Chapter 15 – Drainage Design Memoranda

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DDM7 VDOT Procedures for Documentation and Notification of Activities in FEMA-Mapped Floodplains has been replaced and the requirements are now in the VDM Chapters 4, 8, 12, and 17

DDM8 VDOT Expanded Procedures for Estimating Bridge Scour Using a Variable D50 with Depth

VIRGINIA DEPARTMENT OF TRANSPORTATION

LOCATION AND DESIGN DIVISION

DRAINAGE DESIGN MEMORANDUM

GENERAL SUBJECT: DRAINAGE INSTRUCTIONS	NUMBER: DDM-7
SPECIFIC SUBJECT: VDOT PROCEDURE FOR DOCUMENTATION and NOTIFICATION OF ACTIVITIES IN FEMA-MAPPED FLOODPLAINS	DATE: OCTOBER 15, 2015 SUPERSEDES: N/A
APPROVAL: *Jeffrey S. Bragdon, P.E.* State Hydraulics and Utilities Engineer	

EFFECTIVE DATE

- Unless identified otherwise within this DDM, the information contained in this DDM is effective upon receipt.

PURPOSE

- This DDM establishes minimum requirements for projects including roadway construction and maintenance that are located within Special Flood Hazard Areas (SFHA) Zone A, AE and VE as mapped on a Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM). These requirements require the engineer to fully document, to the extent necessary, compliance with FEMA practices and principles; VDOT standards, guidance and specifications; state and federal regulatory requirements; and all appropriate and necessary construction considerations. This DDM further references a Quality Assurance/Quality Control (QA/QC) process by which all work in the FEMA floodplain will be reviewed for consistency with this DDM and any applicable regulatory requirements.

REFERENCES

- The following editions apply when referenced in this DDM:
  - Virginia Code Section 10.1-602
  - Governors Executive Memorandum 2-97

POLICY

- This section amends and revises the existing VDOT procedures with respect to work in FEMA Designated Floodplains as discussed in Chapter 12 of the VDOT Drainage Manual.

PROCEDURE

- VDOT Hydraulics Staff will review all projects that will be submitted for environmental permits to assess the potential impact on flooding. At VDOT's discretion, the assessment on flooding impact may be qualitative (Engineering Judgment) or quantitative (Engineering Analysis). Documentation regarding this assessment of the potential impacts will be included with the Joint Permit Application (JPA) developed by VDOT to manage the environmental permit process. The Department of Conservation & Recreation (DCR) is included in the distribution of the JPA.

- Any maintenance or construction activity that will restore or maintain the originally-designed hydraulic capacity of a VDOT asset that is present in the FEMA Mapped Floodplain, will not require additional coordination with DCR or the localities beyond what is included in the JPA. This would include, but is not limited to:

  - stream bank stabilization;
  - reconstruction and stabilization of roadway embankments;
  - bridge scour repairs and associated fill;
  - bridge deck replacements;
  - substructure repairs that may involve additional concrete or steel to reinforce the structure;
  - bridge and structure maintenance and repair; and
  - bridge and structure replacement with a Hydraulically Equivalent Replacement Structure (HERS)

- When an Engineering Analysis of flooding impact will be performed on a project within a Zone AE, VDOT will request supporting hydraulic data from FEMA to use as a starting point for the analysis. VDOT will independently evaluate the hydrology for the purposes of comparison. The engineer will update the hydraulic model, as needed, to reflect the results of the VDOT survey and bridge design or construction. In the event that there is a discrepancy between the FEMA data and the Engineering Analysis, the VDOT data will take precedence. Any discrepancies will be noted and documented for future use but will not require a CLOMR submission. The hydraulic model and supporting documentation shall be forwarded to the Locality implementing the National Flood Insurance Program (NFIP) in that jurisdiction and DCR's Division of Dam Safety & Floodplain Management, upon their request.

- VDOT Design Policy is written such that it will support the goals of DCR to preserve the capacity of the floodplain to carry the 100-year flood and exceed the minimum requirements of the NFIP:

    - VDOT will limit impacts to the 100-year flood elevation to a cumulative 1.0' for work that is performed within FEMA Zone A areas, provided there is no adverse impact to offsite structures. Any impacts may require coordination with the community.

