METRIC 18 SCOUR ANALYSIS FOR EXISTING STRUCTURES

Prepared for:

South Carolina Department of Transportation

Prepared by:

CDM Smith

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FOR INFORMATION ONLY

DISCLAIMER

THE SCOUR ANALYSIS GUIDANCE DOCUMENT IS PUBLISHED SOLELY TO PROVIDE INFORMATION AND GUIDANCE FOR THE EXECUTION OF SCOUR ANALYSIS OF BRIDGES OVER WATER IN THE STATE OF SOUTH CAROLINA. THIS GUIDANCE DOCUMENT IS ISSUED TO SECURE, SO FAR AS POSSIBLE, UNIFORMITY OF PRACTICE AND PROCEDURE IN COMPLIANCE WITH STATE AND FEDERAL REQUIREMENTS. THIS GUIDANCE DOCUMENT IS NOT INTENDED TO BE A COMPLETE GUIDE IN ALL AREAS OF HYDRAULICS SCOUR ANALYSIS AND IS NOT A SUBSTITUTE FOR ENGINEERING JUDGMENT

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GUIDANCE DOCUMENT APPROVALS

The purpose of this Guidance Document is to provide guidance and direction for the scour analysis of bridges over water in South Carolina. Any modifications to this Guidance Document require approval of the South Carolina Department of Transportation (SCDOT) Hydraulic Design Support Office and Federal Highway Administration (FHWA). This Guidance Document will be reviewed and updated as needed by the State Hydraulics Support Engineer or designated representative. However, HDSO reserves the right to make interim updates to the procedure to address lessons learned, evolving approaches, updates to federal, state, local laws, regulations, and policies; provided those updates are reviewed with HDSO oversight.

Approved: ____

HDSO Engineer   Date
SCDOT

Approved: ____

Bridge Engineer   Date
FHWA

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Section 1. Introduction

1.1 Purpose

The purpose of this Scour Analysis Guidance Document is to provide project specific guidance for the Scour Critical Assessment and Management System project by defining the South Carolina Department of Transportation's (SCDOT) policies and procedures for performing scour studies for all existing bridges over water within the State of South Carolina. This Guidance Document is intended to establish procedures for performing scour studies, coding NBI Item 113, and completing Plan of Actions (POA) for bridges identified as scour critical and/or unknown foundations contained in this METRIC 18 SCDOT Scour Critical Assessment and Management System Project. This Guidance Document presents guidelines and procedures to provide uniformity in performing scour analyses for bridges and outlines the required documentation and establishes a standard of practice for the Scour Critical Assessment and Management System Project.

1.2 Scope

The requirements presented in this Guidance Document are to be followed by SCDOT hydraulics engineering staff as well as all other hydraulics engineering design consultants performing work for SCDOT in the scour analysis of bridges over water.

There are approximately 9420 existing bridges in the State of South Carolina. About 75% of these bridges are water crossings and therefore require scour studies. The scour analysis should identify the correct scour code for Item 113 of NBI (specifically which of these bridges are scour critical) and determine the need for a POA for each scour critical bridge. There are several thousand bridges, other than the estimated number requiring scour studies, that have unknown foundations, all of which will require a simplified risk based POA. **Table 1** summarizes the number of South Carolina bridges falling into the previously discussed categories.

Table 1: Bridge Numbers: Scour Analysis Required/POA Required

Category	Number
Existing Number of Bridges over Water	6977
Number of Bridges Requiring Scour Analyses	3011
Number of Bridges Requiring POAs	2877
Number of Bridges with Unknown Foundations	2450
Number of Culverts (with Bottoms)	1014

The LEAD CONSULTANT (CDM Smith) will develop a method of prioritizing bridges that need additional documentation while giving priority to performing scour evaluations, developing POAs, and implementing POAs as applicable. A final database of prioritized bridges, showing each bridge's ranking, will be provided once approvals from SCDOT HDSO have been received.

The LEAD CONSULTANT will provide the approved prioritization resulting in an ordered Bridge List for each of the four Non-Lead Consultants. The bridges identified as requiring scour studies will be strategically distributed amongst the five consulting firms (NON-LEAD & LEAD) based on the hydraulics engineering technical capabilities of each team.

