintain the channel stability and enhance the natural values of the stream. If the existing channel is unstable, then the objective is one of determining practical, cost-effective approaches to establishing a stable channel and achieving other stream restoration and enhancement techniques in the reach of the stream in which the highway structures is located. Other environment studies conducted during this phase of the work typically include, but are not limited to, the inventory and evaluation of the following items with respect to the impacts and benefits of the project:

1. wetlands
2. habitat for and passage of fish and wildlife,
3. native and invasive species of plants and trees,
4. endangered species of plants and animals

SHA guidance in the field of stream geomorphology continues to improve, as new methodologies become available. Current guidance on the subject is contained in the following references:

- Chapter 9, Channels,
- Chapter 10, Bridges

- Chapter 13, Culverts.
- Chapter 14 , Stream Morphology and Channel Crossings

For culverts and small bridges, particular attention is given to the design of upstream and downstream flow transitions to avoid creating stream stability problems (Chapter 13). A desirable goal in culvert design is to maintain, to the extent practicable, the flow pattern and distribution on the flood plain that existed prior to the initiation of the highway project.

3.2.3.5 Conceptual Design for Channel Stability, Stream Restoration and Enhancement

This step is to determine what actions, if any, are necessary to establish or maintain a stable channel in the reach of the river crossed by the bridge structure. For unstable streams, the general approach is to use cross-vanes or other rock structures to reestablish a stable grade and cross-section for the stream. In some cases, this may require a relocation of the channel in order to achieve a favorable grade. In addition, particularly for distressed stream channels, consideration is given to opportunities for stream restoration and enhancement.

3.2.3.6 Assessment of Structure/Stream Channel Alternatives

Chapter 13, Culverts, contains considerable information on the relative advantages and disadvantages of culverts and bridges. The first five steps of the design process discussed above serve to provide information on the type of structure and the stream channel design that will best fit the conditions at the stream crossing. This sixth step serves to focus the designer's attention on the most important priorities and objectives, in order to select the structure/stream channel alternative that best fits the site conditions. It is emphasized that the combination of the structure design and the stream channel design needs to be considered as a unit in developing and selecting a project alternative. Design personnel need to make every effort to assure that project reviewers are kept appraised of this process of developing alternatives and selecting the preferred alternative.

The process of evaluating alternative designs involves consideration and balancing of a number of factors including:

- safety,
- legal concerns (Chapter 2),
- flood hazards to highway users and neighboring property owners (Chapters 9, 10 and 13),
- stability of the structure (Chapters 11 and 13),
- costs (Chapters 10 and 13),
- environmental and social concerns (Chapter 5, Project Development, Chapter 9 Channels, Chapter 13 Culverts, Chapter 14, Stream MorphologyChapter 15, Surface Water Environment and Chapter 16, Erosion and Sediment Control), and other site-specific concerns (Chapter 18, Coastal Zone, etc.)

The hydraulic analysis is normally made utilizing the HEC-RAS 1-D model. Other models may be appropriate for special conditions:

- HEC-2 where the proposed structure will affect existing FEMA flood studies
- FESWMS or other appropriate 2-D model for conditions such as wide flood plains or complex flow patterns where the inherent limitations of the 1-D model would be inadequate to evaluate the flow.
- Tidal flow models such as TIDEROUT2 to account for the effect of tidal flow on peak and duration of flood flows.
- Three-dimensional or physical models to evaluate special flow conditions. An example of the use of 3-D and physical models is in the design of the Woodrow Wilson Bridge where it was cost effective to build models of the complex river piers for the purpose of evaluating scour.

Detailed discussions and guidance relating to use of various hydraulic design procedures are contained in Chapters 9, 10 and 13. The designer is referred to Appendix A of this Chapter to review the checklist of items to be considered in the development and hydraulic analysis of alternative designs.