    - VDOT will limit impacts to the 100-year flood elevation to 0.0' for work that is performed within FEMA Zone AE areas.

If the impact limits noted above cannot be met, VDOT will coordinate with the NFIP community regarding the impact and determine the subsequent course of action. This may include supplemental surveys, a Conditional Letter of Map Revision (CLOMR), and as needed, a Letter of Map Revision (LOMR).

REPORTING AND DOCUMENTATION

For projects determined by using engineering judgement to have no adverse hydraulic impact as discussed above will require no additional coordination with the Locality or DCR except for the abbreviated Hydraulic Commentary provided in the JPA.

For projects located in a FEMA Designated A, AE, V or VE Zone, where a detailed hydraulic analysis has been performed, VDOT will:

- Modify the current documentation practices to include a comparison of the published and VDOT-determined discharges, including the published, revised existing and proposed condition flood elevations.

- Upon review and approval by the Hydraulics Staff the Preliminary Bridge Report based on the preliminary bridge design will be submitted to the Project Manager and the Central Office Hydraulics Section. This will include the LD293, FEMA FIRMette, the preliminary Bridge Front Sheet and preliminary Roadway Plan and Profile.

- The Central Office Hydraulics Staff will notify the Locality and DCR upon completion of the preliminary H&HA and provide that documentation for their use. In the event that the impact limits noted above are not met, there will be additional coordination with the locality regarding the need to engage in the CLOMR and LOMR process.

- If there is a difference between the VDOT and FEMA data and the existing versus proposed analyses shows that it meets the 100-year impact limits set above, this will not require a CLOMR / LOMR to update the FIRM and FIS. Upon receipt of the VDOT information, DCR and the Locality may coordinate with FEMA, as needed, regarding areas where the published FIS appears to be erroneous.

- In the event that there are changes in the final design that warrant modification of the analysis, the preliminary Bridge Report will be reissued to the PM and the Central Office Hydraulics Section. The Central Office will distribute copies to DCR and the Locality.

- Upon approval of the final bridge design and scour analyses by the Hydraulics Staff a Final Bridge Report will be submitted to the PM and the Central Office Hydraulics Section and will include the LD293, FEMA FIRMette, the Bridge Front Sheet, Roadway Plan and Profile, the hydraulic model, scour computations and scour plot.

- The Central Office Hydraulics Staff will distribute the final Bridge Report to the Locality and DCR. Survey data and engineering computations will be provided upon request. If required by this document, a CLOMR will be submitted at this time.

- These provisions are limited to projects where VDOT is the designated permittee. For VDOT-funded projects, where the environmental permits are held by others (i.e., Locally Administered Projects, Design Build Contractors, PPTAs, etc.), they will be responsible for independent coordination with the community with regards to Floodplain Development.

- VDOT will establish a centralized repository for the hydraulic analyses to facilitate requests made by DCR or FEMA for specific studies.

- In the event that CLOMR is submitted it will be necessary that the project schedule and budget be modified to accommodate the submission of a LOMR at project completion. This will include an as-built survey and possible modification to the hydraulic modeling as needed.

VIRGINIA DEPARTMENT OF TRANSPORTATION

LOCATION AND DESIGN DIVISION

DRAINAGE DESIGN MEMORANDUM

GENERAL SUBJECT: DRAINAGE INSTRUCTIONS	NUMBER: DDM-8
SPECIFIC SUBJECT: VDOTS EXPANDED PROCEDURE FOR ESTIMATING BRIDGE SCOUR USING A VARIABLE D50 WITH DEPTH AND ESTIMATED D50 BASED ON BEDROCK CORE MATERIAL	DATE:
	SUPERSEDES: N/A
APPROVAL: *Jeffrey S. Bragdon, P.E.* State Hydraulics and Utilities Engineer	

EFFECTIVE DATE

- Unless identified otherwise within this DDM, the information contained in this DDM is effective upon receipt.