The following bullets provide a short summary of each chapter contained in this ***METRIC 18 SCOUR ANALYSIS For Existing Structures*** document:

- Chapter 2 provides details referencing the required in- office (desktop) data collection and review of the data.
- Chapter 3 provides the details required for the Field Inspections for bridges requiring a scour analysis or a POA. The necessary Field Inspection Form(s) are included in this chapter.
- Chapter 4 provides details referencing required Field Surveys for bridges lacking the essential information to conduct a scour analysis.
- Chapter 5 provides details/guidance on the acceptable methods for determining the Hydrologic & Hydraulic Modeling for the required bridge scour analyses.
- Chapter 6 provides details/guidance on scour assessments utilizing the USGS Envelope Curves Spreadsheets, FHWA HEC-18 methodology, and Tidal Scour Analysis.
- Chapter 7 provides details/guidance referencing the required QC & QA processes for each bridge scour analysis or POA.
- Chapter 8 provides details/guidance referencing Item 113 Coding for each scour study.
- Chapter 9 provides details/guidance referencing the POAs required for bridges that are coded as scour critical or as unknown foundation.

1.3 Methodology for Bridge Scour Analysis & POA Prioritization

Lead Consultant shall identify all bridges over water that require scour analysis (having removed those bridges that have adequate scour studies, are bridge sized culverts, or meet other justifications from the list shown in Section 1.4. **Figure 1** is a schematic diagram/flowchart showing the following methodology:

1. Unknown Foundations – ***Scour Analysis is not possible, therefore, a POA must be developed for each bridge.*** Refer to Appendix A in the POA Guidance Manual. Prioritize as provided in each Team's Bridge List.
2. Known Foundations - ***Scour Analysis required.*** Prioritize as provided in each Team's Bridge List.
3. Scour Analysis Method: The desired scour analysis method will be determined by the Lead Consultant and provided in the bridge list for each bridge. The analysis should use existing data when available including existing SCDOT hydraulic studies or FEMA studies. The

bridge opening and channel section can be determined from the plans, from tape downs provided by SCDOT, or from tape downs derived from the field/site visit. Minimal hydraulic models are preferred; however, the engineer should determine the model sensitivity to domain selection and adjust as necessary.

