Chapter 12 – Bridge, Structure and Riverine Hydraulics

TABLE OF CONTENTS

CHAPTER 12 - BRIDGE AND STRUCTURE HYDRAULICS....12-1

12.1 Introduction....12-1
12.1.1 Definition 12-1
12.1.2 Analysis/Design....12-1
12.1.3 Riverine Hydraulics....12-1

12.2 Design Policy....12-3
12.2.1 FEMA Floodplain Compliance....12-3
12.2.2 FHWA Compliance....12-3
12.2.3 AASHTO General Criteria....12-3
12.2.4 Department Criteria....12-3
12.2.4.1 Travelway....12-4
12.2.4.2 Design Floods....12-4
12.2.4.3 Backwater/Increases Over Existing Conditions....12-4
12.2.4.4 Flow Distribution....12-4
12.2.4.5 Scour....12-5
12.2.4.6 Multibarrel Culverts....12-5
12.2.4.7 Culvert Countersinking....12-5
12.2.4.8 Lateral Encroachments....12-5
12.2.4.9 Stream Restoration....12-5

12.3 Design Concepts....12-6
12.3.1 Methodologies....12-6
12.3.2 Bridge Scour or Aggradation....12-6
12.3.3 Riprap 12-6
12.3.4 Hydraulically Equivalent Replacement Structure (HERS)....12-6

12.4 Riverine H&HA....12-8
12.4.1 Background....12-8
12.4.2 Necessary Resources....12-8
12.4.3 Hydrologic Analysis....12-9
12.4.4 Hydraulic Analysis....12-9
12.4.4.1 Existing Effective Model....12-9
12.4.4.2 Existing Conditions Model (Adjusted)....12-10
12.4.4.3 Calibration....12-10
12.4.4.4 Proposed Conditions Model....12-10
12.4.5 Documentation....12-10
12.4.5.1 Detailed Hydrologic & Hydraulic Analysis (H & HA) Outline – LD-293D 12-10
12.4.5.2 Multipart Letter - LD-293....12-10
12.4.5.3 System of Units....12-11
12.4.5.4 Level of Precision for Documentation....12-11
12.4.6 H&HA Submission....12-11

12.5 H&HA for Major Tidal Structures and Bridges....12-13
12.5.1 Background....12-13

12.5.2 Necessary Resources 12-13
12.5.3 Coastal Bridge and Culvert Design Techniques 12-13
12.5.4 Computer Modeling 12-14
12.5.5 Hydrologic Analysis 12-15
12.5.5.1 Bridge Location 12-16
12.5.5.2 Channel Cross Section 12-16
12.5.5.3 Drainage Area Characterists 12-16
12.5.5.4 Storm Tides 12-16
12.5.5.5 Flow Velocity 12-17
12.5.6 Hydraulic Analysis 12-18
12.5.7 Documentation 12-19
12.5.8 H&HA Submission 12-19

12.6 Riprap for Protection of Bridge Abutments and Piers 12-20

12.7 Removal of Existing Bridge and Approach Embankments 12-21

12.8 Temporary Construction Causeway Design 12-23
12.8.1 Background 12-23
12.8.2 Causeway Design 12-23
12.8.2.1 Design Objectives 12-23
12.8.2.2 Plans 12-23
12.8.2.3 General Notes 12-24
12.8.3 Design Procedure 12-24

12.9 Daily Stream Flow Information 12-25
12.9.1 Background 12-25
12.9.2 Development of a Composite Stream Flow Hydrograph 12-25

12.10 References 12-27

List of Figures

Figure 12-1. Removal of Approach Embankment 12-22

Figure 12-2. Quantifying Removal of Approach Embankment 12-22

Figure 12-3. Temporary Construction Causeway Design 12-24

List of Appendices

Appendix 12A-1 Definitions and Abbreviations

Appendix 12B-1 Hydrologic and Hydraulic Analysis Report Distribution List

Appendix 12B-2 LD-293D Hydrologic and Hydraulic Analysis Documentation Outline

Appendix 12B-3 LD-293 Hydraulic Analysis Report

Appendix 12B-4 LD-293B Report to VDOT Road Designer

Appendix 12B-5 LD-293C Report to VDOT District Environmental Manager

Appendix 12C-1 LD-23 Structure and Bridge Data Sheet

Appendix 12C-2 Tidal Bridge Scour Data and Worksheet

Appendix 12C-3 Table of Storm Tide Description of Virginia Coast

Appendix 12C-4 Virginia Coastal Maps Showing Predicted Water Surface Elevations

Appendix 12D-1 Guidelines for the Determination, Documentation, and Processing of Hydraulically Equivalent Replacement Structures (HERS)

Appendix 12E-1 Daily Stream Flow Information

Chapter 12 - Bridge, Structure* and Riverine Hydraulics

12.1 Introduction

12.1.1 Definition

Bridges are defined as:

- Structures that transport traffic over waterways or other obstructions
- Part of a stream crossing system that includes the approach roadway over the floodplain, relief openings, and the bridge structure
- Structures with centerline span of 20 feet or more. However, structures designed hydraulically as bridges, as described above, are treated as bridges in this chapter, regardless of length

- Major Culvert crossings with a total 100-year Discharge > 500 cfs are to be evaluated and documented as if they were bridges, unless otherwise exempted by VDOT Hydraulics Staff.

- Three sided structures (bottomless culverts, precast concrete arches, cast in place concrete frames, corrugated metal plate arches and similar structures) shall be treated as bridges.

12.1.2 Analysis/Design

Proper hydraulic analysis and design is as vital as the structural design. Stream crossing systems should be designed for:

- Minimum cost subject to criteria
- Desired level of hydraulic performance up to an acceptable risk level
- Mitigation of impacts on stream environment
- Accomplishment of social, economic, and environmental goals
- The requirements of existing Federal Emergency Management Agency (FEMA) or other officially delineated or regulatory floodplains

12.1.3 Riverine Hydraulics

In addition to stream crossings other VDOT projects have the potential to adversely impact flood elevations by modifying the flood plain or the stream channel. The project

* Rev 9/09

types are listed below, these should also be evaluated using the methods and criteria found in this chapter.*

- Stream Restoration Projects
- Lateral Encroachments into the Flood Plain

* Rev 9/09

12.2 Design Policy/Criteria

12.2.1 FEMA Floodplain Compliance

- The final design should not significantly alter the flow distribution in the floodplain
- Where design considerations permit, the "crest-vertical curve profile" should be considered as the preferred highway crossing profile when allowing for embankment overtopping at a lower discharge
- For FEMA Zones determined by Approximate Methods it is allowable to increase the flood elevations up to 1.0 foot provided that coordination with the community shows that the cumulative impact requirements have been addressed.
- For FEMA Zones determined by Detailed Methods it is not allowable to increase the 100-year flood elevation.

12.2.2 FHWA Compliance

- Degradation or aggradation of the river should be estimated and contraction and local scour determined. The appropriate positioning of the foundation, below the total scour depth if practicable, should be included as part of the final design

12.2.3 AASHTO General Criteria

Design criteria are the tangible means for placing accepted policies into action and become the basis for the selection of the final design configuration of the stream-crossing system. Criteria are subject to change when conditions so dictate as approved by the Department.

Following are certain American Association of State Highway Transportation Officials (AASHTO) general criteria adopted by the Department related to the hydraulic analyses for bridges as stated in their highway drainage guidelines:

- Backwater will not significantly increase flood damage to property upstream of the crossing
- Velocities through the structure(s) will not damage either the highway facility or increase damages to adjacent property
- Maintain the existing flow distribution to the extent practicable
- Pier spacing and orientation and abutment designed to minimize flow disruption and potential scour
- Foundation design and/or scour countermeasures to avoid failure by scour
- Minimal disruption of ecosystems and values unique to the floodplain and stream

12.2.4 Department Criteria

These criteria augment the general criteria. They provide specific, quantifiable values that relate to local site conditions. Evaluation of various alternatives according to these criteria can be accomplished by using water surface profile programs such as HEC-RAS, HEC-2, or WSPRO.

12.2.4.1 Travelway

Inundation of the travelway and clearance below the low shoulder dictates the level of traffic services provided by the facility. The travelway overtopping flood level identifies the limit of serviceability. Desired minimum levels of protection from travelway inundation for functional classifications of roadways are presented in Chapter 6, Hydrology.

12.2.4.2 Design Floods

Design floods for such things as the evaluation of backwater, clearance, and overtopping, unless available from FEMA or other appropriate sources, should be established predicated on local site conditions. They should reflect consideration of traffic service, environmental impact, property damage, hazard to human life and floodplain management criteria. Design floods for roadway inundation and culverts being evaluated in this section are specified in Chapter 6, Hydrology. It should be noted, in the case of bridged waterways, that the design flood is normally whichever of the customarily documented events (i.e. the 2, 5, 10, 25, 50, 100, & 500-yr. floods) that will pass under the bridge superstructure at its lowest elevation with at least one or more feet of freeboard, provided that level of protection is acceptable to the bridge designer.

12.2.4.3 Backwater/Increases Over Existing Conditions

Designers shall conform to FEMA flood elevation increase limitations for sites covered by the National Flood Insurance Program (NFIP). It is the Department's policy not to allow any increase in the level of the 1 percent (100-year)[*] flood for delineated floodplains established under the NFIP. An increase is permitted in FEMA Zones determined by Approximate Methods of up to 1.0 foot provided that coordination with the community shows that the cumulative impact requirements have been addressed and the increase doesn't impact upstream development.. For areas not covered by an existing mapped flood zone the increases are not to exceed one foot during the passage of the 1 percent flood and the increase does not impact upstream development. Refer to section 12.4.1 for additional details.

12.2.4.4 Flow Distribution

The conveyance of the proposed stream crossing should be calculated to determine the flow distribution and to establish the location of bridge opening(s). The proposed facility should not cause any significant change in the existing flow distribution. Relief openings in the approach roadway embankment or other appropriate measures should be investigated if there is more than a 10 percent redistribution of flow provided such openings do not create a concentration of flow which could damage downstream properties.

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[*] Rev 9/09

12.2.4.5 Scour

Design for bridge foundation scour should consider the magnitude of the flood that generates the maximum scour depth up to the 1% (100-year) event. In addition the design should then be checked using a super-flood up to the 0.2% (500-year) event. A plot or sketch showing the scoured bed profile for both events shall be prepared and included with documentation (LD-293) described in Section 12.6.5.2.

12.2.4.6 Multibarrel Culverts

For Culvert Crossings with multiple barrels the hydraulic analysis shall consider any culvert opening area that is below the natural flood plain elevation up or downstream of the crossing to be obstructed.

12.2.4.7 Culvert Countersinking*

All Culvert crossings should comply with the USACOE countersinking requirements as outlined in Chapter 8 of this manual.

12.2.4.8 Lateral Encroachments

When a project places fill that is parallel to a stream within a flood plain this is considered a lateral encroachment. This reduces the effective flow area of the flood plain and has the potential to increase the flood elevations. The analytical methods and impact limits described in this chapter shall be applied to projects of this type. Documentation shall conform to the requirements of this chapter and shall include 100-year flood elevation comparison tables for the reach impacted by the encroachment.

12.2.4.9 Stream Restoration

To meet the environmental regulations VDOT is engaged in a number of projects to improve impaired streams through restoring sediment transport and creating wildlife habitats. The filling of oversized channels and the planting of riparian vegetation has the potential to adversely impact flood elevations. The analytical methods and impact limits described in this chapter shall be applied to projects of this nature. Documentation shall conform to the requirements of this chapter and shall include 100-year flood elevation comparison tables for the reach impacted by the stream restoration..

12.2.4.10 Impounding Structures (Dams)

As discussed in Chapter 8 a structure that is not designed as an impounding structure or dam shall not be evaluated as such to reduce the hydrology or ultimate headwater elevation. VDOT does not encourage the use of roadways as dams for impounding water. It is not VDOT practice not accept responsibility for portions of new roadways that have been designed as dams. Where there are existing roadways that are dams, it may be necessary to address current DCR Dam Safety Regulations prior to making any improvements to the roadway or outfall structure.

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* Rev 9/09

12.3 Design Concepts

12.3.1 Hydraulic Computation[*] Methodologies

At a minimum, a one dimensional step-backwater computer model will be employed to perform the hydraulic analysis in these situations due to the complexity of the hydraulic conditions and the risk involved. No single method is ideally suited for all situations. If a satisfactory computation cannot be achieved with a given method, an alternate method should be attempted. Where the use of a one-dimensional step backwater computer model is indicated, the Department accepts any computer model currently approved by FEMA but prefers HEC-2 or HEC-RAS. A two dimensional flow model may be necessary to adequately represent the hydraulic conditions found at the stream and road crossings. The Department accepts any current two dimensional flow model approved by FEMA. Because of the extensive data requirements, the extra time involved in performing this type analysis, etc., the use of a two-dimensional model in any given situation should be prior approved by the Department's Hydraulics Section.

12.3.2 Bridge Scour or Aggradation

The Department employs the procedures and criteria presented in the FHWA's "Evaluating Scour at Bridges" (HEC-18) and "Stream Stability at Highway Structures" (HEC-20) to determine and counteract the impact of scour and long term aggradation/degradation on bridges. Both these publications can be accessed and/or downloaded from the publications section of the FHWA's Internet web site at http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm.