3.2.3.7 Proposed Condition Hydraulics

The proposed condition hydraulics for the selected alternative is conducted as a part of the Pre-TS&L/TS&L for Structures. This work includes:

- Development of water surface profiles for the selected alternative (Chapters 9, 10 and 11),
- Final hydraulic studies for FEMA or MDE, as appropriate, for permits/approvals
- Resolution of environmental issues pertinent to obtaining necessary permits
- Preliminary evaluations of bridge scour
- Semi-final evaluations and designs for channel stability, restoration and enhancement.
- Preliminary evaluation of bridge deck drainage systems

3.2.3.8 Design Plans, including temporary measures during construction for erosion control and stream diversions)

Ideally, hydraulic design, environmental and permit issues should be resolved and finalized prior to the preparation of design plans. However, some details such as erosion control and stream diversions may require detailed information that is not available until the design plans are developed.

Typically, final scour studies and subsurface soil investigations are initiated subsequent to the pre-TS&L/TS&L stage to develop the Foundation Report. This report specifies foundation design details for piers and abutments. Once the Foundation Report is approved, the structure project proceeds to final design.

The primary responsibility of the Engineer is to provide for the safety of the public. Bridges are to be designed to withstand scour from extreme events in accordance with the procedures set forth in Chapter 11, Evaluating Scour at Bridges.

Similarly, culvert inlets and outlets need to be evaluated and protected with riprap or other measures to limit the extent of scour and erosion as described in Chapter11, Evaluating Scour at Bridges and Chapter 13, Culverts.

Bridge deck drainage systems are typically designed during the development of the design plans. The MPADD Program (Maryland Pavement and Deck Drainage Program) is used to make the design calculations. Policy and Design Criteria regarding bridge deck drainage systems are set forth in Chapter 12

3.3 HYDRAULIC DESIGN POLICIES

3.3.1General Policies

Hydrologic, hydraulic, geotechnical, structural and geomorphic design methodologies constitute the design process representative of the present "normal engineering practice" or "State of Practice". Utilization of these study areas, coupled with the use of engineering judgment, represents the approach to be followed by a "reasonably competent and prudent designer" in evaluating, selecting, and approving a final design. The following policies apply to this design process.

- The primary responsibility of the Engineer is to provide for the public safety. Structures are to be designed to be stable and to resist damage from scour and hydraulic forces for extreme flood events (See Chapter 11, Evaluating Scour at Bridges, and Chapter 13, Culverts).

- Bridge deck drainage systems are to be designed to limit the spread of gutter flow into the traveled way (See Chapter 12, Bridge Deck Drainage).

- The detail of design studies should be commensurate with the risk associated with the structure, its approach roads and with other economic, engineering, social, or environmental concerns.

- Various peak flood events, including consideration of flows based on ultimate development in the upstream watershed, are to be estimated and used to evaluate the adequacy of the of the proposed structure in regards to safety of the traveling public, compliance with State flood plain regulations and compatibility with the stream morphology. Hydrologic studies are to be conducted in accordance with the guidance in the SHA/MDE report entitled "Application of Hydrologic Methods in Maryland" dated February 1, 2001. (See Chapter 8, Hydrology.)

  - Only models approved by the Office of Bridge Development are to be used in hydrology studies to estimate flood peak flows, hydrographs, storm tide discharges and other hydrologic variables.

  - Only models approved by the Office of Bridge Development are to be used in hydraulic studies for the development of water surface profiles as described in Chapter 9, Channels, Chapter 10, Hydraulic Design of Bridges and Chapter 13, Culverts. The Engineer conducting the study should be prepared to demonstrate that input data and output results have been carefully examined and determined to be representative of the site conditions. High water marks, previous hydraulic studies performed by the SHA or others, or other similar types of information or measurements should be carefully evaluated for accuracy and reliability prior to their use in calibrating a model.

- In the design of highway stream crossings, full consideration is to be given to maintaining the stability of the stream's bed and banks, to providing opportunities for stream restoration and enhancement, and to providing reasonable conditions for habitat and the passage of fish and wildlife (See Chapter 9, Channels; Chapter 10, Hydraulic Design of Bridges and Chapter 13, Culverts).

- The project development process for bridge structures shall proceed in general conformance with the procedures established by the Office of Bridge Development and other SHA offices (Chapter 5, Project Development) to assure full consideration of the social, economic and environmental effects resulting from the construction of highways and bridge structures in flood plains. Early and continued coordination within SHA and with Federal and State agencies involved in the project review is essential in achieving a successful and efficient project development process.