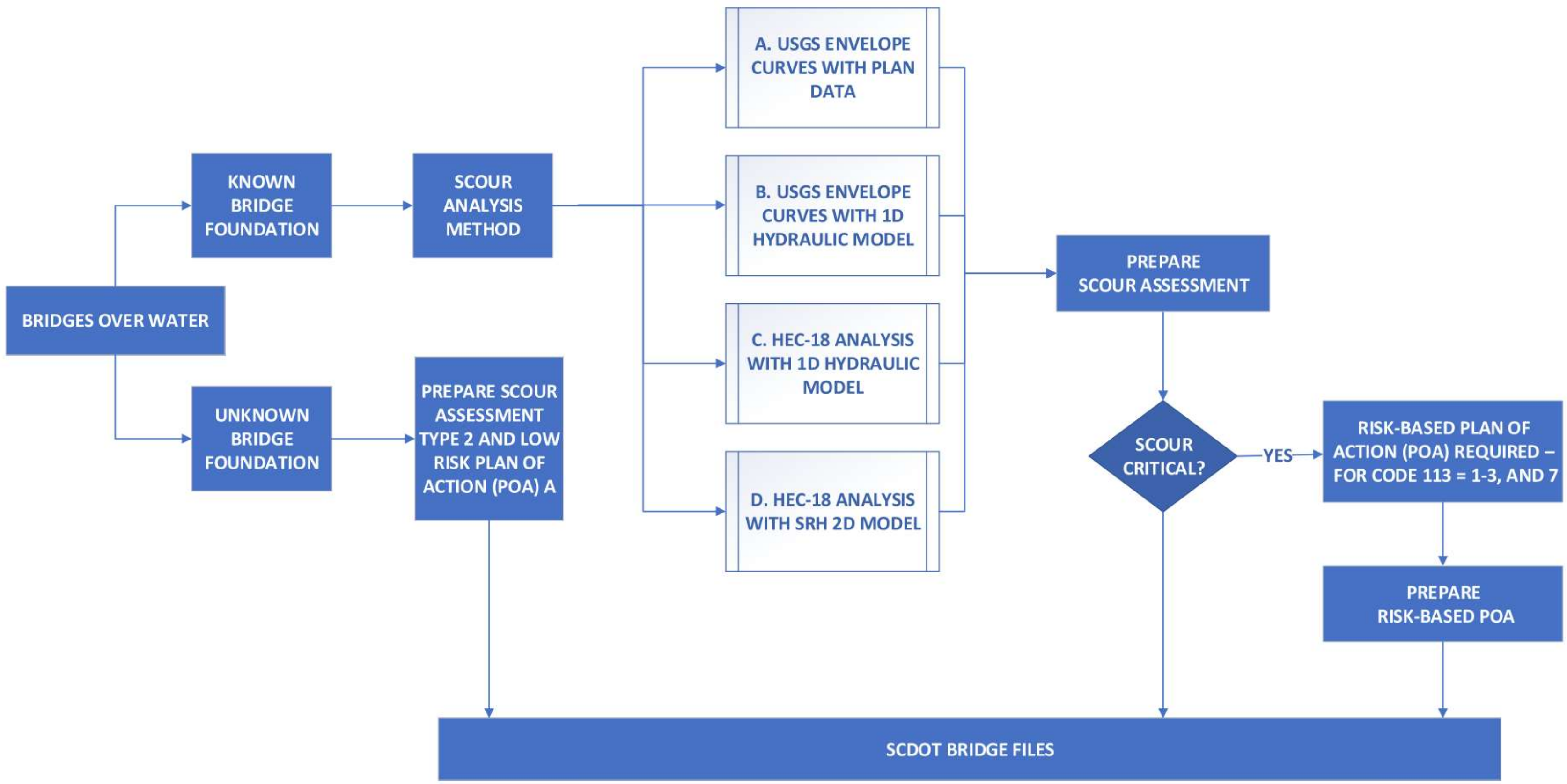
a. USGS Envelope Curve Methodology (USGS 2018) with existing plans showing an adequate natural cross-section. No surveys should be required for this analysis.

b. USGS Envelope Curve Methodology with survey data and a 1D hydraulic model. Cross section/channel data may be obtained from field survey or from tape downs which should be used to construct a simple 1D hydraulic model (HEC-RAS with a minimum of four cross sections) at riverine sites.

c. US Federal Highway Administration Hydraulic Engineering Circular No.18 - Evaluating Scour at Bridges (HEC-18) with survey data and a 1D hydraulic or 2D riverine model. Where a watershed or bridge parameter is outside of the recommended limits of the USGS Envelope Curves, HEC-18 will be used to perform the scour analysis. Cross section/channel data may be obtained from field survey or from tape downs, which may be used to construct a simple 1D hydraulic model (HEC-RAS with a minimum of four cross sections) at sites dominated by riverine flow. An unsteady downstream boundary condition may be applied to riverine locations affected by tidal fluctuations.

d. HEC-18 with survey data, HEC-RAS 1D model, and SRH2D model for tidal bridges. Tidally influenced bridges in estuary settings (or riverine settings not suited for HEC-RAS), where storm surge is anticipated to dominate the bridge hydraulic response, should be modeled with SRH2D. Utilize existing hydraulic models where possible. The Single Design Hydrograph method described in SCDOT 2019 Draft Requirements for Hydraulic Design Studies will be used for the boundary condition.

Figure 1: Schematic Diagram of Scour Analysis Methodology



Note: Unknown Bridge Foundations may include Item 113 Code – 3, 7, and U

1.4 Type 2 Assessments

The following exceptions indicate conditions under which a scour analysis will not be performed, but a Type 2 Assessment shall be completed:

1) Foundations embedded in rock.

   Bridge foundations that are embedded into competent rock are exempt from scouring due to the hardness of the rock material and its resistance to scour. A scour assessment will be completed with a Type 2 Assessment form and a scour code of Item 113 = 5 or 8 will be assigned.

2) Foundations with penetration into Marl or similar consolidated material.