12.3.3 Riprap

Riprap is not to be used for scour protection at piers for new bridges. Riprap may be used to protect exposed abutment slopes or as a scour countermeasure at existing bridge piers and abutments. Design guidelines for placement and sizing of riprap are presented in the FHWA's "Bridge Scour and Stream Instability Countermeasures" (HEC-23) publication. To qualify as a scour countermeasure the riprap must be placed as prescribed in HEC-23, otherwise it is only considered as being slope protection. This publication can be accessed and/or downloaded from the publications section of the http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm.

12.3.4 Hydraulically Equivalent Replacement Structure (HERS)

The goal of the Hydraulic Analysis is to document that the proposed project does not have an unacceptable impact on the flooding in the vicinity of the crossing. There are cases where this can be determined without performing a detailed hydraulic study. When the proposed structure is hydraulically equivalent to the existing structure in all

[*] Rev 9/09

parameters, the Hydraulic Engineer (with the concurrence of the Department) can state that the crossing is hydraulically equivalent and document this on the LD293s as shown in the Appendix 12D. This documentation is all that is required.

12.4 Riverine H&HA

12.4.1 Background

A detailed hydrologic and hydraulic analysis (H&HA) should be performed for all of the Department's new or replacement major drainage structures, bridged waterways, significant lateral encroachments (resulting from the placement of highway fill embankments within a floodplain) and stream restoration projects*. It is necessary to do this such that Department construction is in compliance with national (i.e. FHWA, FEMA, etc.), State (i.e. Department of Conservation and Recreation), and municipal (locally delineated floodplains) rules and regulations. Detailed analysis, as used here, means that the hydraulic analysis shall be performed using an appropriate step-backwater computer model. In the case of Department construction in or in proximity to a FEMA detailed study floodplain, the existing effective analysis should be obtained as a basis for a revised step-backwater computer model.

Regardless of whether a bridged waterway, culvert, lateral encroachment or stream restoration is being evaluated, in situations where a FEMA or other officially delineated floodplain is being considered, no increase in the established natural 100-yr. flood level will be permitted either up or downstream. In situations where no FEMA or other officially delineated floodplain exits (including FEMA Zone A designated floodplains), it will be acceptable to increase the cumulative level of the 100-yr flood event not to exceed one foot upstream, provided such increase does not adversely impact adjacent properties, buildings, etc. If an increase in the 100-yr flood level will cause such adverse impact then no increase shall be permitted. An exception allowing more than 1 ft. increase may be granted in the case of a non officially delineated floodplain provided the increase is fully contained within the right of way and/or a permanent drainage easement. A design waiver issued by the Department would be required under such circumstances.

12.4.2 Necessary Resources

The resources necessary to perform an H&HA usually include, but would not be limited to: topographic maps, aerial photographs, and sufficient roadway plans, profiles, and typical sections to cover the width of the floodplain in the vicinity of the crossing.

In the event a FEMA floodplain (or other officially delineated floodplain) is involved, it will be necessary to have any available flood profiles, maps, and hydraulic model data. The Department will secure and provide any necessary hydraulic model data. In the event a bridged waterway is involved, it will be necessary to have a schematic bridge layout or proposed bridge plan, bridge situation survey, and bridge data sheet.

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* Rev 9/09

12.4.3 Hydrologic Analysis

If the site is not covered by a FEMA (or other officially delineated) floodplain, it will be necessary to determine a range of design peak discharges to use in the subsequent hydraulic analysis. See Chapter 6, Hydrology, for detailed information on application and procedures of hydrologic methods.

Methods employing total storm runoff (i.e. a hydrograph) consideration, such as the USACE HEC-1 or HEC-HMS or the NRCS' TR-20 and TR-55 models can be employed but aren't normally be necessary unless a hydrograph (as opposed to an instantaneous peak) is otherwise needed as in the case of an impoundment structure.

If the site is covered by a FEMA (or other officially delineated) floodplain, the peak discharges employed in making the official floodplain delineation shall be employed. Any exception to this policy must be approved by the VDOT Hydraulics Section.

In all cases the 2, 5, 10, 25, 50, 100, and 500-year flood magnitudes will either be determined or obtained (from appropriate sources) and employed and documented in the subsequent hydraulic analysis. In addition, the Ordinary Highwater discharge, usually taken to be the drainage area (in square miles) times 1.1 in units of cubic feet per second, shall be determined and documented for the purposes of applying for certain environmental permits.

12.4.4 Hydraulic Analysis

When an existing study is available[*] the Department prefers a three-step procedure for performing the hydraulic analysis using an approved (or preferred) step-backwater computer model. When there is no Existing Effective Model then proceed directly to the Existing Conditions Model.

12.4.4.1 Existing Effective Model

If a FEMA (or other officially delineated) floodplain is involved, the first step will be to mathematically reproduce the hydraulic model if practicable using the same step-backwater computer model on which the original floodplain was based. If the step-backwater computer model used to perform the original hydraulic analysis is no longer available or is not readily available, one of the approved step backwater computer models may be employed as long as it is adjusted to match the official model as closely as practicable. In accordance with FEMA directives HEC-RAS may be used in lieu of the originally employed computer model provided: (1) the program version employed must be at least version 3.1.1 or higher and (2) it ties back in to the original study model within 0.5 ft. at the upstream and downstream ends for the reach being modeled. Any exception to this criterion must be approved by the VDOT Hydraulics Section. The first hydraulic model will be referred to as the "EXISTING EFFECTIVE" model.

[*] Rev 9/09

12.4.4.2 Existing Conditions Model (Adjusted)

The next step would be to use the most recent survey and detailed bridge data to create or update any natural ground cross sections to the locations necessary to subsequently model any proposed construction. Any new model should extend sufficiently downstream and upstream of the crossing to adequately evaluate the conditions. This is typically at least 1000 feet in both directions. It should be emphasized that any changes made in the "EXISTING EFFECTIVE" model should be for the purpose of facilitating the modeling of proposed conditions, updating the survey and correcting any observed errors in modeling methodology within the area of the project. This model then becomes the basis for measurement of any changes that would take place as a result of the proposed construction. This second hydraulic model will be referred to as the "EXISTING CONDITIONS" model.

12.4.4.3 Calibration

Reasonable efforts should be made to assess any existing studies or historical data (if available) at the crossing and if the model can be calibrated using this information. Calibration efforts should discussed in the submitted documentation.

12.4.4.4 Proposed Conditions Model

Once the Existing Condition Model has been calibrated the hydraulic model will be modified to include any and all proposed construction and will be referred to as the "PROPOSED CONDITIONS" model. The allowable impacts to the 100-year flood elevation are subject to the limitations disuccsed previously in Section 12.2.4.3[*]

12.4.5 Documentation

12.4.5.1 Detailed Hydrologic & Hydraulic Analysis (H & HA) Outline – LD-293D

The first part consists of an outline in which every item shown is to be addressed in its entirety. The outline will be permanently filed as part of the computation assembly. A blank outline is included in Appendix 12B-2. In the case of a lateral floodplain encroachment due to a highway fill embankment or stream restoration projects, the outline may be adjusted to allow for the fact that a drainage structure is not involved. In such cases it should also be modified or supplemented as necessary to include a tabulation or spreadsheet showing existing and proposed water surface elevations at various locations along the highway embankment. A separate narrative and tabulation may be prepared in lieu of using the outline in this case.

12.4.5.2 Multipart Letter - LD-293

The second part consists of multi-part letter, officially known as the LD-293 assembly, advising various disciplines within the Department of the results of the hydrologic and hydraulic analysis. Both the outline and the LD-293 assembly are available, upon request, as a series of blank document files in "MICROSOFT WORD" word processing formats. Optionally these blank document files may be downloaded at the following web address: http://www.extranet.vdot.state.va.us/forms/. A copy of the entire LD-293

[*] Rev 9/09

assembly is to be retained with the permanent computation file. Blank copies of the LD-293 assembly are included in Appendices 12B-3 through 12B-5. It should be noted that form LD-293 is only used in the case of a bridge waterway to report the results of the H&HA to the bridge designer. Form LD-293B may additionally be used for a major culvert installation to report pertinent hydraulic design information to the road designer, as a cover letter forwarding form LD-294 (hydraulic commentary necessary for environmental permit applications) to the appropriate District Environmental Manager, and as notification of anticipated hydraulic impacts to the Location & Design Public Involvement Section. A form letter is not available which addresses the hydraulic impacts associated with a lateral encroachment due to a highway fill embankment. However, any necessary changes, modifications, etc. affecting the roadway alignment and/or grade must be coordinated with the road designer.

12.4.5.3 System of Units

The LD-293 assembly will be prepared reflecting exclusively those units employed in the road plans and/or bridge plans whereas, the remainder of the documentation (the actual hydrologic and hydraulic analysis, the outline, etc.) will be left to the discretion of the engineer performing the work..

12.4.5.4 Level of Precision for Documentation

The following are guidelines governing the level of accuracy to show in the LD-293 assembly:

1. Elevations, etc. obtained from the survey, whether in English or metric, are to be shown exactly as obtained.

2. Elevations, distances, etc. obtained from the plans, whether in English or metric, are to be shown exactly as obtained.

3. The magnitude of peak discharges should be shown to three significant digits in English or metric units. For example, show 12,687 cfs as 12,700 cfs. Show 359.3 cms as 359 cms.

4. Show velocities to the nearest 0.1 (tenth) fps or 0.01 (hundredth) mps.

5. Show calculated water surface elevations to the nearest 0.1 (tenth) ft. or 0.01 (hundredth) m.

6. Show changes in calculated water surface elevations to the nearest 0.1 (tenth) ft. or 0.01 (hundredth) m.

7. Show watershed areas to the nearest sq. mi. or sq. km.

12.4.6 H&HA Submission

When the H&HA has been performed by the consultant for the Department, the following items should be submitted to the Department:

1. The completed H&HA outline, as a document file on a CD and as a hard copy printout.

2. The completed LD-293 assembly, as a document file on a CD and as a hard copy printout (including a hardcopy printout or sketch of the anticipated final scoured bed profile for both the design and check flood events) in the event the H&HA was for a bridged waterway.

3. A CD containing any and all copies of the hydraulic model data on which the H&HA was predicated (i.e. HEC-2, HEC-RAS, etc. data files).

4. Hard copy printouts of all hydraulic model data calculations (i.e. output); Hard copies of full output reports should be printed out for analyses using HEC-2. For HEC-RAS, printouts of Standard Tables 1 and 2 should be submitted. The consultant should contact the Department for guidance when using other models.

5. Copies of any supplemental calculations incidental to the H&HA;

6. Copies of any supplemental documentation not covered in either the H&HA outline or the LD-293 assembly. Any materials and/or resources that have been loaned out by the Department to assist in performing the H&HA such as FEMA studies, etc.

7. If the project crosses or otherwise impacts a FEMA regulatory floodplain or floodway, an excerpt from the FEMA Community Map Panel covering the site should be included.

This information is to be submitted to the VDOT contact person who has been designated as the coordinator for drainage design.

12.5 H&HA for Major Tidal Structures and Bridges

12.5.1 Background

A detailed hydrologic and hydraulic analysis (H&HA) should be performed for all of the Department's new or replacement major tidal drainage structures and/or bridged tidal waterways. It is necessary to do this in order that VDOT construction be in compliance with national (i.e., FHWA, FEMA, etc.), state (DCR, etc.), and municipal (locally delineated floodplains) rules and regulations. The recommended procedures are described in the FHWA publication "Tidal Hydrology, Hydraulics and Scour at Bridges" (HEC-25). This publication is available at the FHWA's Internet web site: http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm.

Detailed analysis, as used here, also means that a three-level analysis such as outlined in HEC-20 and HEC-18 will be employed to evaluate the potential for scour around bridge foundations in order to design new and replacement bridges to resist scour. The complexity of the hydraulic analysis increases if the tidal structure or bridge constrict the flow and affect the amplitude of the storm surge (storm tide) so that there is a large change in elevation between the ocean and the estuary or bay, thereby increasing the velocities in the constricted waterway opening.

12.5.2 Necessary Resources

The resources necessary to perform an H&HA of tidal crossings, as for riverine crossings, usually include, but would not be limited to: topographic maps, aerial photographs, maintenance records for the existing bridge, bridge data sheet, bridge situation survey, proposed bridge plans, and sufficient roadway plans, profiles, and typical sections to cover the width of the floodplain in the vicinity of the crossing.

Other resources necessary for tidal analysis are: velocity meter readings, cross section soundings, location of bars and shoals, magnitude and direction of littoral drift, presence of jetties, breakwater, or dredging of navigation channels, and historical tide records. Sources of data include NOAA National Ocean Service, USACE, FEMA, USGS, U.S. Coast Guard, local universities, oceanographic institutions and publications in local libraries. NOAA maintains tidal gage records, bathymetric charts, and other data on line at www.nos.noaa.gov. Also refer to Chapter 13, Shore Protection, for details on working with tidal datums.