3.3.2 Federal Policies

Chapter 2 lists Federal legislation which may affect drainage design and construction. This Chapter also gives the legislative reference, regulations, purpose, applicability, general procedures, and lead agencies for coordination and consultation. For more detailed information about specific Federal policies, the applicable legislation should be consulted.

In order to assure that bridge designs are developed in a timely manner that is consistent with applicable Federal policies, continuing coordination and consultation with SHA environmental specialists and appropriate Federal and State agency representatives needs to be carried out throughout the project development process. Early coordination with the Federal agencies via the Interagency Review Process is particularly important for major planning projects, major structures and projects affecting environmentally sensitive watersheds. At the Pre-TS&L stage (or its equivalent) for such projects, efforts should be made to obtain the appropriate permits and or preliminary approvals from the Federal agencies in accordance with the recommended procedures set forth in Chapter 5, Project Development.

For bridge replacement projects initiated by the Office of Bridge Development, a more abbreviated project development process can normally be used as described in Chapter 5, Project Development, to achieve the necessary coordination. The primary Federal policies affecting hydraulic design are addressed in detail in the individual chapters of the Manual. See also Section 3.3.3 below

3.3.3 State Policies

The design of bridge structures needs to be coordinated with appropriate SHA offices and State agencies at an early stage of project development. The typical items of concern involve treatment of wetlands and other environmentally sensitive flood plain areas; design of structures, particularly culverts, to minimize obstructions to passage of fish and wildlife; maintaining the stability of stream beds and banks; providing opportunities for stream restoration and enhancement and meeting the State requirements regarding flood plain management by limiting increases in water surface elevations. Chapter 5, Project Development, presents the process for achieving this coordination; Chapters 8-10 address specific SHA policies and practices developed for meeting the State flood plain regulations

3.3.4 Municipal Policies

When the design of a bridge structure affects a flood plain that falls under the jurisdiction of the National Flood Insurance Program, it is important for the Engineer to coordinate the design with the local community responsible to FEMA for administering the flood plain program. Details regarding this coordination are contained in Chapter 5, Project Development. Chapter 2, Legal Aspects, also contains a general discussion of local laws and applications.

3.4 HYDRAULIC DESIGN CRITERIA AND PROCEDURES

3.4.1 Hydraulic Design Criteria

Appendix A of this chapter presents detailed guidance regarding the format and criteria to be used and the procedures to be followed in preparing Hydrology, Hydraulic. Stream Morphology and Bridge Scour Evaluation reports. Additional guidance is presented in the individual chapters of the Manual. This information is to be used in the preparation of study reports involving the hydraulic design of structures designed by the Office of Bridge Development

3.4.2 Hydraulic Design Procedures

The format and procedures for preparing study reports is explained in detail in Appendix A of this chapter. Particular emphasis is placed on the need to follow the project development process presented in Chapter 5, Project Development, in order to achieve an orderly, logical and cost-effective design approach.

The accuracy and reliability of Hydrologic, Hydraulic, Geotechnical, Stream Stability and Scour Studies are dependent upon the Engineer's judgment to select and apply appropriate models, equations and coefficients in a manner that is representative of the actual conditions that exist at the site of the stream crossing. Mathematical equations and computer programs selected for use should have the capability of modeling actual hydrologic and hydraulic conditions within a reasonable degree of accuracy. The Engineer is expected to be familiar with the limitations of models selected for use. The concurrence of SHA personnel should be obtained prior to the use of any methodology, if there is a question as to its ability to adequately represent the site conditions under study. In certain cases, it may be necessary to use a 2-D mathematical model or a physical model study conducted in a hydraulic laboratory for purposes of evaluating a hydraulic design in an adequate manner.

As discussed earlier in this chapter, it is desirable to obtain field measurements, historic records, or other means of verification whenever practicable to calibrate the results of model studies. However, care must be exercised to validate the reliability and accuracy of any such data before it is used to calibrate a model.

3.5 REFERENCES

For further references to items on the check list, please consult the individual chapters in the manual addressing the item of interest.