   Previous study (Experimental Investigation of Scour Around Bridge Piers, Chaudhry, August 2003, FHWA-SC-03-12) has determined that since Marl exhibits very similar scour resistance to rock. The rate of scour in Marl has been determined through laboratory analysis to be so slow that ultimate scour depths would not be reached within the service life of the structure and therefore, can be considered as scour resistant. A scour assessment will be completed with a Type 2 Assessment form and a scour code (Item 113 = 5 or 8) can be assigned.

3) Unknown foundations in the Piedmont Region.

   When a bridge is founded on timber piles In the Piedmont and Blue Ridge regions of the State, where rock is relatively shallow and pile penetration is limited by the depth to rock, the timber foundations are scour critical when the depth to rock is less than five (5) feet. Because this is known to be a common condition in this region, a scour assessment will be completed with a Type 2 Assessment form. The scour code can be assigned as scour critical (Item 113 = 3) under these conditions; but a POA is also required. All other types of foundations (and materials) should be coded as unknown foundation, as described in 4) below.

4) Unknown foundations.
   Where no data exists to describe the type and depth of foundation, a scour code (Item 113 = U) for Unknown foundation will be assigned and a risk based POA will be prepared and updated until the foundation condition is determined. A Type 2 Assessment form should be completed for this condition.

5) Countermeasures installed.

   Where nondesigned countermeasures are known to be installed at a bridge to correct scour issues, they are assumed to be effective and a scour assessment will be completed with a Type 2 Assessment form and a scour code (Item 113 = 7) can be assigned, but a POA is also required.

6) Bridge Size Culverts.

   Culverts are not normally subject to scour risk unless they are bottomless. Bottomless culverts should be treated as bridges with regard to scour potential.

Because culverts are also typically protected with scour resistant inlet and outlet design elements, they pose a very low risk. There have been cases where issues with stream degradation and abutment like scour affects bridge size culverts; this is not common. It typically occurs at locations where a bridge should be used instead of a culvert. A scour assessment will be completed with a Type 2 Assessment form and a scour code (Item 113 = 8) can be assigned.

7) Bridges over Reservoirs.

Bridges over reservoirs are generally at low risk of scour. For many bridges over reservoirs, a scour study is not required for a scour code (Item 113 = 5 or 8) to be assigned. However, justification of Item 113 coding should be based on a review of the particular conditions present. Where bridges span a reservoir without a causeway or constricting embankment, the velocities are minimal due to the reservoir submergence and are not considered to be strong enough to initiate particle motion, inducing scour. These structures are at a very low risk of scour. For other conditions where the bridge geometry results in a constriction of the reservoir, the structures are considered scour prone. For all such cases where the constriction is severe; for instance, where the geometric contraction ratio, m, is greater than 0.75 (m=1-b/B, where b is the constricted top width of the bridge opening and B is the top width of the approach section), a scour study should be conducted. For constricted crossings over reservoirs with a geometric contraction ratio less than 0.75, available site specific data (such as historical tape down measurements and geotechnical borings) can be used to assign a scour code. A scour assessment will be completed with a Type 2 Assessment form and individual justification should be prepared for SCDOT HDSO review.

The final deliverables for this project, including all new POAs, and Scour Assessments (with supporting calculations and analyses) will be uploaded to the **SCDOT's Bridge File** system by the Lead Consultant. The **Bridge File** is located on SCDOT ProjectWise under the Bridge Maintenance folder. It is organized by County and then Asset Identification for each Bridge. Each asset ID within the State System has a family of folders that include a designated folder for waterway. The Lead Consultant will be populating these folders with the current approved Scour Assessments during the data collection process (Task 2). The Scour assessment files and POAs from this project will be retained in this directory permanently after this project is complete.

The Type 2 Assessment Form and the accompanying instructions for completing the form are shown on the following pages.

SCOUR ASSESSMENT – TYPE 2

Reference the Metric 18 Scour Analysis For Existing Structures Section 1.4 for additional details on each of these categories, suggested Item 113 coding and POA requirements.