12.5.3 Coastal Bridge and Culvert Design Techniques

The hydraulic design guidelines for coastal or tidally influenced waterway bridge openings lag behind similar designs on riverine systems. The complicated phenomenon is difficult to simulate for several reasons, but primarily because tidal simulations often require modeling dynamic (time-varying) conditions. Coastal waterways are subject to storm surges and astronomical tides which play an important role in hydraulic behavior. The collection of adequate data to represent the actual condition also adds to the complexity of the problem. Data such as flows and storm surge description may be difficult to estimate. For small bridges, complex modeling may not be cost effective since the cost of the study may exceed the cost of the bridge.

Presently there is no standard procedure for the design of tidally influenced waterways. In many cases, the bridge hydraulic opening is designed to extend across the normal open water section. This may be an appropriate design from an economic standpoint; since the total cost of a larger bridge may approximates the cost of a smaller bridge considering approach embankments and abutment protection measures. This design is also desirable from an environmental perspective since it results in minimal environmental impacts. In most designs, the extent of detail in the analysis must be commensurate with the project size or potential environmental impacts. However, analytical evaluation of the opening is often required and is necessary when a full crossing cannot be considered or when the existing exhibits hydraulic problems. The complexity of these analyses lends themselves to computer modeling.

Because of the lack of standard procedures for the design of costal waterways, research is being conducted on this matter. A FHWA pooled fund study coordinated by the South Carolina Department of Transportation has developed recommendations for modeling of tidally influenced bridges. In addition to design guidelines, technical research needs to be conducted to better understand the hydraulics in tidally influenced waterways.

Research is needed in the following areas: sediment transport and scour processes, coastal and tidal marsh ecosystems, environmental impacts and the development of comprehensive coastal hydraulics models.

12.5.4 Computer Modeling

Existing models cover a wide range from simple analytical solutions to heavy computer intensive numerical models. Some models deal only with flows through inlets, while others describe general one-dimensional or two-dimensional flow in coastal areas. A higher level includes hurricane or other storm behavior and predicts the resulting storm surges.

One-dimensional steady state models are the most commonly used models because they demand less data and computer time than the more comprehensive models. Most analyses for tidal streams are conducted with steady state models where the tidal effects are not simulated. This may be an adequate approach if the crossing is located inland from the mouth where the tidal effects are insignificant. Computer modeling for steady state hydraulics is generally preformed with the Corps of Engineers HEC-RAS (or HEC-2).

In the event that either tidal fluctuations or tidal storage are significant, simulation of the unsteady hydraulics is more appropriate. Unsteady flow computer models were evaluated under a FHWA pooled fund research project administered by the South Carolina Department of Transportation (SCDOT). The purpose of this study was to identify the most promising unsteady tidal hydraulic models for use in scour analyses. The study identified UNET, FESWMS-2D, and RMA-2V as being the most applicable for scour analysis. The research funded by the FHWA pooled fund project is being continued to enhance and adapt the selected models so that they are better suited to the assessment of scour at tidal bridges.

The pooled fund research project also resulted in guidance on the appropriate methodology to use based on the geomorphic characteristics of the tidal waterway. Where complicated hydraulics exists, for instance as in wide floodplains with interlaced channels or where flow is not generally in one direction, a one-dimensional model may not represent adequately the flow phenomena and a two-dimensional model is more appropriate. Two-dimensional models in common use to model tidal flow hydraulics are FESWMS-2DH and RMA-2V. FESWMS-2DH, a finite element model was prepared for the FHWA by David C. Froehlich and includes highway specific design functions such as pier scour, weirs, and culverts. RMA-2V, also a finite element model, was developed by the US Army Corps of Engineers. FESWMS-2DH and RMA-2V can also incorporate surface stress due to wind. These models require considerable time for model calibration. Thus, they do not lend themselves for analysis of smaller structure sites.

The US Army Corps of Engineers' UNET model is widely accepted in situations where the more complicated two-dimensional models are not warranted or for use in making preliminary evaluations. UNET is a one-dimensional, unsteady flow model. The Corps of Engineers has now modified HEC-RAS to incorporate dynamic routing features similar to UNET.

Alternatively, either a procedure by Neill for unconstricted waterways, or an orifice equation for constricted tidal inlets can be used to evaluate the hydraulic conditions at bridges influenced by tidal flows. The procedure developed by Neill can be used for tidal inlets that are unconstricted. This method, which assumes that the water surface in the tidal prism is level, and the basin has vertical sides, can be used for locations where the boundaries of the tidal prism can be well defined and where only small portions of the inundated overbank areas are heavily vegetated or consists of mud flats. The friction loss resulting from thick vegetation tends to attenuate tide levels thereby violating the assumption of a level tidal prism. The discharges and velocities may be over estimated using this procedure. In some more complex cases a simple tidal routing technique (TIDEROUT) or a simple UNET or other 1-dimensional model (HEC-RAS) can be substituted with a similar level of effort. UNET includes storage areas that are assumed to fill as level pools.

12.5.5 Hydrologic Analysis

The flow associated with a tidal bridge generally consists of a combination of riverine and tidal flows. VDOT's Tidal Bridge Scour Data & Worksheet (Appendix 12C-2) will be used to calculate both the tidal and riverine flow components for tidal crossings. This worksheet utilizes a "VDOT only" modification of Neil's method for calculating tidal flow and USGS Regression equations for riverine flow. The data required to complete this worksheet is generally available from field data and limited research. A discussion which addresses the information needed to complete the Tidal Bridge Scour Data & Worksheet follows.

12.5.5.1 Bridge Location

- Bridge Number, Route, County, Length and River Crossing can be obtained from bridge plans and inspection reports.

- Tidal Bridge Category:

  - Islands: Passages between islands or between an island and the mainland where a route to the open sea exists in both directions.
  - Semi-Enclosed Bays & Inlets : Inlets between the open sea and an enclosed lagoon or bay where most of the discharge results from tidal flows.
  - Estuaries : River estuaries where the discharge consists of river flow as well as tidal flow.

12.5.5.2 Channel Cross Section

Channel cross section data may be obtained from several sources such as VDOT Central or District offices, bridge plans and/or bridge inspection reports.

12.5.5.3 Drainage Area Characterists

Drainage area characteristics are required for estimating peak flood discharges using the USGS regression equations for Virginia. (See FHWA Tidal Pooled Fund Study “Tidal Hydraulic Modeling For Bridges” Section 3.4 for guidance in combining storm surge and upland runoff.)

- Drainage area estimated from USGS topographic maps (1:24000), NOAA Navigation maps or similar topographic maps from other sources such as county topographic maps.

- Percentage of forested area, main channel slope, average basin elevation and main channel length can be estimated from USGS topographic maps, street maps or other types of topographic maps.

12.5.5.4 Storm Tides

- The surface area of the tidal basin is required for estimating tidal flows. From USGS topographic maps or NOAA navigation maps, the surface area of the tidal basin can be obtained by planimetering several different contour line levels, and then developing a graph of the surface area vs elevation. Since the maximum tidal flow normally occurs at midtide, the preferred method of analysis is to determine the surface area of the tidal basin at this elevation. The surface area of the tidal basin at the midtide elevation can be determined from the graph by interpolation.

- The 10, 50, 100 and 500-year storm tides can be obtained from the maps and figures of the coastal regions of Virginia located in the appendix. The maps and table of storm tide description have been compiled and developed from existing FEMA Flood Insurance Study reports, NOAA tidal records, US Army Corps' tidal analysis and Ho's <u>Hurricane Tide Frequencies Along The Atlantic Coast</u>.

- Tidal flow is the product of the surface area and the rate change of the tidal height and may be expressed by the following equation:

$$Q=24312\ A_s \frac{H}{T}$$

where Q = Tidal flow, in cfs

A_s = Surface area of the tidal area upstream from the bridge at the midtide elevation, in sq. mi.

H = Tidal height, between low tide and high tide, in ft.

T = Period of the storm tide, in hours. (See Note 1)

Note 1: Obtain both H and T from the maps and table in Appendix 12C-3 and 12C-4.

12.5.5.5 Flow Velocity

The flow velocities should be calculated for the flow conditions that may result in higher velocities. These conditions include: (a) the peak riverine flow with a low downstream water level and (b) the combined tidal flow and the flood peak flow, with the water level at the midtide elevation.

There is an additional condition, (c), that needs to be investigated for tidal bridges located on estuaries some distance upstream from a bay or ocean. The flow depth at bridges in such cases is less likely to be controlled by the tidal elevation in the bay and more likely to be controlled by the channel slope, boundary roughness and channel geometry. Using the low sea level to calculate the flow velocity for such bridges may result in an unreasonably high velocity due to underestimation of the flow depth and cross-sectional area. Manning's equation should be used to estimate the flow velocity in such cases. Engineering judgment should be applied when estimating the flow conditions and appropriate flow depth to be used in calculating the velocity of flow. Particular attention needs to be directed at determining the appropriate combination of riverine and tidal flows for use in estimating worst case scour conditions.

The flow velocities estimated by the above methods represent an approximate value for use in the screening process. A detailed H&H Study is required if a more accurate estimation of velocities is desired.

The analysis of the flow velocity in this Worksheet assumes steady flow even though tidal flow is an unsteady flow phenomenon. The resulting velocity will generally be slightly different from a velocity calculated on the basis of unsteady flow. Since the rate of the vertical motion of storm tides is on the order of only three to eight thousandths of a foot per second, the velocity estimates obtained from the method discussed above should be reasonable for locations in unconstricted bays and estuaries where velocities are on the order of 3 feet per second or less.

Maps and figures of the coastal regions of Virginia that describe the tidal storm surge periods and predicted water surface elevations for the 10, 50, 100 and 500-year storms are shown in Appendix 12C-3 and 12C-4

12.5.6 Hydraulic Analysis

VDOT's Tidal Bridge Scour Data and Worksheet (Appendix 12C-2) will be used during the Level 1 Analysis (see HEC-18) in order to estimate the maximum flow velocities through the tidal bridge during the passage of a storm tide. This estimate should be considered as a first approximation for use in judging whether the proposed tidal bridge requires a more detailed H&HA.

Normally, Neill's method of analysis should provide an acceptable degree of accuracy for tidal inlets and estuaries that are not significantly constricted and where flow velocities are 3 feet per second or less.

Where the waterway is constricted and estimated flow velocities exceed 3 feet per second, it may be appropriate to route the storm tide through the structure for purposes of obtaining a more accurate estimate of storm tide velocities. The TIDEROUT computer program is recommended for use when making calculations involving tide routing through a structure. TIDEROUT is a BASIC computer program developed by Mr. Raja Veeranachaneni, MD SHA. A copy of the TIDEROUT program is available on request from the department's Hydraulics Section. If the estimated flow velocity from the Tidal Worksheet is 7 feet per second or greater, routing of the storm tide through the structure should be considered.

Where the simplified methods yield overly conservative results, the use of routing techniques or unsteady flow computer models (Level 2) will provide more realistic predictions of hydraulic properties and scour.

For certain types of open tidal waterway crossings, worst-case scour conditions may be caused by the action of the wind. In other cases, such as passages between islands or an island and the mainland, the worst-case condition may represent a combination of tidal flow and wind forces. These specialized cases require careful analysis and should be studied by engineers with a background in tidal hydraulics.

Electronic spreadsheets are available which assist in the generation of storm surge hydrographs for use in defining downstream boundary conditions during hydrodynamic modeling. These spreadsheets are available on request from the Department's

Hydraulics Section. Maps showing the locations of ADCIRC stations along the Virginia coast where storm surge hydrographs are available are included in Appendix C of the "Tidal Hydraulic Modeling for Bridges" publication. Also available are spreadsheets that assist in the computation of time dependent scour and wave heights for tidal sites.

The FHWA Tidal Pooled Fund Study's "Tidal Hydraulic Modeling for Bridges" publication presents guidance on the appropriate methodology to use based on the geomorphic characteristics of the tidal waterway.

12.5.7 Documentation

The documentation for a tidal H&HA will be the same as required for a riverine H&HA.

12.5.8 H&HA Submission

When the H&HA has been performed for a tidal site by the consultant for the Department, the level of documentation to submit to the Department should be the same as required for a riverine site.

12.6 Riprap for Protection of Bridge Abutments and Piers

Riprap is frequently used for protection of the earthen fill slopes employed in spill-through abutments. In such situations, it can serve the two-fold purpose of protecting the underlying shelf abutment and piers against runoff coming from the approach roadway and bridge superstructure as well as from scouring due to impinging flow resulting from floodwaters. However, in order to qualify as a true scour countermeasure, the riprap thickness, placement, and coverage must be predicated on the procedures described in HEC-23. Riprap can also be used around solid, gravity abutments to protect against scour. Riprap is considered an acceptable scour countermeasure for protection of bridge abutments. The use of riprap at bridge piers, on the other hand, is not acceptable for use in new construction and is considered only as a temporary countermeasure in the case of rehabilitation. The Department employs the riprap design procedures presented in the FHWA publication “Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance” (HEC-23). The Department has developed a computer program entitled “BRRIPRAP” which sizes the riprap necessary for abutment protection in accordance with HEC-23. It is available upon request at the following web address: http://www.virginiadot.org/business/locdes/notification.asp

This riprap shall be placed over an appropriate bedding material. For geotextile bedding under the riprap being used for bridge spill slopes, a stone cushion layer consisting of VDOT no. 25 or 26 aggregate should be placed between the riprap and geotextile bedding in accordance with the following:

- In the case of Class AI and I riprap, the aggregate cushion layer should be 4 inches thick
- In the case of Class II, Class III, Type I, and Type II riprap, the aggregate cushion layer should be 6 inches thick

When it is found necessary to employ riprap as a scour countermeasure around existing bridge piers for rehabilitation purposes, the design shall be performed in accordance with HEC-23 and/or must be reviewed and approved by an appropriate Department River Mechanics Engineer. Bedding requirements in such situations shall be in accordance with the above or as directed by the District Materials Engineer.

