

## **9.3 Design Criteria**

### **9.3.1 AASHTO General Criteria**

Following are the AASHTO general criteria related to the hydraulic analyses for the location and design of bridges as stated in the 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.
- Underclearance at structure(s) designed to pass anticipated debris and ice.
- Acceptable risks of damage or viable measures to counter the vagaries of alluvial streams.
- Minimal disruption of ecosystems and values unique to the floodplain and stream.
- Provide a level of traffic service compatible with that commonly expected for the class of highway and compatible with projected traffic volumes.

### **9.3.2 ConnDOT General 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 the water surface profile programs such as HEC-RAS, HEC-2, or WSPRO.

- **Travelway** - Inundation of the travelway 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 the Hydrology chapter.

- **Risk Evaluation** -The selection of hydraulic design criteria for determining the waterway opening, road grade, scour potential, riprap and other features should consider the potential impacts to traffic, adjacent property, the environment and the infrastructure of the highway.

The consideration of the potential impacts constitutes an assessment of risk for the specific site. The least total expected cost (LTEC) alternative should be developed in accordance with FHWA HEC-17 where a need for this type of analysis is indicated by the risk assessment. This analysis provides a comparison between other alternatives developed in response to considerations such as environmental, regulatory and political. (See Section 9.6.7)

- **Design Floods** - Design floods for the purpose of the evaluation of backwater, clearance and overtopping should be established predicated on risk based assessment of local site conditions. They shall reflect consideration of traffic service, environmental impact, property damage, hazard to human life and floodplain management criteria. ConnDOT has defined various structure types based on watershed area as defined below. (See Table 9-2):

- **Backwater/Increases Over Natural Conditions** - Conform to FEMA regulations for all sites and stream channel encroachment line requirements for sites within established encroachment lines. In general, for sites not specifically identified in the FEMA or SCEL programs, backwater over natural conditions should not exceed 0.3m (1 ft.) during the passage of the 1% exceedence probability flood. (See Table 9-2)
- **Underclearance** - Where practicable a minimum clearance of 0.6 m (2 ft.) should be provided between the design approach water surface elevation and the low chord of the bridge for the final design alternative to allow for passage of ice and debris. Where this is not practicable, the clearance should be established by the designer based on the type of stream and level of protection desired as approved by the Hydraulics and Drainage section. (See Table 9-2).
- **Flow Distribution** - The conveyance of the proposed stream-crossing location shall be calculated to determine the flow distribution and to establish the location of bridge opening(s). The proposed facility shall 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% redistribution of flow.
- **Scour** - Design for bridge foundation scour considering the magnitude of flood, including the 1% event, that generates the maximum scour depth. The foundation shall be evaluated by geotechnical and structural engineers for both a design event (100-yr. storm) and an extreme event (500 year) to insure that the appropriate stability criteria are met. (See Section 9.5.)

### 9.3.3 Minor Structures

These shall include culverts or bridges providing waterway for the drainage of adjacent land, in which there is no established watercourse, having a drainage area less than 2.59 km<sup>2</sup> (1 mile<sup>2</sup>) (See Table 9-2).

Minor structures shall be designed to pass the 25-year frequency discharge determined by the appropriate method found in the Hydrology chapter. The water surface upstream at design discharge shall not be elevated so as to damage adjacent property or endanger the highway.

### 9.3.4 Small Structures

These shall include culverts or bridges providing waterways for the drainage of areas of less than 2.59 km<sup>2</sup> (1 mile<sup>2</sup>) in which there is an established watercourse. (See Table 9-2).

Small structures shall be designed to pass a 50-year frequency discharge as outlined in the Hydrology chapter. The effects of a discharge equal to the 100-year flood passing through the proposed construction shall be investigated.

At locations where the stream has been studied in detail (FIS Study includes water surface profiles in the area of the design proposal), a 100-year return frequency shall be used for the design discharge.

Where a likelihood of danger to persons, extensive property damage or other than temporary interruption of traffic will exist under these conditions, increases in waterway or other improvements shall be provided to alleviate the danger.

The water surface upstream shall not be elevated so as to endanger the roadway or damage private property. At the upstream highway property boundary, the elevation shall generally be not more than 0.3m (1 ft.) over that which is achieved under natural flow conditions.

Where successive culverts are utilized on a project and the flow in upper culverts is affected by headwaters in the lower culverts, a water surface profile and appropriate computations shall be submitted for review.

### **9.3.5 Intermediate Structures**

These shall include culverts or bridges providing waterway for the drainage of areas larger than 2.59 km<sup>2</sup> (1 mile<sup>2</sup>) and less than 25.9 km<sup>2</sup> (10 mile<sup>2</sup>) (See Table 9-2.).

Intermediate structures shall be designed to pass a discharge equal to the 100-year flood with low chord underclearance not less than 0.3m (1 ft) (not required for culverts) and a backwater usually not to exceed 0.3m (1 ft) above that which would have been obtained in the natural channel if the highway embankment were not constructed except when other limitations may be required by the General Statutes and the resulting water surface elevation which will not endanger the roadway nor cause damage to developed property upstream. The effects of a discharge equal to the 500-year flood passing through the proposed construction shall be investigated. Where a likelihood of danger to persons, extensive property damage or other than temporary interruption of traffic will exist under these conditions, increases in waterway or other improvements shall be provided to alleviate the danger, whenever possible.

