

Chapter 17 - Flood Plain Hydraulic Studies

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Chapter 17 - Flood Plain Hydraulic Studies

17.1 Introduction

17.1.1 Purpose

The purpose of this chapter is to consolidate discussion of activities in flood plains into a single chapter that is consistent with the FHWA Guidance as outlined in Chapter 4. It includes language previously presented in Chapters 8 and 12.

This chapter addresses procedures for compliance with waterway and flood plain management requirements or regulations. The procedure described herein allows for the Department to obtain approvals from various regulatory agencies while fulfilling the applicable requirements and regulations discussed in Chapter 4.

17.1.2 Definitions

Action – Shall mean any highway construction, reconstruction, rehabilitation, repair or improvement undertaken by the Department.

Base Flood – This is the common description of the 1 percent chance flood as used in the Federal Documentation for both FEMA and FHWA. This is also commonly referred to as the 100 year flood, which describes the recurrence interval for the base flood event. See Chapter 6 for means and methods to estimate this value.

Base Flood Plain – That area subject to flooding by the base flood.

Base Flow – This is the flow that can be typically expected in the stream under normal flow conditions. See Chapter 6 for means and methods to estimate this value.

Design Flood – The storm event based on the criteria described in Chapter 6 for roadway safety; typically it is not to be less than 18” clearance to the low shoulder.

Design Hydraulic Study – Study performed via detailed methods in support of projects that are determined by VDOT Hydraulics Staff to have higher risk of adverse impact to the base flood elevation.

Encroachment – An action within the limits of the base flood plain

Flood Insurance Rate Map (FIRM) – FEMA published map showing flood plain zones, floodways, and other features used for implementation of the National Flood Insurance Program (NFIP).

Insurable Structure - For floodplain management purposes, a structure is a walled and roofed building, including a gas or liquid storage tank, principally above ground, as well as a manufactured home. The terms "structure" and "building" are interchangeable in the National Flood Insurance Program (NFIP). Residential and non-residential structures are treated differently. A residential building built in a floodplain must be elevated above the Base Flood Elevation (BFE). Non-residential buildings may be elevated or floodproofed.

Due to the magnitude of the changes to this section, shading has been omitted.

Regulatory Flood Plain – A delineated flood plain presented on the FEMA FIRMs that may or may not have a flood way and may or may not be based on detailed computations

Regulatory Floodway – A delineated zone located in some regulatory flood plains identifying an area of greater development restriction.

Location Hydraulic Study – Study based an engineering evaluation of the site conditions. A Location Hydraulic Study may be supported by approximate methods or abbreviated computations if needed.

Longitudinal Encroachment – An action that involves placement of fill within a base flood plain that is not directly in support of a stream crossing. This is often associated with a road widening project for an existing roadway adjacent to a stream or a new roadway

Maintenance – Any action that is necessary to maintain the serviceability or function of an existing roadway, stream crossing, longitudinal encroachment, stream element or flow conveyance.

New Construction – Any action involving a new roadway or modification of an existing roadway by substantially changing the alignment or grade.

Risk – In the context of the discussion in this chapter shall mean the consequences associated with probability of flooding during the base flood event attributed to an encroachment.

Stream Crossing – A VDOT asset that passes from one side of a waterway to the other, with the expressed purpose of conveying the traveling public.

Stream Realignment – Actions taken to relocate a portion of a stream as needed to facilitate other construction activities, improve approach angle or repairing damage to the roadway.

Stream Restoration – Actions taken within the degraded stream and flood plain with the intent to restore sediment transport balance and improve riparian habitat.

Temporary Measures – Actions within the base flood plain that are necessary to facilitate construction, or as a condition of an environmental permit, which will be removed prior to the end of the project.

17.1.3 Analysis and Design

When designing, constructing and maintaining VDOT assets within the base flood plain proper care should be taken to:

- Provide desired level of hydraulic performance up to an acceptable risk level
- Mitigate impacts to the stream environment
- Limit increases to base flood elevation
- Limit adverse impacts to offsite areas affected by the base flood
- Comply with the relevant recommendations of 23 CFR 650

17.1.4 Hydraulic Studies

The level of analysis necessary to make hydraulic determinations referenced in 17.1.3 will be commensurate with the level of risk associated with the scale, scope and location of the project.

