South Carolina
Department of Transportation

September 25, 2019

HYDRAULIC DESIGN BULLETIN NO. 2019-3

SUBJECT:	Release of the USGS Scour Manual and Updated Guidance on Bridge Scour Analysis
EFFECTIVE DATE:	Immediately for projects that have not completed the Design Field Review (DFR)
SUPERSEDES:	Section 1.3.1 Step 9 - May 26, 2009 edition of the Requirements for Hydraulic Design Studies (RHDS)
RE:	None

This bulletin provides updated design guidance for scour analysis at bridges using the U.S. Geological Survey (USGS) bridge-scour envelope curves based on a newly released USGS report. Section 1.0 provides a brief overview of the new USGS report. Section 2.0 specifies the associated updates to Section 1.3.1 of the *Requirements for Hydraulic Design Studies* (RHDS) and Section 3.0 specifies additional references for inclusion in the RHDS.

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1.0 USGS Report Overview

The U.S. Geological Survey (USGS) in cooperation with the South Carolina Department of Transportation recently (November 2016) completed research project SPR No. 701, "Development of a Guidance Manual for Assessing Scour Using the South Carolina Regional Bridge-Scour Envelopes," and has released the associated report (Benedict, Feaster, and Caldwell, 2016; Reference 54). The report synthesizes the findings of the previous USGS scour investigations in South Carolina (References 48, 49, and 50 in *Requirements for Hydraulic Design Studies*, May 26, 2009, and new Reference 53 per this Memo) and provides an integrated procedure for applying the South Carolina bridge-scour envelope curves. The report includes a companion spreadsheet to assist in applying the envelope curves. While the previous USGS scour reports should still be referred to for background information, the new report should be the primary source for guidance on applying the USGS bridge-scour envelope curves. The report and companion spreadsheet can be found at the following internet address:
https://pubs.er.usgs.gov/publication/sir20165121

2.0 Update for Scour Analysis in the RHDS

This guidance supersedes Section 1.3.1, **Step 9 Scour Analysis** (page 20) of the *Requirements for Hydraulic Design Studies* (May 26, 2009). The following should replace all of the original text for Step 9:

Step 9 Scour Analysis

A scour analysis for the 1-percent Annual Exceedance Probability (AEP; 100-year) and 0.2-percent AEP (500-year) flows shall be performed for each bridge, using the USGS bridge-scour envelope curves (Reference 54) and the FHWA's Hydraulic Engineering Circular No. 18, *Evaluating Scour at Bridges* following the guidance listed below. The USGS and HEC-18 manuals note that assessment of scour requires a strong measure of engineering judgment, and therefore, the engineer should have read and be familiar with the content in these manuals. Other references that should be consulted are HDS-6 *River Engineering for Highway Encroachments*, HDS-7 *Hydraulic Design of Safe Bridges*, HEC-20 *Stream Stability at Highway Structures*, HEC-9 *Debris Control Structures – Evaluation and Countermeasures*, and Reference 55. A copy of all scour studies and determination for Item 113 must be sent to the Hydraulic Design Support Office for inclusion in Bridge Maintenance's Bridge Files.

Riprap protection should be provided on all abutment end fills following the guidance in Section 1.1.6 of this manual. With the exception of riprap protection for abutment end fills, new bridge foundations should be designed to withstand scour based on the design criteria below without the aid of bridge-scour countermeasures (see Section 1.1.4).

A. General Analysis Steps

1. Review historical data to gain insights on scour potential at the site of interest, including:
   - Site comparisons from USGS scour databases (see Reference 54).
   - Flood and scour history at site of interest and comparative bridges (see Section

1.3.1, Steps 1 and 2-A).

- Bridge inspection reports (underwater inspections, if applicable) from the Bridge Maintenance Office.
- Contact with District Bridge Maintenance Engineer and (or) Bridge Inspection Team Leader to inquire about flood history and any scour related problems at the bridge of interest.

2. A scour analysis for the 1-percent AEP (100-year) and the 0.2-percent AEP (500-year) flows should be made using the USGS envelope curves (see Reference 54 and the USGS application spreadsheet) and the HEC-18 methods following the published guidance in the respective manuals. (Note: When site characteristics are within the limits of the data used to develop the USGS envelope curves, the USGS method will be the primary tool for assessing scour, and the HEC-18 analysis will be used as supplemental analysis information.)
    - The initial scour analysis will assume erodible sediments to determine the maximum potential scour for both methods. [Note: Scour-resistant soils (cohesive soils or rock) are addressed in item 6 below.]
    - Using the Geotechnical Data Report and other available soils data, in conjunction with engineering judgement, select appropriate median grain sizes (D50) to be used in the scour analysis, with separate D50s determined for the floodplain and channel. A representative D50 for the surface bed material near the region of anticipated scour will typically be appropriate for the initial analysis that assumes erodible sediments. Reference should be made to the USGS and HEC-18 manuals for additional guidance on appropriate selection of D50.
    - If deemed appropriate, the HEC-18 scour analysis should include unusual site conditions such as pressure flow, overtopping, hydraulically wide piers, and complex piers, following the guidance in HEC-18.
    - If site of interest has characteristics beyond the limits of the USGS envelope curves, still apply the envelope curves to gain insight on scour potential.