Rating curves for intermediate structures are required in order to better enable reviewers to determine the probabilities of danger to persons or property for floods of various return frequencies. These rating curves shall be extended far enough to determine the effects of a recurrence equivalent to the flood of record, if such flood is greater than the design discharge. They shall in all cases show the effects of 2, 10, 50-year, 100-year and 500-year frequency storms.

### **9.3.6 Large Structures**

These shall include culverts or bridges providing waterway for the drainage of areas larger than 25.9 km<sup>2</sup> (10 mile<sup>2</sup>) and less than 2590 km<sup>2</sup> (1000 mile<sup>2</sup>) (See Table 9-2).

Large structures shall normally be designed to pass a discharge equal to the 100-year flood with a low chord underclearance generally not less than 0.6m (2 ft.) (not required for culverts) and an increase in water surface elevation at the upstream highway property line of not more than 0.3m (1 ft.) above that which would have been obtained in the natural channel if the highway embankment were not constructed except where other limitations may be required by the General Statutes. This elevation may be decreased as needed to avoid damage to developed property upstream. The effects of a discharge equal to the 500-year flood passing through the proposed construction shall be investigated. Where a likelihood of danger to persons, extensive property damage or other than temporary interruption of traffic will exist under these conditions, increases in waterway or other improvements shall be provided to alleviate the danger, whenever possible.

Rating curves for large structures are required in order to better enable reviewers to determine the probabilities of danger to persons or property for floods of various return frequencies. These rating curves shall be extended far enough to determine the effects of a recurrence equivalent to the flood of record, if such flood is greater than the design discharge. They shall in all cases show the effects of 2, 10, 50-year, 100-year and 500-year frequency storms.

### 9.3.7 Monumental Structures

Bridges providing waterway for streams draining areas greater than 2590 km<sup>2</sup> (1000 mile<sup>2</sup>). (See Table 9-2).

Monumental structures shall be designed to meet requirements established by the Inland Water Resources Division (IWRD), of the Department of Environmental Protection, the U.S. Army Corps of Engineers and the U.S. Coast Guard, communicating with these agencies for the particular location, taking into consideration channel encroachment lines, navigation requirements and past flooding history. As a minimum, the design shall conform to the requirements of large structures.

The hydraulic characteristics of monumental structures shall be established by special studies initiated during the planning or early design stages by or in cooperation with the Hydraulics and Drainage Section.

### 9.3.8 Tidal Structures

These shall include all structures of whatever type providing waterway on streams subject to tidal action. They shall be classified as minor, small, intermediate, etc. depending on their riverine drainage area.

Tidal structures shall normally be designed to pass the appropriate design discharge for the foregoing category into which they would normally be classified with the same limitations as apply to the appropriate class.

Unlike inland rivers where the design discharge is fixed by runoff and is virtually unaffected by the waterway provided, the size of the waterway opening of a tidal structure can modify the tidal regime and the associated tidal discharges.

Long-term aggradation and degradation at a tidal inlet or estuary are influenced primarily by the periodic tidal fluctuations associated with astronomical tides. Therefore, flow hydraulics at a bridge should be determined considering the tidal range for evaluation of long-term aggradation or degradation.

Extreme events associated with riverine floods and tidal storm surges should be used to determine the hydraulic adequacy of a bridge. These events would have a return period based on the structure classifications as previously defined. Difficulty arises in determining whether the storm surge, flood or the combination of the storm surge and flood should be considered controlling.

When inland flood discharges are small in relationship to the magnitude of the storm surge and are the result of the same event, then the flood discharge can be added to the discharge associated with the design tidal flow, or the volume of the runoff hydrograph can be added to the volume of the tidal prism. If the inland flood and the storm surge may result from different storm events, then a joint probability approach may be warranted to determine the magnitude of the design discharge.

In some cases there may be a lag time between the storm surge discharge and the stream flow discharge at the highway crossing. For this case, streamflow-routing methods such as the NRCS TR-20, USACOE HEC-1 or HEC-HMS model can be used to estimate the timing of the flood hydrograph derived from runoff of the watershed(s) draining into the sound or estuary.

The selection of the method to use to combine flood and tidal surge flows is a matter of judgement and must consider the characteristics of the site and the storm events.

For further information regarding tidal hydrology and hydraulics, the designer is directed to the manual entitled "TIDAL HYDRAULIC MODELING FOR BRIDGES", Ayres Associates, March 2002. This manual was developed under a "Pooled Fund Study" entitled "Development of Hydraulic Computer Models to Analyze Tidal and Coastal Stream Hydraulic Conditions at

Highway Structures". The Department participated in the study with the FHWA and several other coastal states with the purpose of developing improved methods to determine hydraulic conditions at bridges in tidal waterways. Chapter 3 of the referenced manual contains the storm surge hydrology results of the study. This chapter presents equations for estimating astronomical tides and storm surge hydrographs. Guidance is also presented on the combining of inland runoff (riverine discharge) with storm surges. A copy of this manual may be obtained from the Hydraulics and Drainage Section for Department funded projects. This manual should be consulted prior to developing the scope of work for the hydraulic analysis of tidal structures. See also Section 9.4.5 regarding the hydraulic analysis and modeling of coastal or tidally influenced waterways.