PURPOSE

- This DDM applies to a hydraulic evaluation of a steady state flow condition that will provide the maximum theoretical scour. At this time, VDOT does not provide general guidance for the use of the scour computations that take into account long term variable flow as it applies to cohesion or abrasion. These approaches may be considered on a case-by-case basis at the discretion of VDOT staff.
- The methods provided in HEC-18, 5th edition, were largely developed in isolation to one another and there are significant gaps between the theory as presented, and the hydraulic and geotechnical conditions found in the field.
- The processes and procedures within HEC-18, 5th edition, do not describe how to incorporate the computational process when the geotechnical report returns results that provide an increasing D50 with depth.
- The processes and procedures within HEC-18, 5th edition, do not include discussion or practices to evaluate the scour potential in material that can be cored, but is fractured and does not meet an RQD of 50%.

- In general, the procedures in HEC-18, 5th edition, treat live-bed scour and clear-water scour as a binary choice determined based on the flood condition. However, the live-bed scour equations alone are not capable of incorporating the effects of a coarser material overlain by a finer material. This procedure will also look at both conditions to evaluate which condition controls.
- This DDM establishes an expanded procedure for the estimation of bridge scour using the existing equations available within HEC-18, 5th edition. In the event that supplemental guidance is issued by the FHWA, these processes will need to be reevaluated for applicability.
- The procedure described was developed by VDOT staff for use on VDOT projects. If this process is to be utilized by other agencies or in other areas, it should be thoroughly evaluated for applicability to that alternate use.
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- Quarrying and plucking scour (Annandale method) for fractured material is applicable to pier scour only.

REFERENCES

- The following editions apply when referenced in this DDM:
  - FHWA HEC-18, 5th edition
  - Materials Manual of Instruction rev May 2016
  - VDOT Drainage Manual Chapter 12

POLICY

- This section expands the existing VDOT recommendations with respect to scour as discussed in Chapter 12 of the VDOT Drainage Manual.

PROCEDURE

- The Materials Division has modified the Geotechnical Manual of Instruction to expand upon the requirements for coring and reporting of D50 values:
  - Report more frequent D50 values for soil data, especially when there is a change in character including larger components
  - Report the median core size for those samples of bed rock that to not display RQD values ≥ 50% and classified as moderately hard to very hard and moderately weathered to unweathered.
  - Includes the position that until more actionable guidance on the scour resistance of rock is provided by the FHWA, that VDOT will consider rock with an RQD ≥ 50% to be scour resistant.

General

Scour estimation processes were developed, based upon data collected in controlled laboratory conditions. Unfortunately, these processes do not cover many of the conditions typically encountered in the field. To accommodate these conditions, the processes described below will focus on a multipronged approach to evaluating both live-bed and clear-water scour based on a variety of materials encountered, to establish what is likely to be the controlling condition.

In addition, individual site characteristics should also be taken into account in the determination of live-bed vs. clear-water scour. The conditions that could limit the potential Live Bed condition are:

- A dam located in close proximity upstream, capturing the sediments upstream of the crossing
- The crossing is within a normal/flood pool of a lake/reservoir, and the sediments would be expected to fall out upstream.
- An overbank area functioning as an independent scour zone, located downstream of an area that is well-vegetated.

Contraction Scour

If there is the potential for live-bed scour, determine via HEC-18 (Section 6.2.1 Eq. 6.1), then the material present in the stream bed is in motion. If the live-bed conditions exist, then both live-bed and clear-water scour are to be computed in the channel. If live-bed conditions are not indicated, only clear-water scour is to be computed and included below.

The recommended equations to consider are the Live Bed Scour Equation (Section 6.3 Eq. 6.2), the Clear Water Scour Equation (Section 6.4, Eq. 6.4) and if applicable, the Vertical Contraction Scour Equation (Section 6.10 Eq. 6.16).

Compute all three using the D50 of the stream bed material, as applicable to the specific equations (minimum D50 is 0.2mm). Combine the vertical scour to both the live-bed and clear-water scour, and compare the results to each other. The estimate with the least total scour will be considered the controlling condition. Once the controlling condition is determined, evaluate the soil boring data to see if the scour is contained within the limits of the material defined by the D50 selected. If the controlling scour is confined to this layer (Layer 1), then the contraction scour is arrested at this elevation and this portion of the computaitons is complete. However, if the controlling scour terminates in material that is below Layer 1, then additional computations are needed.