For practical purposes only those actions in the base flood plain, which are likely to cause a noticeable adverse effect, or those that otherwise require environmental permits, would prompt a Location Study. The exempted actions would include, but are not limited to, painting, pothole repair, signage, guardrail repair, bridge maintenance activities, temporary measures, etc.

Evaluations of work being taken in base flood plains maybe divided into 2 categories, Location Hydraulic Study and Design Hydraulic Study.

17.1.4.1 Location Hydraulic Study

All new construction projects and those few maintenance projects subject to detailed environmental permits shall have a Location Hydraulic Study performed. This is to assess the potential for the project to impact the base flood plain elevation based on an appropriate prior condition. If it cannot be determined using sound engineering judgement that the project will not increase the base flood elevation, then a Design Hydraulic Study may be necessary. In addition there may be other factors that would dictate the need for a detailed study, primary among these would be scour computations.

17.1.4.2 Design Hydraulic Study

The Location Study, may conclude that a detailed engineering analysis is necessary to document the base flood elevation and aid in the design process for the purposes of assessing compliance with the impact limits. The Design Hydraulic Study will document the analysis using the appropriate prior condition and proposed condition flood elevations for comparison. The appropriate analysis tool will be selected based on the risk associated with the location and the complexity of the project.

17.2 Design Policy/Criteria

17.2.1 FHWA

17.2.1.1 Code of Federal Regulations

VDOT is subject to the federal guidance provided in 23 CFR 650 with respect to proposed actions and coordination with FEMA and Localities. VDOT is to apply the guidance to all base flood plains mapped or otherwise.

- Avoid longitudinal encroachments where practical
- Avoid significant encroachments where practical
- Limit impacts to the base flood elevation to no more than a 1' rise
- Be consistent with the intent of the NFIP where appropriate
- Apply these standards to all construction, repair, rehab and maintenance actions
- Location Studies shall be commensurate with the associated level of risk
- Design Studies, when necessary, shall be commensurate with the associated level of risk

In cases where a project impacts a FEMA mapped flood plain the following additional requirements are to be adhered to consistent with the correspondence between FHWA and FEMA in 1982 establishing the working relationship between the two Federal Agencies. Coordination with FEMA is required when:

- An encroachment into a regulatory floodway would cause an amendment to the floodway map
- An encroachment into a detailed study area without a floodway or a mapped area without base flood elevations (BFE) would cause more than a 1' rise.

17.2.1.2 Hydraulic Studies

A Location Hydraulic Study shall include the NFIP data if available, discussion of alternatives, risks to the base flood elevation, measures taken to minimize base flood impacts, and involve NFIP community coordination.

A Design Hydraulic Study shall be commensurate with the associated level of risk, detailed engineering analyses utilizing the NFIP data if available and appropriate, use of appropriate design storms, and consistent with the NFIP as practical.

No highway structure should be evaluated as a flood control element unless specifically designed as such and approved by the relevant state and federal agencies..

17.2.1.3 New Construction Criteria

The design hydraulic study shall include the following items for new construction not associated with an existing roadway.

- evaluation and discussion of the practicability of alternatives
- risks associated with implementation of the action/alternative
- impacts on natural and beneficial flood-plain values
- support of probable incompatible flood-plain development
- measures to minimize flood-plain impacts associated with the action
- measures to restore and preserve the natural and beneficial flood-plain values impacted
- evaluation and discussion of any support of incompatible flood-plain development

Due to the magnitude of the changes to this section, shading has been omitted.

For lateral encroachments also include

- reasons why the proposed action must be located in the flood plain
- alternatives considered and why they were not practicable

17.2.2 AASHTO

AASHTO guidance on flood plains suggests that increases in the flood elevation due to a transportation project will not significantly increase flood damage to property upstream of the project area and maintain the existing flood distribution to the extent practical.

17.2.3 VDOT

17.2.3.1 Design Storm

Inundation of the travelway and clearance below the low shoulder dictates the level of traffic services provided by the facility and would apply to all roadways located within the base flood plain (stream crossings and longitudinal encroachments). New construction and projects that significantly change the alignment or grade of the roadway shall have an 18" freeboard from the low shoulder to the design storm as determined by the functional classifications of roadways presented in Chapter 6, Hydrology.