12.7 Removal of Existing Bridge and Approach Embankments

In the process of building a new bridged waterway and approaches, it often becomes necessary to remove all or a portion of the existing bridge approach roadway fill throughout the floodplain area. This is necessary for two reasons. First, leaving portions of the old bridge approaches in place may hinder the hydraulic capacity and efficiency of the new facility. In most instances the hydraulic performance of the new facility is predicated on the complete removal of the old one. Second, many State and/or Federal Environmental review agencies require that the old bridge and roadway approaches be removed in their entirety and the land graded back to its natural contour as a contingency for the issuance of certain environmental permits. The hydraulic engineer responsible for the performance of the hydrologic and hydraulic analysis for the proposed bridged waterway will notify the road designer as to whether or not it will be necessary to remove all or portions of the existing bridge and approaches.

When an existing bridge is to be removed, the bid item for removal of the existing bridge will include the entire superstructure and all portions of the substructure, such as abutments, wing walls and piers, pilings and riprap or slope protection. No portion of the approach roadway embankment is to be included in this bid item.

The limits of the approach roadway embankment to be removed will be furnished to the road designer by the Hydraulics Section and shown on Form LD-293B (Appendix 12B-3). These limits are to be shown on the road grading plans along with the following note:

> "The existing approach roadway embankments will be removed between Station ______________ and Station ___________________ _____________________ and will be included in the quantity for regular excavation."

When a portion of existing approach embankments are removed for flood control, the remaining approach embankment surface should be graded on an approximate 0.5 percent slope toward the waterway in such a manner as not to impound any water on the surface after the flood waters have receded or after normal rainfall as shown in Figure 12-1.

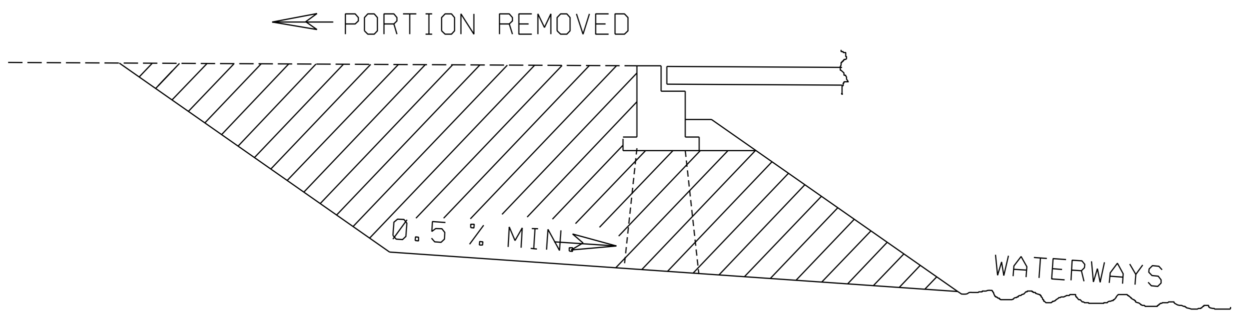

Figure 12-1. Removal of Approach Embankment

The determination of quantities for the removal of approach embankment should be set up on a cubic yard basis and included in the plan quantity for regular excavation. The limits for computing the quantity is a vertical plane through the joint between the approach pavement and the end of the bridge as shown in Figure 12-2.

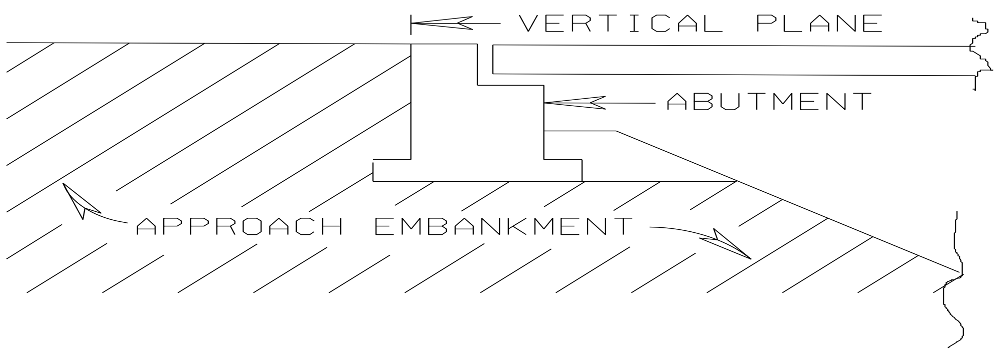

Figure 12-2. Quantifying Removal of Approach Embankment

The road designer will request such additional survey information as is necessary to delineate and estimate the quantities of the embankment to be removed.

The District Engineer must be afforded an opportunity to review and comment on the embankment removal proposal prior to completing the plans.

12.8 Temporary Construction Causeway Design

12.8.1 Background

The need to provide a construction access facility that will not have a significant impact on normal flow conditions is mandated by the state and federal agencies that issue and/or approve the issuance of appropriate environmental permits.

12.8.2 Causeway Design

12.8.2.1 Design Objectives

- Provide a design that is reasonably convenient, economical, and logistically feasible for the contractor to build and remove.
- Provide a design that will not be subject to failure due to normal stream flow conditions. This should consider in-stream obstructions such as piers or islands that could direct high velocity jets at points along the causeway.
- Provide a design that will not cause a significant increase in the Ordinary High Water stage, will not significantly increase the velocity of flow through the causeway opening(s) for that flow rate, will not significantly alter flow distribution, and will not concentrate flow on the piers and foundations that would subject them to forces for which they were not designed. The causeway's influence on flood flow elevations should be checked in the event that it does not wash out during a significant flood.
- Provide a design that will not obstruct over 50% of the width of the normal stream unless sufficient temporary drainage structures are placed under the causeway to offset greater reduction.

12.8.2.2 Plans

The temporary construction causeway should be designed as a rock prism. The design details and required notes should be shown on the typical section sheets (series 2 plan sheets) in the project plans or on a separate detail sheet for "Bridge Only" projects. A note, "Temporary Construction Causeway Required, See Sheet ______ of _____ for details" should be shown on the road plan sheet where the causeway appears. The design details and required notes for the "Temporary Construction Causeway" will be shown on the front sheet of Bridge plans for "Bridge Only" projects. A typical causeway design detail is shown in Figure 12-3.

The pay item(s) for causeways will be included with the road plans. For "Bridge Only" projects, the causeway pay item(s) will be included in the bridge plans.

The contractor should bid the rock causeway as shown on the plans. The contractor may elect to revise the design or substitute another design after being awarded the contract. If so, he should submit a revised design including necessary sketches and notes for review by the district construction, hydraulic and environmental personnel.

The Department should obtain a revised environmental permit if necessary, for the contractor's revised design.

The material used in construction of the causeway should normally be Standard Class I Dry Riprap. The Hydraulic Engineer performing the hydraulic design for the causeway may, at his discretion, specify or authorize larger stone for the causeway's slope faces but must have sufficient justification for doing so. Such justification should be fully addressed in the hydraulic design documentation.

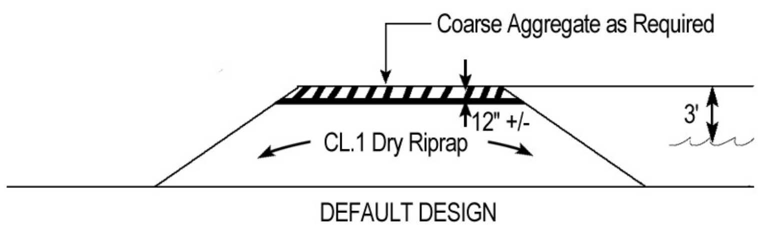

Figure 12-3. Temporary Construction Causeway Design

Show the top of the causeway as being 3' over "Ordinary High Water".

12.8.2.3 General Notes

1. The basis of payment for the temporary causeway will be lump sum, which price should include all labor, equipment, materials and incidentals needed for construction, maintenance, removal and disposal of the causeway.

2. The Project Engineer may make minor adjustment in the location of the causeway provided that the adjustment does not change the design of the causeway.

12.8.3 Design Procedure

Step 1 Set the alignment of the causeway to facilitate construction activity. Set the finished grade 3'± above the Ordinary High Water elevation. Set the side slope angle at approximately 1½:1.

Step 2: Determine the required waterway opening(s) and the resulting hydraulic performance using appropriate hydraulic design techniques. It is recommended that pipes be used whose diameter (or rise as appropriate) is 2-feet less than the causeway is high. In other words, if the causeway is 6-feet high, then use 48-inch pipe(s).

12.9 Daily Stream Flow Information

12.9.1 Background

In instances where a VDOT project crosses and/or is in the floodplain of a major waterway, it will be necessary to provide the contractor (or others as appropriate) with a means of determining which times of year would be most suitable for in-stream work (i.e. periods of normally extended low flows) as well as those times when larger or flood flows can be expected. When such information is available, the best source is usually stream gaging information from gage stations which provide daily flow data.

12.9.2 Development of a Composite Stream Flow Hydrograph

To provide the needed information, it will be necessary to plot approximately 10 consecutive Water Years of daily stream flow hydrographs, superimposed one upon the other, for a given stream gage. The department has developed computer software for this purpose. A "Water Year" starts October 1st of the previous year and goes through September 30th of the year under consideration. It is therefore desirable, when generating these plots, to have them start with October of the first Water Year under consideration and end in September of the last (usually 10th) Water Year. It is also desirable to use the most recent 10 consecutive years for which uninterrupted daily flow data is available for the stream gage being employed. Ideally, a stream gage would be used which is located relatively near (either up or downstream) of the project. It may not always be possible or feasible to utilize a stream gage located on the same stream and/or in very close proximity to the project. In such instances it will be acceptable to utilize a gage on another nearby stream, which in the judgment of the hydraulic engineer, can provide more appropriate stream flow information. The most important objective is to provide an indication of those times of year when sustained periods of low flow or high flows can be expected.

After selecting a stream gage, it is highly recommended that the gaging records be reviewed prior to utilizing the plotting software to insure that the gage is of the recording type (i.e. that daily stream flow records are available) and to determine the most recent 10 consecutive years for which uninterrupted data is available. The usual references for this information are the U.S. Geological Survey's annual publications entitled WATER RESOURCES DATA VIRGINIA, VOLUME 1, SURFACE-WATER-DISCHARGE AND SURFACE-WATER-QUALITY RECORDS (for each Water Year under consideration) and their Internet web site which is entitled "NWISWeb Data for Virginia", the "URL" for which is http://waterdata.usgs.gov\va\nwis\.

The software necessary to generate these plots – COMPOSITE HYDROGRAPH – is currently only available to Department employees. Access to the software will normally be granted to any VDOT personnel involved in drainage design and is an integral part of the department's "Hydraulic

Engr. Package" of software. Consultants needing these hydrographs must currently request them from the designated drainage design coordinator.

The software's database contains daily stream flow records for all recording stream gages in the state of Virginia. This data will, for gages currently in operation, be available up through the most recent Water Year for which data has been published. The software can, at the user's option, generate the hydrograph either as a ".BMP" file saved to disk or as a letter size hard-copy printout. The ".BMP" file should be made available to the Road Designer so he can import it into MicroStation and convert into a plan sheet for inclusion in the plan assembly. Probably the quickest and most convenient way to do this will be to attach the file to the cover e-memo used to transmit the usual "LD-293B" memorandum (in the case of a bridged waterway) to the Road Designer. If no bridged waterway is involved, as would be the case when the floodplain involvement is by virtue of a major culvert or roadway encroachment, the file should be generated and transmitted at the conclusion of the hydrologic & hydraulic analysis. An example daily stream flow composite hydrograph plot is included in the Appendix 12-E1, "Example Daily Stream Flow Information".

12.10 References

Federal Highway Administration Hydraulic Engineering Circular No. 17, “The Design of Encroachments on Flood Plains Using Risk Analysis” – October 1980.

Federal Highway Administration Hydraulic Engineering Circular No. 18, “Evaluating Scour at Bridges” – May 2001.

Federal Highway Administration Hydraulic Engineering Circular No. 20, “Stream Stability at Highway Structures” – March 2001.

Federal Highway Administration Hydraulic Engineering Circular No. 23, “Bridge Scour and Stream Instability Countermeasures” – March 2001.

Survey Instructions Manual – Virginia Department of Highways & Transportation.

U. S. Army Corps of Engineers - HEC-2 Water Surface Profiles

U. S. Army Corps of Engineers - HEC-RAS River Analysis System

Federal Highways administration Hydraulic Design Series No. 6 “Highways in the River Environment” – December 2001.