In this case it can be concluded that, at minimum, the scour will reach the point where the material changes between Layer 1 and Layer 2. Clear water scour computations are repeated using the same hydraulic parameters as in the analysis above, assuming that the subsequent D50 material is present in the entire soil column. Combine this result with the vertical scour and compare to the previously computed live-bed and vertical scour, then estimate with the least total scour will be considered the controlling condition.

If the controlling scour is above this layer, then the scour is arrested at the interface between the two layers. If the controlling scour confined to this layer, then the contraction scour is arrested at this elevation. However, if the controlling scour terminates in material that is below the layer characterized by the D50 selected, then additional computations are needed. Repeat these last two steps until a controlling scour is reached, or scour resistant material is encountered.

Pier Scour

Use the most applicable method that would apply to the project for the pier configuration, where there is little distinction between live-bed and clear-water scour. Combine this with the estimated contraction scour. Assess the material at the estimated bottom of the scour hole. If the material in the soil column affected by the combined contraction and pier scour has a D50 > 20mm, then the method described by Pier Scour in Coarse Bed Material (Section 7.11 Eq. 7.34) may be used. This method is reported to be applicable to clear-water conditions only. However, in the event that the coarse layer is overlain by the finer layer, this equation would be applicable. The process in evaluating successive layers is similar to what is considered under contraction scour. In this case, any material with a D50 smaller than 20mm will have been removed above the originally estimated elevation.

Abutment Scour

Abutment scour is much more complex than the other scour modes, and the equations are more often difficult to apply. Both live-bed and clear-water scour are to be computed:

(1) If the abutments are significantly close to the channel, not meeting the setback limits,
(2) If there is the potential for live-bed scour, as determined by HEC-18 (Section 6.2.1 Eq. 6.1) and
(3) The other live-bed criteria are present.

If live-bed conditions are not indicated, only clear-water Scour is to be considered.

The recommended equations to consider are the Froelich's Equation (Section 8.6 Eq. 8.1), the HIRE Equation (Section 8.6.2, Eq. 8.2), and the NCHRP 24-20 Method for both clear-water and live-bed (Section 8.6.3 Eq. 8.5 and Eq. 8.6).

Compute all four (4) equations using the D50 of the stream bed material as applicable to the specific equations (minimum D50 is 0.2mm). Combine the total contraction scour as computed above to Froelich's and HIRE results. The NCHRP 24-20 Method already incorporates the scour based on lateral contraction. However, this should be combined with the vertical contraction component to both the clear-water and live-bed results.

Compare the results of the four (4) methods to each other, and the estimate with the least total scour will be considered the controlling condition. Once the controlling condition is determined, evaluate the soil boring data to see if the scour is contained within the limits of the material defined by the D50 selected. If the controlling scour is confined to this layer (Layer 1), then the scour is arrested at this elevation and this portion of the computaitons is complete. However, if the controlling scour terminates in material that is below Layer 1, then additional computations are needed.

In this case it can be concluded that, at minimum, the scour will reach the point where the material changes between Layer 1 and Layer 2. Clear water scour computations are repeated using the same hydraulic parameters as in the analysis above, assuming that the subsequent D50 material is present in the entire soil column. Combine the results as described above, the estimate with the least total scour will be considered the controlling condition.

If the controlling scour is above this layer, then the scour is arrested at the interface between the two layers. If the controlling scour is confined to this layer, then the scour is arrested at this elevation. However if the controlling scour terminates in material that is below the layer characterized by the D50 utilized, then additional computations are needed. Repeat this cycle until a controlling scour is reached, or scour resistant material is encountered.

REPORTING AND DOCUMENTATION

- The submission requirements for analysis using this procedure should include the following:
    - o Excerpts from the Geotechnical Report documenting the D50 and RQD values of the materials
    - o Detailed computations identifying the controlling scour determination at each substructure
    - o Scour Plot to scale

Worked example