17.2.3.2 Allowable Backwater

To protect the public from adverse impacts of flooding due to VDOT projects and meet the federal guidance, designers shall limit the increase to the base flood elevation (BFE) outside of the VDOT ROW to the values reported in Table 17-1.

Table 17-1. Allowable Base Flood Elevation Increases

Situation	Increase in BFE
Insurable structure within the base flood plain	0.0'
FEMA Zone A Area	1.0'*
FEMA Zone AE or A# but not within a floodway	1.0'
FEMA Zone AE floodway	0.0'
FEMA Detailed Study Stream with a Floodway	0.0'
Unmapped or undeveloped area	1.0'
Other zone designations not considered	Not applicable

* When data provided by the locality determines that the cumulative impact is no greater than 1.0'

In the event that the limitations in Table 17-1 cannot be met there will be additional coordination measures required such as pursuing a CLOMR and LOMR with FEMA or the acquisition of flood easements.

17.2.3.3 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% redistribution of flow provided such openings do not create a concentration of flow which could damage downstream properties.

17.2.3.4 Stream Restoration

To meet 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 base flood elevation comparison tables for the reach impacted by the stream restoration.

17.2.3.5 Flood Control Structures

A structure that is not designed as an impounding structure, dam or levee shall not be evaluated as such. VDOT does not permit the use of roadways as dams or levees. It is VDOT practice to not accept responsibility for portions of new roadways that have been designed as dams. Where there are existing roadways that are located on dams, it may be necessary to address current DCR Dam Safety Regulations prior to making any improvements to the roadway or any outfall structure.

17.2.3.6 Temporary Measures

The use of cofferdams, causeways or other measures necessary to meet environmental permit requirements or facilitate construction shall be minimized to the extent practical. However they will not be assessed for impacts to the base flood event, except at the discretion of the Engineer.

17.2.3.7 Hydrologic Methods

The methods as described in Chapter 6 may be used as appropriate. Alternate methods may be used at the discretion of VDOT. If it is determined that the NFIP Published discharges are inappropriate for use, this will be documented in the Design Study and computational methods used consistent with Chapter 6 to determine the discharges to be used for analysis and design.

17.2.3.8 Coastal

When the base flood plain is determined to be due to storm surge and not riverine flow, it is not expected that a VDOT project will affect the base flood elevations. As such activities in coastal areas will typically be limited to a Location Hydraulics Study. However there may be cases where a Design Hydraulic Study is required and they will be addressed on a case by case basis.

17.3 Design Concepts

If the Location Hydraulic Study determines that a Design Hydraulic Study is warranted such studies should reference the appropriate chapter of the Drainage Manual for detailed engineering means and methods based upon the nature of the work being performed. (See Chapter 8 for minor culverts, and see Chapter 12 for all other conditions.)

The following are guidelines governing the level of accuracy to show in the Location Hydraulic Study and Design Hydraulic Study:

- Elevations and distances from surveys are to be shown one decimal places.
- Elevations, distances, from plans, are to be shown up to two decimal places.
- The magnitude of peak discharges are to be shown to three significant figures.
- Velocities are to be shown to the nearest 0.1 fps.
- Calculated water surface elevations are to be shown to the nearest 0.1'.
- Changes in calculated water surface elevations are to be shown to the nearest 0.1'.
- Watershed areas are to be shown to the nearest square mile (sq.mi.) or 3 significant figures if less than 100 sq.mi.

17.4 Location Hydraulic Study

All design projects and those maintenance projects required to have detailed environmental permits are subject to a Location Hydraulic Study. The scope and scale of the study is determined by the nature of the work being performed. The study may be based upon best available data or may require a field visit. It may be appropriate to include computations to support the engineer's assessment of the conditions but they are not always necessary. Sample Location Hydraulic Study can be found in Appendix 17.A.

The Location Hydraulic Study shall include:

- Project Identifying information
- Project Description: general description and actions being performed within the base flood plain (encroachment)
- Project Type: Maintenance, replacement/rehab, improvement, new construction
- Drainage Area
- Published Regulatory Flood Plain: as applicable
 - Published Mapping
 - Zone Descriptor
 - Provide published base flood elevation if available
 - Note actions in Floodway as applicable^{*}
 - Any other notations as applicable
- Engineers assessment and evaluation criteria
- Conclusion, No further study is required. or: Design Hydraulic Study is required to determine.