Appendix 12A-1 Definitions and Abbreviations

Definitions:

Bridges are defined as:

- Structures that transport traffic over waterways or other obstructions,
- Part of a stream crossing system that includes the approach roadway over the floodplain, relief openings, and the bridge structure and
- Structures with a centerline span of 20 feet or more. However, structures designed hydraulically as bridges, as described above, are considered bridges in this chapter, regardless of length.

Abbreviations:

AASHTO	American Association of State Highway and Transportation Officials
DCR	Department of Conservation and Recreation
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
HDS	Hydraulic Design Series
HEC	Hydraulic Engineering Circular
LTEC	Least Total Expected Cost
NFIP	National Flood Insurance Program
NHS	National Highway System
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
TR	Technical Release
USCOE/USACE	United States Corps of Engineers
USGS	United States Geological Survey
VDOT	Virginia Department of Transportation

Appendix 12B-1 Hydrologic and Hydraulic Analysis Report Distribution List

Distribution of LD-293 Assembly and Associated Documentation

Note: Where possible and practicable, it is desirable to distribute this documentation electronically as an e-mail attachment.

Bridge designer who requested the analysis (district or Central Office as appropriate)

- LD-293 (including design & check scoured bed profile sketches as appropriate)
- LD-293C

Central Office Hydraulics Section – Asst. State Hydraulics Engineer for Bridge Hydraulics & River Mechanics Engineering

- LD293 (including design & check scoured bed profile sketches as appropriate)
- LD293B
- LD293C

Central Office Structure & Bridge Division
Assistant Structure & Bridge Engineer – District Coordination (if a district job other than a secondary)

- LD293 (including design & check scoured bed profile sketches as appropriate)
- LD293C

District River Mechanics Engineer (DRME) or District Drainage Engineer (DDE) as appropriate unless the H&HA was performed by the DRME or DDE

- LD293 (including design & check scoured bed profile sketches as appropriate)
- LD293B
- LD293C
- H&HA Outline
- Electronic copies of all data files (i.e. HEC-RAS, HEC-2, etc.), preferably in a single WINZIP file[*]

Road designer responsible for the associated roadway project (or the District L&D Engineer in the district in which the project is located if there is no associated road project)

- LD293B
- Hydrologic Data Sheet
- Stream Flow Hydrograph (if gage data is available & appropriate) – either as a computer file or plotted on a plan sheet as generated by our "COMPOSITE HYDROGRAPH" software

[*] Rev 9/09

Appendix 12B-1 Hydrologic and Hydraulic Analysis Report Distribution List

District Environmental Manager

LD293B

LD293C

Excerpt from the FEMA Flood Map covering the crossing site if applicable (Note that this can be done electronically by creating a "Firmette" file using the* "FEMA MAP STORE" on the FEMA Internet web site at http://store.msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1

Central Office Public Involvement Section

Administrator – Public Involvement Section

LD293B

* Rev 9/09

Appendix 12B-2 LD-293D Hydrologic and Hydraulic Analysis Documentation Outline

LD-293D
(3/20/07)

Page 1 of 6

DEPARTMENT OF TRANSPORTATION
LOCATION AND DESIGN
HYDROLOGIC & HYDRAULIC ANALYSIS OUTLINE

DATE:		ENGINEER:		
HYDROLOGIC & HYDRAULIC ANALYSIS OUTLINE				
ROUTE:	PROJ. #:			UPC:
CITY/COUNTY:	STREAM NAME:			
DRAIN. AREA:	STATION:	LAT:	LONG:	

EX #	REFERENCE DATA
	MAPS:
	PHOTOS:
	OTHER:
	APPLICABLE FLOOD PLAIN MANAGEMENT:
	STUDIES BY EXTERNAL AGENCIES:
	STUDIES BY INTERNAL SOURCES:
	GAGING DATA AVAILABLE:
	AVAILABLE SURVEY DATA:
	TECH. AIDES & FILE NAMES:
	OTHER DATA:

REMARKS:
Add any relevant comments concerning the data obtained and its quality (particularly if it is questionable).

Appendix 12B-2 LD-293D Hydrologic and Hydraulic Analysis Documentation Outline

LD-293D
(3/20/07)

Page 2 of 6

HYDROLOGY	
	METHODS USED FOR DISCHARGES:
	REASONS FOR FINAL SELECTION OF DISCHARGE VALUES:
	INFLUENCE AND CONTROL OF SITE:
	HIGH WATER ELEV: DATE & SOURCE:**
** See documentation data at the end of form for approximate discharge and frequency of event:	
REMARKS:	

STREAM STABILITY – LEVEL 1: QUALITATIVE ANALYSIS PER HEC-20	
	BRIDGE CHARACTERISTICS:
	STREAM CHARACTERISTICS:
	LAND USE CHANGES:
	OVERALL STABILITY:
	LATERIAL STABILITY:
	VERTICAL STABILITY:
	STREAM RESPONSE:
BASED UPON THE ABOVE ANALYSIS, IS A MORE DETAILED ANALYSIS NECESSARY: YES: NO:	
IF YES, WHAT LEVEL:	SEE EXHIBIT #:
REMARKS: Please complete with general comments based on observations of the conditions at the site.	

LD-293D
(3/20/07)

Page 3 of 6

EX #	HYDRAULIC ANALYSIS OF EXISTING STRUCTURE		
	Computer Model:	FILE:	Plan:
	DESCRIPTION OF EXISTING STRUCTURE:		
	SPAN LENGTH:	PARAPETS:	
	ABUTMENT TYPE:	SKEW TO CL:_	TO FLOOD FLOWS:
	NO. OF PIERS & TYPE:		
	PIER WIDTH:	TOTAL PIER AREA:	
	ABUTMENT "A" STA:	FINISH GRADE ELEV:	
	ABUTMENT "B" STA:	FINISH GRADE ELEV:	
	ELLC ELEV:	ELLC FOR PRESSURE FLOW:	
	STREAM BED ELEVATION:		
	WEIR ELEV. ON EACH SIDE OF STRUCTURE:	LEFT:	RIGHT:
	EXPANSION COEF:	CONTRACTION COEF:	
	ENERGY S_0	"n" VALUES:	
	BRIDGE MODELING APPROACH:		
	REASON FOR SELECTION:		
	HIGH FLOW METHOD:		
	REASON FOR SELECTION:		

DISCHARGE	EXCEEDANCE PROBABILITY	WSP ELEV. AT COMMON UPSTREAM SECTION #	WSP ELEV. AT UPSTREAM FACE OF BRIDGE #	VEL. AT DOWNSTREAM FACE OF STRUCTURE #
(cfs)	(%)	(ft)	(ft)	(fps)
	50			
	20			
	10			
	4			
	2			
	1-N			
	1-FW			
	0.2			
	OHW			
	HW Event			

	EVENT	STAGE ELEV.	DISCHARGE	EXC. PROB.
	High Water Flood			
	Base Flood			
	Overtopping Flood			

REMARKS:

Comment on the modeling approach and correction or observations relative to the original analysis.

DOCUMENTATION OF STEPS TAKEN TO CALIBRATE MODEL

If there is difficulty in calibrating the model to a historical event contact VDOT to see if there is additional information available regarding that particular event.

Appendix 12B-2 LD-293D Hydrologic and Hydraulic Analysis Documentation Outline

LD-293D
(3/20/07)

Page 4 of 6

EX #	HYDRAULIC ANALYSIS OF PROPOSED STRUCTURE	
	SCHEME #:	
	Computer Model: FILE:	Plan:
	DESCRIPTION OF PROPOSED STRUCTURE:	
	SPAN LENGTH:	PARAPETS:
	ABUTMENT TYPE:	SKEW TO CL:_ TO FLOOD FLOWS:
	NO. OF PIERS & TYPE:	
	PIER WIDTH:	TOTAL PIER AREA:
	ABUTMENT "A" STA:	FINISH GRADE ELEV:
	ABUTMENT "B" STA:	FINISH GRADE ELEV:
	ELLC ELEV:	ELLC FOR PRESSURE FLOW:
	STREAM BED ELEVATION:	
	WEIR ELEV. ON EACH SIDE OF STRUCTURE:	LEFT: RIGHT:
	EXPANSION COEF:	CONTRACTION COEF:
	ENERGY S_o "n" VALUES:	
	BRIDGE MODELING APPROACH:	
	REASON FOR SELECTION:	
	HIGH FLOW METHOD:	
	REASON FOR SELECTION:	

DISCHARGE	EXCEEDANCE PROBABILITY	DIFFERNCE AT COMMON SECTION #	WSP ELEV AT COMMON UPSTREAM SECTION #	WSP ELEV AT UPSTREAM FACE OF BRIDGE #	VEL AT DWNSTREAM FACE OF STRUCTURE #
cfs	%	ft	ft	ft	fps
	50				
	20				
	10				
	40				
	2				
	1-N				
	1-FW				
	0.2				
	OHW				
	HW Event				

	EVENT	STAGE ELEV	DISCHARGE	EXC. PROB	
	Design Flood				
	Base Flood				
	Overtopping				

REMARKS:

DOCUMENTATION OF STEPS TAKEN FOR PROPOSED MODEL - SCHEME #:

Comment on modification to existing conditions model to develop the proposed model

Appendix 12B-2 LD-293D Hydrologic and Hydraulic Analysis Documentation Outline

LD-293D
(3/20/07)

Page 5 of 6

EX #	**HYDRAULIC ANALYSIS OF PROPOSED STRUCTURE**	
	SCHEME #:	
	Computer Model: FILE: Plan:	
	DESCRIPTION OF PROPOSED STRUCTURE:	
	SPAN LENGTH:	PARAPETS:
	ABUTMENT TYPE:	SKEW TO CL:_ TO FLOOD FLOWS:
	NO. OF PIERS & TYPE:	
	PIER WIDTH:	TOTAL PIER AREA:
	ABUTMENT "A" STA:	FINISH GRADE ELEV:
	ABUTMENT "B" STA:	FINISH GRADE ELEV:
	ELLC ELEV:	ELLC FOR PRESSURE FLOW:
	STREAM BED ELEVATION:	
	WEIR ELEV. ON EACH SIDE OF STRUCTURE:	LEFT: RIGHT:
	EXPANSION COEF:	CONTRACTION COEF:
	ENERGY S_o "n" VALUES:	
	BRIDGE MODELING APPROACH:	
	REASON FOR SELECTION:	
	HIGH FLOW METHOD:	
	RESAON FOR SELECTION:	

DISCHARGE	EXCEEDANCE PROBABILITY	DIFFERNCE AT COMMON SECTION #	WSP ELEV AT COMMON UPSTREAM SECTION #	WSP ELEV AT UPSTREAM FACE OF BRIDGE #	VEL AT DWNSTREAM FACE OF STRUCTURE #
cfs	%	ft	ft	ft	fps
	50				
	20				
	10				
	40				
	2				
	1-N				
	1-FW				
	0.2				
	OHW				
	HW Event				

	EVENT	STAGE ELEV	DISCHARGE	EXC. PROB	
	Design Flood				
	Base Flood				
	Overtopping				

REMARKS:

DOCUMENTATION OF STEPS TAKEN FOR PROPOSED MODEL - SCHEME #:

Comment on modification to existing conditions model to develop the proposed model

LD-293D
(3/20/07)

Page 6 of 6

EX #:	**SCOUR DATA**
	SCOUR POTENTIAL: SEE EX. # FOR COMPUTATIONS AND PLOT SUMMARY OF RESULTS:
	RIPRAP RECOMMENDATIONS: IF DESIRED, CLASS , D= , OVER FILTER CLOTH BEDDING WILL BE SATISFACTORY.

HISTORICAL RETURN PERIOD

The approximate frequency of the event that caused the highwater at the existing structure is the____Year or the _____% Exc. Event.

CAUSEWAY ANALYSIS RESULTS

The use of causeways for temporary construction access was not considered in this analysis. If it is subsequently found necessary to use causeways, they must be submitted to the Hydraulics Unit for analysis and documentation.

Temporary construction access causeways for this project should be composed of:
Armor layering will/will not be required on either side..
The ordinary highwater will be increased by___ft.
The high flow profiles will not be affected.
The causeway will not affect the water surface profile.
The maximum causeway elevation is ____ft.
From abutment A station________to station________.
From abutment B station________ to station________.
Only one will be in place at a time.

SUMMARY

Make a brief summary statement about the impact of the proposed bridge on the flooding.

Appendix 12B-3 LD-293 Hydraulic Analysis Report

LD-293
(3/20/07)

Page 1 of 6

DEPARTMENT OF TRANSPORTATION
LOCATION AND DESIGN
HYDROLOGIC AND HYDRAULIC ANALYSIS REPORT

LOCATION
Project :
Route :
UPC :
City/County :
Waterway :

PREPARED BY
Name :
Organization :
Date :

STRUCTURE DESCRIPTION

Abutment A Station: Finished Grade Elevation _________ ft. (m)

Abutment B Station: Finished Grade Elevation __________ft. (m)

Minimum Low Chord Elevation ______ft. (m)

Skew ______to centerline ______ to flood flow

Span Length

Abutment Type

Number/Type Piers

HYDROLOGIC/HYDRAULIC DATA

Drainage Area _________________Sq. Mi. (km^2)

HISTORICAL DATA

High Water Elevation ________ft. (m) Date of Occurrence
Estimated Discharge ___________cfs. (m^3/s)
Estimated Exceedence Probability %

Appendix 12B-3 LD-293 Hydraulic Analysis Report

LD-293 Page 2 of 6
(3/20/07)

HYDRAULIC PERFORMANCE

The data presented herein is the result of statistical analysis and indicates an approximate estimate of the performance of this facility.