3. Compare results of USGS and HEC-18 scour estimates:
    - If scour estimates from the USGS and HEC-18 methods are significantly different or scour estimates significantly differ from historical scour data, evaluate and document possible reasons for the differences in the Hydraulic Design Study Report.

4. Use engineering judgment to select the estimate of scour:
    - If the site of interest has characteristics within the limits of the USGS envelope curves (see Reference 54), weight in the selection should be given to the scour assessment based on the USGS envelope curves.
        - If site characteristics are outside the limits of a given USGS envelope curve, engineering judgment may be used to evaluate if it is appropriate to still use the envelope curve.
    - If site of interest has characteristics significantly outside the limits of the USGS envelope curves, weight in the selection process should be given to the scour

assessment based on HEC-18.

- Total scour estimates at the site of interest generally should be based on just one method (USGS envelope curves or HEC-18) and not a combination of the methods.
- There may be unique site conditions that justify modifying the general scour analysis steps listed above. In such cases, justification should be well documented in the Hydraulic Design Study Report.
- The selected estimate of scour will be designated as the Hydraulic Scour Depth (HSD).

5. Evaluation of the initial hydraulic bridge design

   Review the initial hydraulic bridge design and the HSD results with the Geotechnical and Structural Design Sections, as necessary. If the HSD is considered too severe for the bridge of interest (see HEC-18 for guidance on evaluating scour results), alternate hydraulic bridge designs should be considered to mitigate adverse scour impacts. This may include, but is not limited to:

   - increasing the bridge length to reduce flow contraction and velocity, which will tend to reduce scour, especially abutment scour
   - evaluating alternate span configurations and pier locations to limit effects of pier scour
   - for a multiple bridge crossing, adding additional or lengthening floodplain relief bridges to reduce flow contraction and velocity, which will tend to reduce scour

   If adjustments are made to the initial hydraulic bridge design, a scour analysis must be made for the new hydraulic bridge design to determine the new HSD.

6. Transmittal of scour analysis to the Geotechnical and Structural Design Sections (GDS and SDS)

   - A summary of the HSD and a graphical representation of the scour line at the bridge should be documented in the Hydraulic Design Study Report, and provided to and reviewed with the GDS and SDS. (Note: Refer to HEC-18 for guidance on drawing the scour line. The Geotechnical Engineer should be consulted to determine reasonable side slopes for scour holes in the graphical representation, based on the soils at the site.)
   - If the GDS determines there are scour-resistant subsurface soils (cohesive soils or rock), the GDS may request additional scour analysis based on the scour resistant soils, if deemed appropriate. This additional scour analysis will be based on the methods in HEC-18 for scour resistant soils, and the GDS should assist the Hydraulic Design Section by providing technical information on the soil properties that may be required for this analysis. A summary of the revised HSD and a graphical representation of the scour at the bridge, based on any additional analysis, should be documented in the Hydraulic Design Study Report, and provided to and reviewed with the GDS and SDS.
   - Based on the presence of any scour-resistant subsurface soils identified in the Bridge Geotechnical Engineering Report, the GDS may adjust the estimated scour depths, as deemed appropriate. The adjusted scour depths will be designated as the

Geotechnically Adjusted Scour Depth (GASD). Any adjustments should be documented by the GDS for inclusion in the Hydraulic Design Study Report and reviewed with the Hydraulic Design Section and SDS.

- As part of the bridge foundation investigation, the GDS should provide the estimated scour depths, with any adjustments, to the Structural Design Section for inclusion in the analysis and design of the bridge foundations.

B. Bottomless Culverts

A scour analysis shall be made for bottomless culverts using the guidance in HEC-18.

C. Special Considerations

In the scour study, special consideration should be given to areas of the bridge opening where problems or failures have occurred at bridge sites in the past. This may include, but is not limited to:

1. <u>Abutments</u>:

   One of the primary bridge-scour failure modes is scouring of the abutment. This is typically caused by an undersized bridge of insufficient length that produces a large contraction of flow, or by a disproportionately large discharge in the bridge overbank area. These conditions create high velocities and eddies adjacent to the abutment causing a scour hole to develop just off the abutment and often in the vicinity of the first interior bent. For severe flow contractions the slope of the spill-though abutment can be heavily eroded, possibly leading to the washout of the approach embankment. The severe flow contraction may cause piping behind the end bent or bulkhead. This leads to undermining of the pavement and in some cases the road fill material may be completely scoured away but the pavement still remains creating a severe traffic hazard. To minimize the potential for this type of failure, severe flow contractions should be avoided by using a sufficiently long bridge that meets or exceeds SCDOT hydraulic-design criteria. Additionally, to minimize the potential for erosion of the abutment and road embankment, properly sized riprap should be placed on the spill-through abutments following the guidance in Section 1.1.6 of the *Requirements for Hydraulic Design Studies* (May 26, 2009).