**Table 9-2**

**SUMMARY OF HYDRAULIC CRITERIA<sup>5</sup>**

CONNDOT STRUCTURE CLASS <sup>3</sup>	DRAINAGE AREA sq. km (sq. mile)	DESIGN FREQUENCY (year)	CHECK FREQUENCY (year)	MINIMUM FREEBOARD <sup>2</sup> FOR DESIGN FREQUENCY m (ft)	MINIMUM BRIDGE UNDER-CLEARANCE FOR DESIGN FREQUENCY m (ft)
Minor	<2.59 (1) (no established watercourse)	25	-	0.3 (1)	-
Small	<2.59 (1)	50	100	0.3 (1)	-
Intermediate <sup>1</sup>	≥2.59 (1) <25.9 (10)	100	500	0.3 (1)	0.3 (1)
Large <sup>1</sup>	≥25.9 (10) <2590 (1000)	100	500	0.3 (1)	0.6 (2)
Monumental	≥2590 (1000)	100 <sup>4</sup>	500 <sup>4</sup>	0.3(1) <sup>4</sup>	0.6 (2) <sup>4</sup>

<sup>1</sup> The designer shall also consider culvert alternative (see 9.1.2 and Chapter 8) for this class when area > 2.59 km (1 mi<sup>2</sup>)

<sup>2</sup> Freeboard is defined as the vertical distance between the design water surface and the upstream control such as the low point of the roadway edge, sill of a building or other controlling element.

<sup>3</sup> See Section 9.3.3 through 9.3.8 for detailed discussions on structure classification.

<sup>4</sup> Minimum requirements subject to prior approval from Hydraulics and Drainage Section.

<sup>5</sup> See Section 9.3.9, Design Exceptions

### 9.3.9 Design Exceptions

The design criteria stipulated in this manual, including underclearance, freeboard and backwater, may be waived when it can be demonstrated that satisfying these criteria would be impractical or inappropriate due to site conditions and other factors. These factors may include but not limited to, economics, environmental impacts, constructability, rights of way and potential impacts to adjacent property.

With the exception of the specific CTDOT hydraulic design criteria being waived, projects must be demonstrated to be in compliance with the Flood Management Statutes and Regulations for State Agencies and the requirements of the National Flood Insurance Program (NFIP) for Flood Management Certification (FMC).

The reason(s) for not satisfying the design criteria shall be documented in the Hydraulic Design Report and the Floodplain/Floodway Analysis Report (if prepared separately for Flood Management Certification), along with the hydraulic analyses and other information demonstrating compliance with the Flood Management regulations and NFIP requirements..

The criteria shall be waived and the requirements considered satisfied following review and approval of the aforementioned report(s) by the Hydraulics and Drainage (H&D) section.

For projects requiring FMC approval from the DEEP, the FMC application shall advise the DEEP of the specific design criteria waived and H&D's approval of the hydraulic report(s) in conformance to this Section (9.3.9) of the Drainage Manual.

It is important that exceptions to the design criteria and the reasons be identified early in the design process so that they may be properly vetted, reviewed and obtain concurrence from H&D. Design exceptions may not be approved by H&D if it appears that reasonable design changes could have been incorporated into the project to achieve compliance to the hydraulic design criteria.

### 9.3.10 Documentation

The following items shall be included in the documentation file (See Chapter 1, Section 1.6). The intent is not to limit data to only those items listed, but rather establish a minimum requirement consistent with the bridge design procedures as outlined in this chapter. If circumstances are such that the hydraulic design is prepared by other than the normal procedures or is governed by factors other than hydrologic or hydraulic, a narrative summary detailing the design basis shall appear with the other data.

The following items shall be included in the documentation file:

- design discharge values and discharge rating curves
- culvert performance curves
- allowable headwater elevation and basis for its selection
- type of culvert entrance conditions
- outlet velocities and energy dissipation calculations and designs
- cross section(s) used in the design water surface determinations
- roughness coefficient assignments (“n” values)
- observed highwater marks with associated dates and discharges

- natural, existing and proposed conditions water surface profiles for intermediate structures or larger
- velocity measurements and locations or velocity estimates. Include both the through-bridge and channel
- copies of all computer analyses with 3.5” computer disk and standard computation sheets given in this chapter
- magnitude and frequency of overtopping flood if less than the design
- tailwater depth or starting water surface elevation
- roadway geometry plan and profile
- potential flood hazard to adjacent properties
- completed forms in Appendix A
- scour evaluation/analysis for bottomless structures for design 100 yr. flood and 500 yr. flood
- economic analysis of design and alternatives
- risk assessment, if required
- bridge scour results (plan and profile)
- reasons for not satisfying specific design criteria, if applicable