Discharge Cfs (m^3/s)	Estimated Exceedence Probability (%)	Change in existing flood levels ft. (m)	Flood stage upstream of bridge ft. (m)	Velocity thru Bridge Structure ft/s (m/s)
	50%			
	20%			
	10%			
	4%			
	2%			
	1% Natural			
	1% Floodway			
	0.2%			

DESIGN SUMMARY

	Exceedence Probability (%)	Stage Elevation ft.(m)	
Design Flood			
Overtopping Flood			
Base Flood			
Ordinary High Water			

DEBRIS POTENTIAL

ABUTMENT SLOPE PROTECTION RECOMMENDATIONS

26" Class I Dry Riprap over 4" no. 25 or 26 aggregate over filter cloth will be hydraulically satisfactory.
38" Class II Dry Riprap over 6" no. 25 or 26 aggregate over filter cloth will be hydraulically satisfactory.
650 mm Class I Dry Riprap over 100 mm no. 25 or 26 aggregate over filter cloth will be hydraulically satisfactory.
950 mm Class II Dry Riprap over 150 mm no. 25 or 26 aggregate over filter cloth will be hydraulically satisfactory.

Appendix 12B-3 LD-293 Hydraulic Analysis Report

LD-293 Page 3 of 6
(3/20/07)

SCOUR PLOTS
A sketch of the final scoured bed profile and the check scoured bed profile is attached. If scour countermeasures are required, a request must be submitted to the Hydraulics Unit for their design and documentation.

CAUSEWAYS
The use of causeways for temporary construction access was not considered in this analysis. If it is subsequently found necessary to use causeways, they must be submitted to the Hydraulics Unit for analysis and documentation.

Temporary construction access causeways for this project should be composed of <<specify>>.
The ordinary highwater will be increased by ______ft. (m)
The high flow profiles will not be affected.
The causeway will not affect the water surface profile.
The maximum causeway elevation is _____________ft. (m)
From abutment A to station
From station ________to abutment B.
Only one will be in place at a time.

STREAM BANK STABILIZATION
The banks should reestablish themselves to the natural conditions.
The Riprap should be placed on all areas that will not support vegetation.
Disturbed areas outside the bridge should be seeded.

COMMENTS
Note any channel modifications, flood plain impacts and impact mitigation measures as well as other data pertinent to the design. Also comment on the feasibility of using a smaller structure.

This analysis is only applicable to the structures(s) and approaches described. Any changes in these conditions may invalidate this analysis and should be reviewed by this office.

This design represents the smallest structure practicable for use at this site.

The existing structure and the existing approach roadways from station: to station: are to be removed and the land is to be regraded to its natural contour.

If this project is an interstate or other **NHS** project and is expected to be in excess of $1,000,000.00, please notify the **FHWA** that (1) no hydraulic impacts are anticipated or (2) the following hydraulic impacts are anticipated:

If you have any questions or need additional information, please contact _____________ at _______________ or via electronic mail at __________________. The completed

Appendix 12B-3 LD-293 Hydraulic Analysis Report

LD-293
(3/20/07)

Page 4 of 6

"CONFIRMATION OF DESIGN" should be sent to ______________________________.

Appendix 12B-3 LD-293 Hydraulic Analysis Report

LD-293 Page 5 of
(3/20/07)

HYDROLOGIC DATA SHEET
The information presented hereon is to be transcribed to the Hydrologic Data sheet contained in the plan assembly.

LOCATION
Project :
Route :
UPC :
City/County :
Waterway :

DESCRIPTION
Sheet No.______Station

Drainage Area ____________ sq. mi (km^2)

Structure Size

BASE FLOOD
Discharge ____________cfs (m^3/s)

Stage Elevation ________ft. (m)

DESIGN FLOOD
Discharge _________cfs (m^3/s)

Estimated Exceedence Probability _____ %

Stage Elevation ______________ ft. (m)

OVERTOPPING FLOOD
Stage Elevation ______________ ft. (m)

Estimated Exceedence Probability ________ %

HISTORICAL DATA
Date

Stage Elevation ________________ ft. (m)

Estimated Exceedence Probability _______ %

REMARKS

Appendix 12B-3 LD-293 Hydraulic Analysis Report

LD-293
(3/20/07)

Page 6 of 6

CONFIRMATION OF DESIGN

The bridge designer will complete this form and forward it to the Hydraulics Unit confirming that the design that was analyzed is being used.

LOCATION
Project :
Route :
UPC :
City/County :
Waterway :

STRUCTURE DESCRIPTION

Abutment A Station: ______________Finished Grade Elevation _______ ft. (m)

Abutment B Station: ______________Finished Grade Elevation _______ ft. (m)

Minimum Low Chord Elevation ______ft. (m)

Skew______to centerline ______ to flood flow

Span Length

Abutment Type

Number/Type Piers

Appendix 12B-4 LD-293B Report to VDOT Road Designer

LD-293B
(3/20/07)

Page 1 of 1

DEPARTMENT OF TRANSPORTATION
LOCATION AND DESIGN
ROAD DESIGN NOTIFICATION OF HYDRAULIC ANALYSIS

LOCATION
Route :
UPC :
Project :
City/County :
Waterway Name :

PREPARED BY
Name :
Organization :
Date :

HYDRAULIC DATA

The Hydrologic and Hydraulic Analysis has been completed for this site and the report has been furnished to the Bridge Designer. No recommendations were made that would affect the road plans. The following recommendations were made that may affect the road plans:

The estimated ordinary high water elevation is___________ft.(m)

REMARKS
The existing approach roadway embankments from station __________to station __________are to be removed and the land is to be regraded to its natural contour. The work will be included in the quantity for regular excavation.

This project will not exert a significant flood plain impact.

LD-293C
(3/20/07)

Page 1 of 4

DEPARTMENT OF TRANSPORTATION
LOCATION & DESIGN
ENVIRONMENTAL DATA & HYDRAULIC COMMENTARY FOR PERMITS

LOCATION
Project :
Route :
City/County :
Waterway :

PREPARED BY
Name :
Organization :
Date :

1. Identify involvement within the base flood plain:
   This is a skewed crossing of <<stream name >>.
   This is a perpendicular crossing of <<stream name >>
   The existing bridge will be removed.
   The existing bridge will remain in place.

2. Traffic service: ADT
   Detours available ________ Length _______ Miles. (km)
   Frequency of overtopping Flood
   Potential damage to the highway facility

3. Applicable flood plain management criteria:
Note: Use **ONLY the one statement that is applicable and erase all the rest,** including this instruction and the FEMA delineation description information.

For project within a FEMA **delineated floodplain**:

> FEMA regulates flood level, flood velocity, and flow distribution and this project is within FEMA community panel number: __________ and Zone ____. This project complies with FEMA requirements because there will be no increase in flood levels, velocities or flow distribution.

> FEMA regulates flood level, flood velocity, and flow distribution and this project is within FEMA community panel number: __________ and Zone ____. This project complies with FEMA requirements because a bridge/culvert will be replaced with a hydraulically equivalent replacement structure.

LD-293C
(3/20/07)

Page 2 of 4

DEPARTMENT OF TRANSPORTATION
LOCATION & DESIGN
ENVIRONMENTAL DATA & HYDRAULIC COMMENTARY FOR PERMITS

For project permits in a FEMA floodplain carrying a **Zone A** (or **X**) designation that does not have base flood elevations. In such instances, an increase in 100-year flood level not exceeding one foot is acceptable.

> FEMA regulates flood level, flood velocity, and flow distribution and this project is within FEMA community panel number: __________ and Zone A (or X). This project complies with FEMA requirements because there will be no more than a one foot increase in flood levels, velocities and flow distribution will not be changed significantly.

For projects not within a FEMA floodplain, include the following statement:

> FEMA regulates flood level, flood velocity and flood distributions and this project is not within a designated or delineated FEMA floodplain. The project complies because there are no FEMA requirements applicable within the project area.

4. Note social, economic, ecological and human use of the flood plain:

5. Drainage area ________sq. mi. (km^2)

6. Overtopping flood
   Discharge = _________ cfs (m^3/s)
   Exceedence Probability _____ %
   Stage _________ ft. (m)

7. Compare the hydraulic performance of the proposed action to the hydraulic performance of the existing conditions in terms of:
   There will be no change in the flood levels or velocities.
   The flood flow characteristics will not change.
   This proposed bridge will replace an existing bridge.
   There will be no increase in the level of the 1% flood.
   There will be an increase of one foot or less for the 1% flood.
   This is a proposed bridge in a new location.

8. Riprap abutment protection:
   Riprap protection is not being employed
   The following riprap protection is being employed:
   26" Class I Dry Riprap over 4” no. 25 or 26 aggregate over filter cloth
   38" Class II Dry Riprap over 6" no. 25 or 26 aggregate over filter
   650 mm Class I Dry Riprap over 100 mm no. 25 or 26 aggregate over filter
   950 mm Class II Dry Riprap over 150 mm no. 25 or 26 aggregate over filter cloth
   The indicated riprap protection was sized in accordance with the FHWA’s

LD-293C
(3/20/07)

Page 3 of 4

DEPARTMENT OF TRANSPORTATION
LOCATION & DESIGN
ENVIRONMENTAL DATA & HYDRAULIC COMMENTARY FOR PERMITS

The indicated riprap protection was sized in accordance with the FHWA's BRIDGE SCOUR AND STREAM INSTABILITY COUNTERMEASURES (HEC-23) publication or other nationally accepted or recognized procedure.

9. HYDRAULIC PERFORMANCE
The data presented herein is the result of statistical analysis and indicates an approximate estimate of the performance of this facility.

Discharge Cfs (m^3/s)	Estimated Exceedence Probability (%)	Change in existing flood levels ft. (m)	Flood stage upstream of bridge ft. (m)	Velocity thru Bridge Structure ft/s (m/s)
	50%			
	20%			
	10%			
	4%			
	2%			
	1% Natural			
	1% Floodway			
	0.2%			

10. HYDROLOGY

The hydrologic analysis for this project was predicated on Flood Insurance Data for <<county/city name>> county.
The hydrologic analysis for this project was predicated on data obtained by VDOT personnel.

Design Discharge ______cfs (m^3/s) Design Recurrence Interval _____ %

HISTORICAL DATA

Highwater elevations were obtained by field reconnaissance and were correlated with the hydraulic data.
Highwater Elevation _______ ft (m) _____ Date
11. HYDRAULIC

The hydraulic analysis was performed using FHWA water surface profile computer model WSPRO.
The hydraulic analysis was performed using USACE water surface profile computer model (HEC-2/HEC-RAS).

LD-293C
(3/20/07)

Page 4 of 4

DEPARTMENT OF TRANSPORTATION
LOCATION & DESIGN
ENVIRONMENTAL DATA & HYDRAULIC COMMENTARY FOR PERMITS

The hydraulic analysis was performed using accepted principals and techniques of river mechanics applicable to this site.
The proposed facility will not increase the 1% Flood Stage.
The proposed facility will not increase the 1% Flood Stage by more than 1.0 foot.

Design Flood Stage Elevation _______________ ft. (m)

12. CAUSEWAYS

The use of causeways for temporary construction access was not considered in this analysis. If it is subsequently found necessary to use causeways, they must be submitted to the Hydraulics Unit for analysis and documentation.

Temporary construction access causeways for this project should be composed of <<specify>>.
The ordinary highwater will be increased by ______ft. (m)
The high flow profiles will not be affected.
The causeway will not affect the water surface profile.
The maximum causeway elevation is _____________ft. (m)
From abutment A to station
From station ________to abutment B.
Only one will be in place at a time.

13. EROSION AND SEDIMENT CONTROL

An erosion and sediment control plan will be prepared and implemented in compliance with the Erosion and Sediment Control Law, the Erosion and Sediment Control Regulations, and VDOT's Annual Erosion and Sediment Control Standards and Specifications approved by the Department of Conservation and Recreation.

14. STORMWATER MANAGEMENT

Design of this project will be in compliance with the Stormwater Management Act, the Stormwater Management Regulations, and VDOT's Annual Stormwater Management Standards and Specifications approved by the Department of Conservation and Recreation.

Appendix 12C-1 LD-23 Structure and Bridge Data Sheet

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE AND BRIDGE DATA SHEET

Project________________________________County _______________________________________
Federal Route Base No._______________ Situation data for design of bridge on Route ______________
Over____
Plane Coordinates or Latitude and Longitude from Transportation Department County Map ____________
____
Date of Survey:________________________ Location (Nearest Town, etc.)_______________________

GENERAL INSTRUCTION

Fill out all blanks carefully, giving information on all points. High water data is especially important and should be thoroughly investigated. Comments on any item covered in Survey Instruction Manual which are not covered below should be noted on an attached sheet.