The Location Hydraulic Study shall be included in the documentation to be submitted to the Project Manager and provided to the Environmental Division for their use as needed in permitting.

^{*} Action in a Floodway is NOT the sole factor determining that a Design Study is required.

17.5 Design Hydraulic Study

Once a Design Hydraulic Study has been deemed necessary by the Location Hydraulic Study or other engineering criteria, it shall follow the technical guidance provided in the appropriate section of the drainage manual for means and methods. Sample Location Hydraulic Study can be found in Appendix 17.B.

The Design Hydraulic Study shall be appended to the Location Hydraulic Study and shall include:

- Brief Description of the means and methods used in the analysis
- Report the Historical Flood data as available
- Study conclusion Project impacts, success criteria relative to design flood or results as dictated by the nature of the study in CH 8 or CH 12. Include New Construction discussion if applicable.
- Additional actions needed Structure Types evaluated for design and pertinent data (Culvert, Bridge, Other)
- Summary Results as dictated by the nature of the project as per in CH 8 or CH 12.
- Table of Existing and Proposed Flood elevations of all storms evaluated at the VDOT ROW as dictated by the nature of the analysis.
- Published Regulatory Flood Plain: as applicable
 - Comparison of published data to VDOT determined data
 - Hydrology <Published, VDOT, Discussion>
 - Hydraulics <Published, Revised Existing, Proposed, Discussion>
 - Impact to base flood / floodway elevations <Revised Existing, Proposed>
 - Impact to flood / floodway boundary <Revised Existing, Proposed>
 - Is a CLOMR or LOMR necessary? No: The work is consistent with the intent of the NFIP as the documented project impacts do not increase the flood risk to the community. Yes: The project impacts outside the VDOT ROW are such that coordination with FEMA is required or there is modification to the flood boundary or floodway due to the project impacts.
- Electronic Files containing the analysis/modeling on which the conclusions were based. The analysis should be sufficiently annotated to clearly identify the relevant components.
- Existing and Proposed Design Drawings (by reference as applicable):
 - Roadway Plan and Profiles
 - Bridge Front Sheet
 - Survey Drawings

The Design Hydraulic Study shall be included in the documentation to be submitted to the Project Manager and provided to the Environmental Division for their use as needed in permitting. The supporting analyses shall be archived permanently on the VDOT System and entered into a database.

17.6 Coordination

17.6.1 FEMA

In the event that the Design Hydraulic Study determines that a revision to the flood maps is warranted, VDOT will complete the MT-2 Documentation and submit to FEMA for review and approval. The community coordination portion should be completed by the locality and included in the submission.

17.6.2 DCR Flood Plains

DCR Flood Plains will be included in the permit distributions through the IACM process and provided an opportunity to review and comment on any general permit applications.

17.6.3 Locality

When a Location or Design Hydraulic Study documents a project within a Regulatory Flood Plain, after the permit package has been submitted before the IACM for review and comment the locality will be provided with a copy of the VDOT Joint Permit Application which will include the Hydraulic Study for their use. Detailed supporting computations performed are available upon request.

17.7 References

U.S. Code of Federal Regulations. (2018). *23 CFR 650 - Bridges, Structures, and Hydraulics, Subpart A - Location and Hydraulic Design of Encroachments on Flood Plains (§§ 650.101 - 650.117)*.

U.S. Code of Federal Regulations. (2018). *44 CFR Part 60 - Criteria for Land Management and Use*.

U.S. Department of Transportation, Federal Highway Administration. (1982). *Procedures for Coordinating Highway Encroachments on Floodplains with the Federal Emergency Management Agency (FEMA)*. Washington, D.C. Federal Highway Administration.

U.S. Department of Transportation, Federal Highway Administration. (2016). *Hydraulic Engineering Circular No. 17, 2nd Edition: Highways in the River Environment – Floodplains, Extreme Events Risk, and Resilience*. Publication No. FHWA-HIF-16-018. Washington, D.C. Federal Highway Administration.