   Large abutment scour particularly can occur at bridges on wide floodplains because of the lack of (or insufficient number of) overflow bridges, or because the spacing between the overflow bridges is too far. In general, spacing of overflow bridges at multiple-bridge crossings should not exceed ½ mile in wide floodplains. To properly design bridge spacings and openings for multiple-bridge crossings, a two-dimensional hydraulic model, accepted by the SCDOT, should be used. If a two-dimensional hydraulic model cannot be used for the design of a multiple-bridge crossing, a design variance will be required. Guide banks should be considered at these types of bridges to minimize the potential for failure caused by abutment scour.

2. Debris:

   Scour can be caused or increased by debris accumulation on a bent. The debris will cause the flow to be diverted downward and/or laterally. Significant scour damage can occur. To prevent this, the channel should be completely spanned when feasible. Tower bents shall not be used in the channel or on the channel banks. [See Reference 55, HEC-9, and HEC-18 for additional guidance on debris.]

3. Channel Bends:

   If the bridge crossing is located in or near a channel bend, channel migration will probably occur during the life of the bridge. Channel stabilization should be considered using the methods in HEC-11 and HEC-20. Placing the bridge foundations deep enough to withstand channel scour would be a viable alternative if the rate of migration would be such that it would not reach the bridge abutment during the lifetime of the bridge (75 to 100 years).

4. Gravel and Sand Mining:

   If gravel or sand mining occurs on a stream, it may cause channel degradation. This will be added to the other scour components in determining scour depth.

5. Analyzing Scour for Backwater from a Lake or Larger Stream

   If a bridge is significantly affected by backwater from a lake or larger stream, the bridge hydraulics and scour should be evaluated for conditions with and without backwater, and the worst case scour should be selected to represent the HSD. For a lake, the normal-pool elevation can be incorporated into the hydraulic model to estimate backwater conditions, and the condition without backwater can be represented as if the lake was not present. For the case of a larger stream, the 1-percent and 0.2 –percent (100- and 500-year) water-surface elevations for the larger stream can be incorporated into the hydraulic model to estimate backwater conditions at the bridge of interest, and the condition without backwater can be represented as if the larger river was at low-flow condition.

6. Overtopping and Pressure Flow Conditions

   Pressure flow and bridge/roadway overtopping shall not occur for discharges equal to or less than the 1-percent AEP (100-year) flow. While pressure flow and bridge/roadway overtopping are permissible for discharges greater than the 1-percent AEP (100-year) flow, it is preferred that these conditions be avoided for flows less than or equal to the 0.2-percent AEP (500-year) event. If pressure flow and (or) overtopping occurs for an event less than the 0.2-percent AEP (500-year) flow, then guidance in HEC-18 for evaluating scour for these conditions should be followed. The USGS bridge-scour envelope curves may be applied to these conditions to gain insights. However, the field data used in the envelope curves generally did not include bridges with overtopping and pressure flow, and therefore, weight should be given to the HEC-18 scour analysis when selecting the final estimate of scour.

7. Abandoned Fill Material

   Abandoned fill material associated with construction staging or with an abandoned road bed may adversely affect bridge hydraulics and scour if located in close proximity to the bridge. If such adverse conditions exist at the project site or may be caused during construction, a note shall be added to the plans calling for the removal of the abandoned fill down to the natural floodplain elevation, to the extent required to mitigate potential adverse consequences to the bridge.

8. Scour on Tidal Streams:

   The scouring events at tidal streams may be associated with normal tidal flow, weather fronts, or a tidal surge from a hurricane. Channel migration of tidal streams is a particular problem. Historic aerial photographs, dating back as early as possible, should be studied to determine direction and speed of channel migration in the vicinity of the proposed bridge. The USGS envelope curves were not developed for tidal sites and therefore, the guidance in HEC-18 should be used for evaluating scour at tidal bridges.

3.0 Additional References for Inclusion in the RHDS

The following text should be added to the “REFERENCE LIST” Section (at bottom of page 69) of the *Requirements for Hydraulic Design Studies* (May 26, 2009):

53. *Modification of Selected South Carolina Bridge-Scour Envelope Curves,* USGS Scientific Investigation Report 2012-50299.

54. *The South Carolina Bridge-Scour Envelope Curves,* USGS Scientific Investigation Report 2016– 5121. (This includes a companion spreadsheet for applying the envelope curves.)

55. *Effects of Debris on Bridge Pier Scour*, National Cooperative Highway Research Program Report 653.