HYDRAULIC SURVEY

1. EXISTING STRUCTURE

Existing structure is any structure at, upstream, or downstream from the proposed site have comparable drainage area.
Date of original construction:____
Was present bridge in place at time of extreme high water? ___________________________________
Has bridge ever been washed out?__________Date___________Mo.__________ Yr.__________
Explain what portion of bridge or approaches have been washed out: _____________________________
Elevation of maximum high water:
Upstream side of existing structure____
Downstream side of existing structure ____
________Ft. upstream of existing structure ____
________Ft. downstream of existing structure____
At other locations on the flood plain (describe)
____
____
Date of maximum high water: ______Mo.______Yr._______Source of information __________________

2. STREAM FLOW DATA AT PROPOSED SITE

Elevation of maximum high water of this stream at proposed location if different from data for existing site:
______Ft. on upstream side of Proposed____
______Ft. on downstream side of proposed____
At other locations on the floodplain (describe) ____
Date:______Mo.______Yr.______Source of information_______________________________________
____
Elevations of highest backwater caused by another stream____________________________________
Date_____________________ Stream name____
Source of information____
Elev. of normal water:_______ (Average) Elev. of extreme low water ______________________________
Date:______________Mo.____________Yr.____________
Source of information____
Velocity of current at high water:_________ft./sec. Velocity of current at normal water___________ft./sec.

3. SITE CONDITIONS

Amount and character of drift during a freshet or flood: ____
____
Amount and character of ice: ____
Do banks or bed show scour?____
Description and location of scour:____

Appendix 12C-1 LD-23 Structure and Bridge Data Sheet

____
Bed of stream consists mainly of: mud, silt, clay, sand, gravel, cobbles, boulders, soft solid rock, stratified rock, hard rock, silt sedimentation, deposition of large stones, is this material loose or well compacted:

Comments on stream ecology and wild life habitat: ____

4. INFLUENCE & CONTROL OF SITE

Location and condition of dams upstream or downstream that will affect high water or discharge at this site:
____
____
Location and description of any water-gaging stations in the immediate vicinity: ______________________
____
____
Elevation________________ on gage corresponds to elev.____
____________________on survey datum.
Extent to which sinkholes affect runoff, etc.:____
____
Brief description of usage of stream for navigational purposes. By small boats, etc___________________
____
____
____

Railroad Grade Separation Structure Site Data

Railroad milepost__________________ No. of tracks____
Situation data for design of bridge on _________________ over______________________________________
Type of construction: ___________________________ New structure
___________________________ Replacement of existing structure
___________________________ Remodeling of existing structure
___________________________ Paralleling existing structure

Owner of existing structure ____

Owner of grade crossing to be eliminated ____

Date of original construction of any railroad structure being replaced or within approximately 500 feet of the site of a proposed overpass____

Conditions of existing cut slopes, whether stable, eroded, et cetera_________________________________
_______________________. Are ditches open, maintained, et cetera________________________________
NOTE: Show cross-section of existing railroad is at right angles to centerline crossing, with all dimensions, on bridge situation plan. This cross-section should extend from top of cut to toe of fill.

REMARKS

____
____
____
____

Appendix 12C-2 Tidal Bridge Scour Data and Worksheet

VIRGINIA DEPARTMENT OF TRANSPORTATION
TIDAL BRIDGE SCOUR DATA & WORKSHEET

Hydraulic Engineer:_________
Date:_________

I. BRIDGE LOCATION

BRIDGE No. _________ Route: _________ County No. _________
Length: _________ Ft. River: ______________________

TIDAL BRIDGE CATEGORY: Islands Semi-Enclosed Bays & Inlets Estuary

II. CHANNEL CROSS SECTION

Channel Width (U/S 100 ft) W_u = ______Ft. Channel Width (at Bridge) W_o ______Ft.
Width (between abutment) W_d = ______Ft.
Average Water Depth (below MSL/MLW/MTL) D= _________Ft.
Clearance (from MSL/MLW/MTL to Lower Chord) C= _________Ft.
Note: Mean sea level (MSL), mean low water (MLW), mean tide level (MTL)
Skew Angle (Centerline of Bridge with Channel) Phi (ϕ) = _________° (Degrees)

II. DRAINAGE AREA CHARACTERISTICS

(Information per USGS Report 94-4148 for Virginia Department of Transportation dated 1995)
Drainage Area: ___Sq. Mi.; Forest: F = ____%; Average basin elevation: EL=_____Ft.
Main Channel Slope: SI=_____Ft/Mi; Main Channel length: L=_____Mi.
Peak Discharge Region Used:______________________________

Compute from USGS Regression Equation:
Q_{r100} = _________________CFS; $Q_{r500} = 1.7\,(Q_{r100})$ = _________________CFS

III. STORM TIDES

100-year High Tide: H_{100} = _________Ft. Period: T_{100} = _________Hrs.
500-year High Tide: H_{500} = _________Ft. Period: T_{500} = _________Hrs.
Surface Area of Tidal basin at MSL: As = _________Sq. Mi.
at _____Ft.: As = _________Sq. Mi.
at _____Ft.: As = _________Sq. Mi.

Compute Tidal Flows:
Q_{t100} = _________________CFS; $Q_{t500} = 1.7\,(Q_{r100})$ = _________________CFS

IV. FLOW VELOCITY

a) Based on Cross Sectional Area at MSL/MLW
Cross Sectional Area, $A_1 = W_oD$ = _________________Ft^2
$V_{r100} = Q_{r100}/A_1$ = _________Ft/S $V_{r500} = Q_{r500}/A_1$ = _________Ft/S

b) Based on Cross Sectional Area at Midtide Elevation
$V_{t100} = (Q_{t100} + Q_{t100}) / (A_1 + W_oH_{100}/2)$ = _________ Ft/S
$V_{t500} = (Q_{t500} + Q_{t500}) / (A_1 + W_oH_{500}/2)$ = Ft/S

c) Based on Manning Equation (n = 0.025; s = 0.0005)
$V_{t100} = 1.2\,((Q_{r100} = Q_{t100}) / W_o)^{0.4}$ = _________ Ft/S
$V_{t500} = 1.2\,((Q_{r500} = Q_{t500}) / W_o)^{0.4}$ = _________ Ft/S

Attach a Sketch of Cross-Section at Upstream (U/S) Side of Bridge

Appendix 12C-3 Table of Storm Tide Description of Virginia Coast

VIRGINIA DEPARTMENT OF TRANSPORTATION
Table of Storm Tide Description of Virginia Coast

DERIVED CHARACTERISTICS	STORM TIDE DESCRIPTION			
	500-Year (P-0.002)	100-Year (P-0.01)	50-Year (P-0.075)	10- Year (P-0.1)
Suitable R/V Probability	p-0.50	p-0.12	p-0.075	p-0.05
Part A – General Values for Virginia Tidal Waters				
Correspondence R/V Value	2 hr	1 hr	0.8 hr	0.7 hr
Tide Duration, D – 10 R/V	20 hr	10 hr	8 hr	7 hr
Part B – Specific Example for Hampton Roads				
Storm Tide Elevation, E	11.2 ft	8.8 ft	7.8 ft	5.8 ft
E/D, ft/hr	0.56	0.88	0.97	0.83

Appendix 12C-4 Virginia Coastal Maps Showing Predicted Water Surface Elevations

VIRGINIA DEPARTMENT OF TRANSPORTATION
Maps of the Costal Regions of Virginia

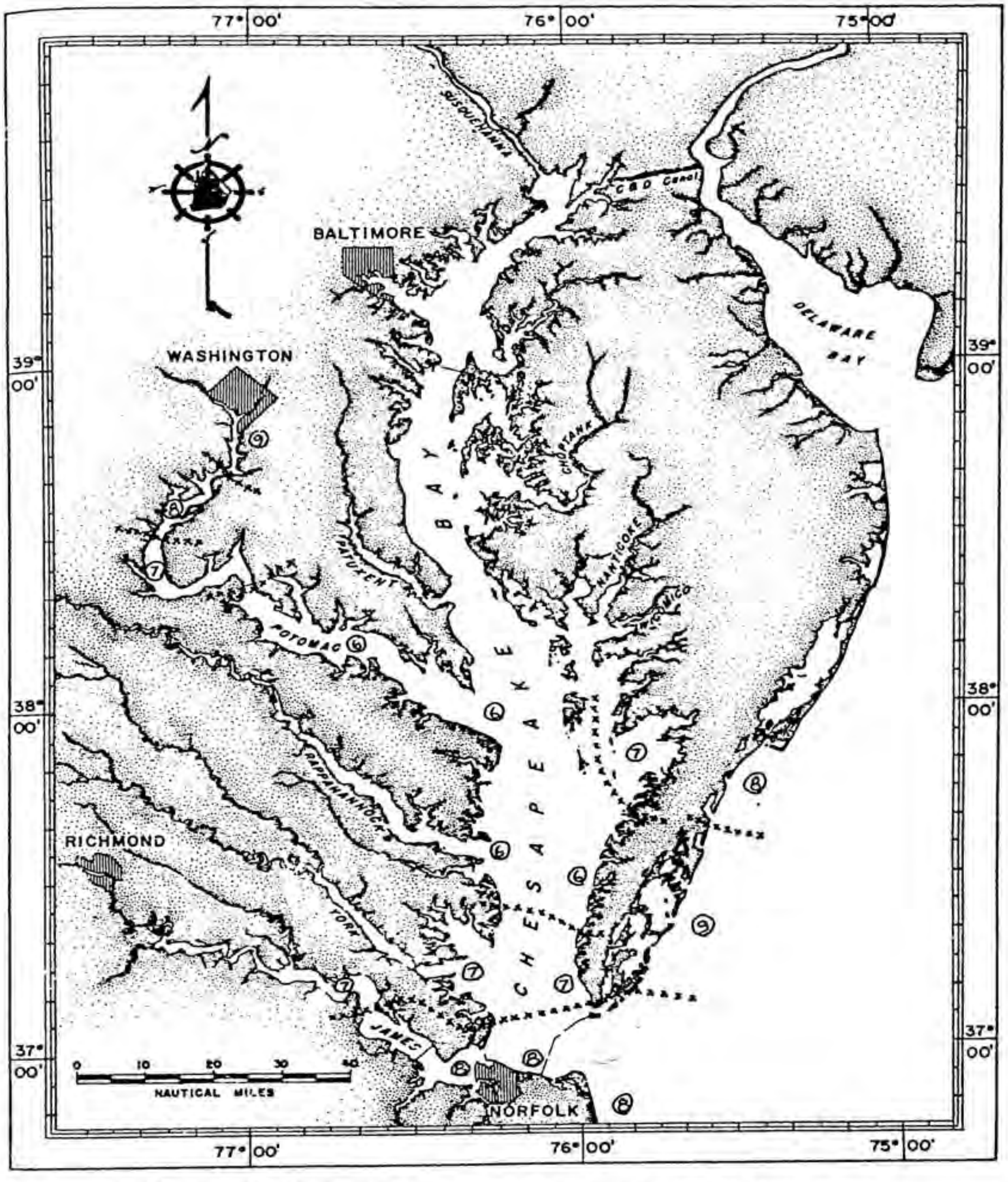

FIGURE 24A. ESTIMATED TIDAL FLOOD ELEVATIONS FOR 50-YEAR EVENT.

Appendix 12C-4 Virginia Coastal Maps Showing Predicted Water Surface Elevations

VIRGINIA DEPARTMENT OF TRANSPORTATION
Maps of the Costal Regions of Virginia

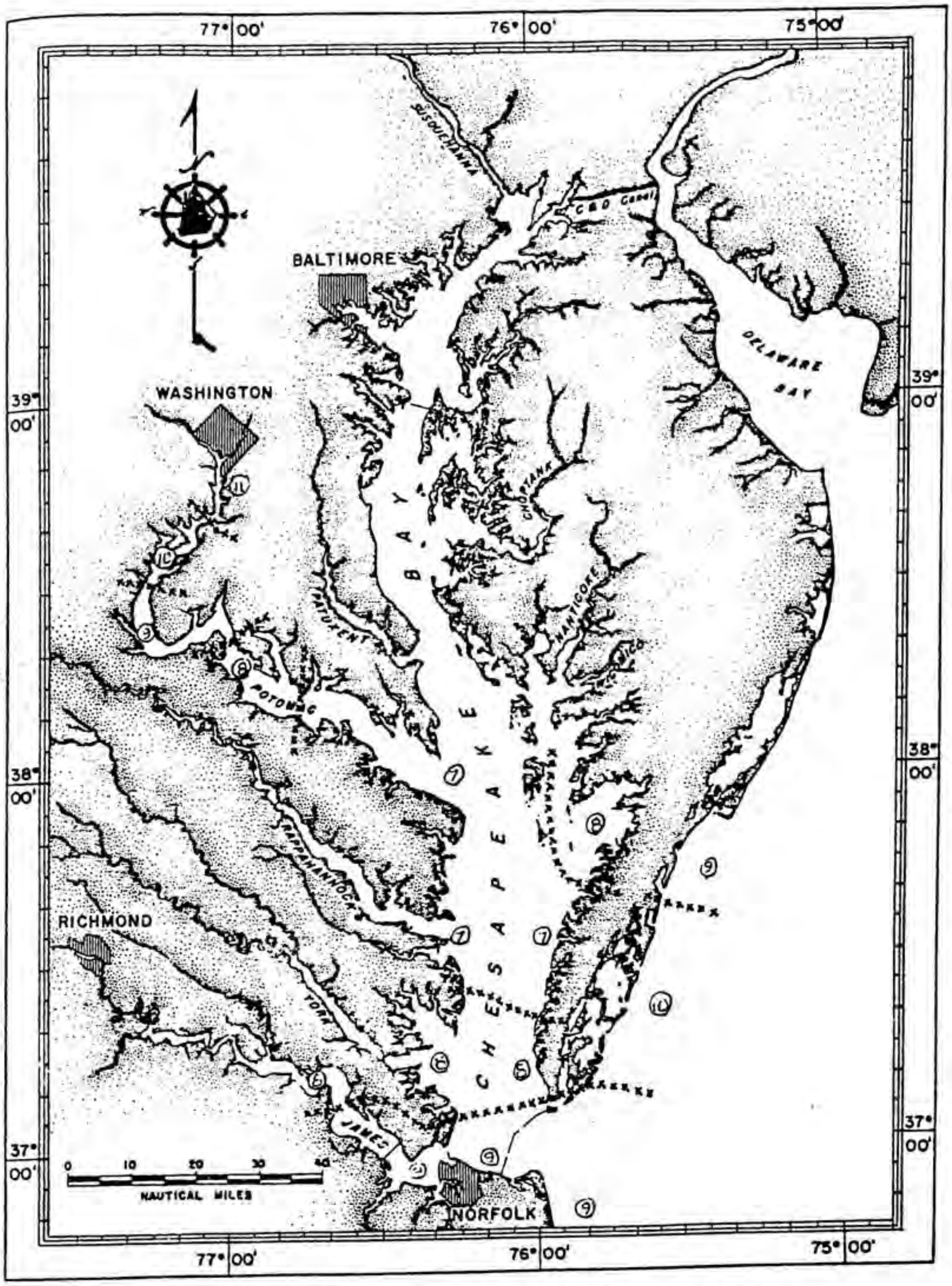

FIGURE 0. ESTIMATED TIDAL FLOOD ELEVATIONS FOR 100-YEAR EVENT, IN FEET ABOVE NGVD. 10 HOURS FOR FLOOD RISE AND FALL IS APPROPRIATE TO HURRICANE PASSAGES CAUSING THIS EVENT.

Appendix 12C-4 Virginia Coastal Maps Showing Predicted Water Surface Elevations

VIRGINIA DEPARTMENT OF TRANSPORTATION
Maps of the Costal Regions of Virginia

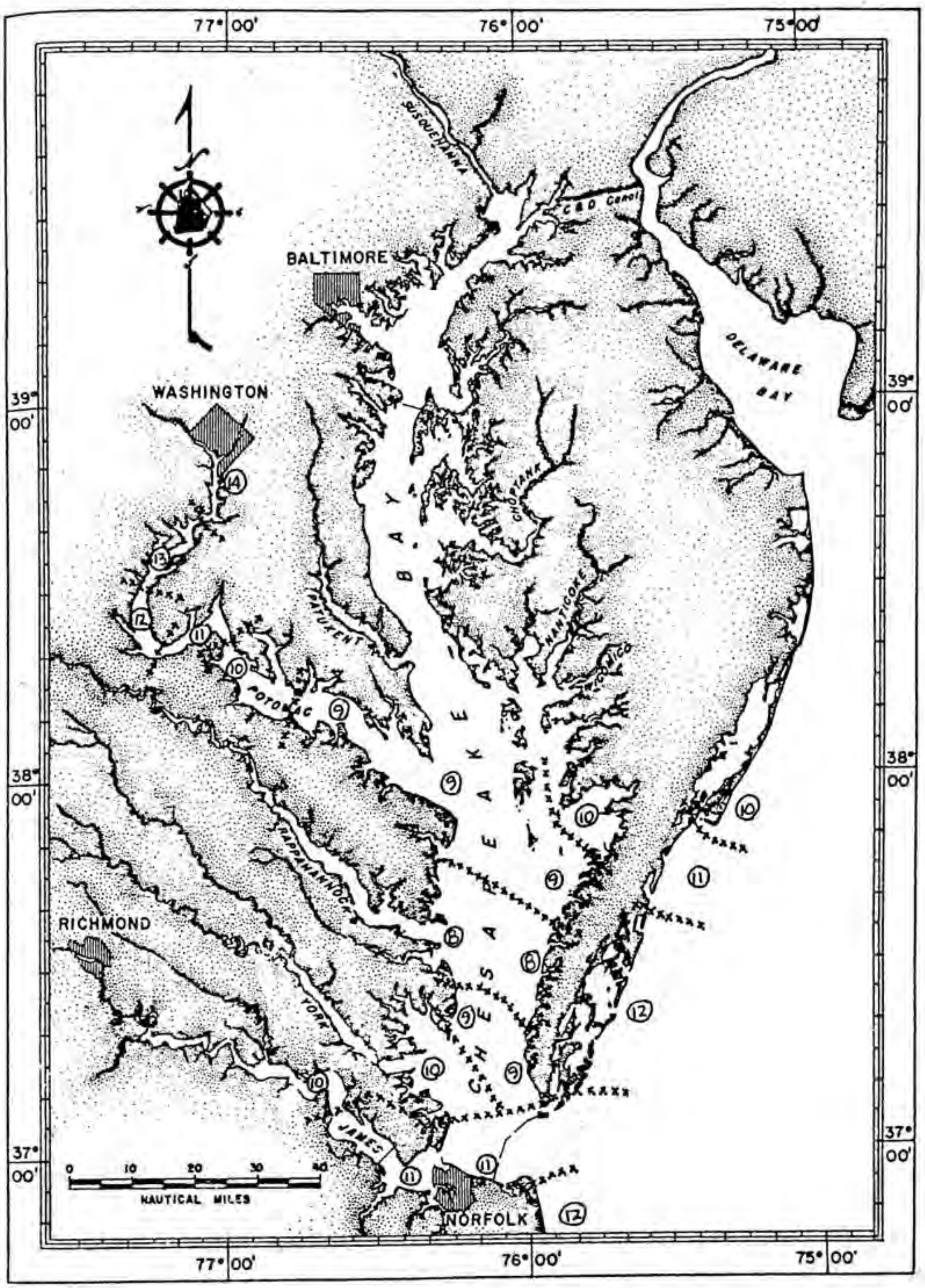

FIGURE 24C. ESTIMATED TIDAL FLOOD ELEVATIONS FOR 500-YEAR EVENT.

Appendix 12D-1 Guidelines for the Determination, Documentation, and Processing of Hydraulically Equivalent Replacement Structures (HERS)

12D-1.1 Background

This is to update the guidelines presented in memoranda from Mr. C.F. Boles, III on November 9, 1987 and November 18, 1987 for Hydraulically Equivalent Replacement Structures (HERS) and includes the supplemental scour evaluation recommendations presented in an e-memo by Mr. D.M. LeGrande on August 15, 2000. The purpose of Mr. Boles' original memoranda was to establish guidelines for the determination, documentation, and processing of proposed HERS facilities.

12D-1.2 Definition

A HERS determination is only applicable to the replacement of a culvert or bridge, either the complete structure or portions thereof, with a hydraulically identical culvert or bridge. It is not intended to be applied to the replacement of a bridge with a culvert or the replacement of a culvert with a bridge. The waterway opening of the proposed structure must provide the same height and width as the existing facility. An exception would be instances where existing bridge piers were being removed and not replaced. The proposed roadway grades on the approaches and parapet walls on the proposed bridge superstructure must be such that the same flood overtopping characteristics prevail as would be experienced by the existing facility. It should be noted that a larger proposed facility, though it may be more hydraulically efficient than the existing facility, would not necessarily qualify for a HERS determination as the scour characteristics and potential would normally be different from that of the existing facility. If it can be determined, via a field review by the structural engineer, the geotechnical engineer, and the river mechanics engineer, that a suitable foundation is present (i.e. rock of good quality is at or near the surface), a formal H&HA would not be needed. Whatever the decision, we need to be ever mindful of the potential consequences of not performing a formal H&HA, be they litigation or failure of the structure or both.

12D-1.3 Authorization

A HERS determination can only be made by one of the Department's River Mechanics Engineers or, if a River Mechanics Engineer is unavailable, by one of the Department's Hydraulic Engineers (including the District Drainage Engineers), provided such Hydraulic Engineer has been properly trained and is experienced in river mechanics engineering and bridge hydraulics. If neither a River Mechanics Engineer or Hydraulic Engineer having the necessary training and/or experience is available, the determination as to whether or not a proposed structure qualifies for a HERS determination shall be as directed by the Department's State Hydraulics Engineer.

Appendix 12D-1 Guidelines for the Determination, Documentation, and Processing of Hydraulically Equivalent Replacement Structures (HERS)

12D-1.4 Required Hydraulic Studies

When the proposed bridge is determined to be the hydraulic equivalent of the existing facility and it has also been determined that scour won't be a problem (refer to "Scour Evaluation Guidelines" shown below), no formal H&HA will be required. However, in the event a previous H&HA has been prepared either for or by the Department or by virtue of a FEMA flood insurance study, this information should be used to complete all required documentation and, in the event a scour evaluation must be performed, as a source of information necessary to perform such evaluation. Regardless of whether or not the proposed structure has been determined to qualify for a HERS classification, if it is found that a formal scour analysis is needed, such H&HA as is necessary to perform the scour analysis shall be conducted. In the event a FEMA hydraulic model is not available or cannot be used, it shall be necessary to conduct a complete H&HA to determine those factors necessary to conduct the scour analysis.

12D-1.5 Scour Assessment and/or Analysis

If the proposed facility has been determined to qualify for a HERS classification and no hydraulic data is available from any source, an assessment of the scour potential may be made using the following guidelines:

(1) A careful review of the bridge inspection reports for the existing bridge
(2) Checking for the availability of scour data for the existing bridge that may have been obtained during the FHWA mandated bridge scour evaluation program
(3) Checking (or having the bridge designer check) the "Item 113" code in the Bridge Inventory under the HTRIS system
(4) An on-site inspection, if possible accompanied by a Bridge Engineer and a Geotechnical Engineer

If there is <u>any evidence whatsoever,</u> that the existing bridge is experiencing scour problems, the designer should assume that a proposed HERS replacement will experience those same problems. In such cases a detailed hydraulic analysis <u>shall be performed</u> to determine such information as will be necessary to perform a detailed scour analysis. If time constraints, no FEMA or other previous hydraulic study is available, lack of or limited survey, etc. or other restrictions prevail, the analysis can be abbreviated but must still be performed. The engineer's findings regarding scour potential could be sufficient justification for the consideration of an entirely different replacement bridge layout.

Appendix 12D-1 Guidelines for the Determination, Documentation, and Processing of Hydraulically Equivalent Replacement Structures (HERS)

12D-1.6 Documentation

If no hydraulic data was available and/or none was performed, and scour was determined not to be a consideration, only the following documentation need be prepared:

(1) The “Hydrologic Data Sheet” (extracted from the LD-293 document) prepared in accordance with the attached example – it should be sent to the bridge designer and the road designer if an associated roadway project is involved

(2) LD-293B – to serve as a cover letter to convey the “Hydrologic Data Sheet” to the road designer (if applicable), to serve as a cover letter to convey the LD-293C document to the District Environmental Manager, and notify the Public Involvement Section of no hydraulic impacts

(3) LD-293C – to be completed with such information as is available and sent to the District Environmental Manager

If hydraulic data was available or if a scour analysis had to be performed (if it was determined that scour potential was significant) then all the usual documentation shall be prepared and distributed.

Appendix 12D-1 Guidelines for the Determination, Documentation, and Processing of Hydraulically Equivalent Replacement Structures (HERS)

EXAMPLE HYDROLOGIC DATA SHEET FOR USE ON HERS FACILITIES

HYDROLOGIC DATA SHEET

The information presented hereon is to be transcribed to the Hydrologic Data Sheet contained in the plan assembly.

DESCRIPTION

Sheet No. 4 Station 31+90

Stream Name Accotink Creek

Drainage Area 17 sq. mi

Structure Size 45' single span bridge

BASE FLOOD

Discharge 11,600[1] cfs

Stage Elevation 265.6[1] ft.

DESIGN FLOOD

Discharge no H&HA performed[2] cfs

Estimated Exceedence Probability no H&HA performed[2] %

Stage Elevation no H&HA performed[2] ft.

OVERTOPPING FLOOD

Stage Elevation 261.8 ft.

Estimated Exceedence Probability no H&HA performed[2] %

HISTORICAL DATA

Date Feb. 1979

Stage Elevation 258.6 ft.

Estimated Exceedence Probability no H&HA performed[2] %

REMARKS

[1] Discharges and elevations are taken from U.S.G.S. open file report 76-442 dated 1977.

[2] This structure and its approaches are the hydraulic equivalent of the existing facility and no formal H&HA was prepared.

No significant hydraulic impact is anticipated as a result of this project.

Appendix 12E-01 Daily Stream Flow information