BRIDGE DATA

Asset ID		**Structure Number**	
County		**Facility Carried**	
Waterbody		**Skew Angle**	
Bridge Length (ft)		**Bridge Width (ft)**	
Year Built		**Span Arrangement**	
Longitude		**Pier Size (ft)**	
Latitude		**Pier Shape**	
Abutment Type		**Roadway Alignment**	

JUSTIFICATION SELECTION

JUSTIFICATION	DESCRIPTION (See p. 3 for Detailed Instructions)
Foundations embedded in rock	A plan sheet or boring data showing the elevation of rock is required. For bridges with piles, the pile logs or pile tip information must show 5 or more feet embedment into rock. For bridges with drilled shafts, the plans must show that the shafts are within the limits of the rock. For bridges with spread footings, the spread footings must be shown on the plans or quantities for rock excavation included in the As-Let or As-Built plans.
Foundations with penetration into Marl or similar consolidated material	A plan sheet or boring data showing 5 or more feet of penetration into consolidated material for piles or drilled shafts is required. For spread footings, 2 or more feet of penetration must be shown on the plans.
Unknown foundations in the Piedmont Region	The bridge must be located in the Piedmont or Blue Ridge Region of SC, have timber piles with unknown penetration depths.
Unknown foundations	The bridge must not have foundation information available.
Nondesigned Countermeasures installed	The bridge must have nondesigned countermeasures installed.
Bridge Size Culverts	The culvert must have an opening of 20 feet or more and have a bottom.
Bridges over Reservoirs	The bridge must be over a reservoir and have a geometric contraction ratio less than 0.75.

DETERMINATION

Justification *Insert justification from list above* **is selected with a scour code Item 113 of** *##* **.**

A POA is *(required/not required)*.

Certification: *This assessment was performed in accordance with Metric 18 Scour Analysis For Existing Structures, May 2021.*

Consultant Certification	Signature:	Date:
QA Acceptance:	Signature:	Date:
HDSO Approval	Signature:	Date:

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SUPPORTING NARRATIVE AND INFORMATION
(Included plans, site visit information, missing information, aerial photograph, topograph map, and other information needed to document the justification and Item 113 Coding)

INSTRUCTIONS FOR USING A TYPE 2 SCOUR ASSESSMENT

The following are the instructions on using the Type 2 Scour Assessment form. Additional information is in *Metric 18 Scour Analysis For Existing Structures*.

1. **Foundations embedded in rock**
   Bridge foundations that are embedded into competent rock are exempt from scouring due to the hardness of the rock material and its resistance to scour. The presence of competent rock indicates that the foundations are safe from the normal processes causing scour. A scour code of Item 113 = 5 or 8 is assigned.
   a. Rock is shown on the plan sheets, soil borings, or structural details.
   b. Plans have quantities for rock excavation at the foundation elements.
   c. Drilled shafts are used for the substructure and elevations are shown on the details for penetration and/or a rock line is noted.
   d. The plan sheet includes a note for rock sockets.
   e. Spread footings are called for on the plans in an area with competent rock.
   f. As-built information includes rock sockets, quantities for rock excavation, or additional foundation information.
   g. Pile log shows pile tips embedded into rock and the proper pile tips are called for on the plans for driving into rock.
2. **Foundations with penetration into Marl or similar consolidated material**
   It has been determined that Marl exhibits very similar scour resistance as rock. The rate of scour in Marl has been determined to be so slow that ultimate scour depths would not be reached within the service life of the structure and therefore, can be considered as scour resistant. A scour code of Item 113 = 5 or 8 is assigned.
   a. Marl is shown on the plan sheets, soil borings, or structural details.
   b. Plans have notes about foundation elements being in Marl.
   c. Drilled shafts are used for the substructure and elevations are shown on the details for penetration into Marl.
   d. Spread footings are called for on the plans and are placed an adequate depth into the Marl.
   e. Pile Log show pile tips embedded into Marl.
3. **Unknown foundations in the Piedmont Region**
   When a bridge is founded on timber piles in the Piedmont and Blue Ridge regions of SC, where rock is relatively shallow and pile penetration is limited by the depth to rock, the timber foundations are scour critical when the depth to rock is less than five (5) feet from the surface. A scour code of Item 113 = 3 is assigned.
   a. Foundation elements are made of timber and are located in the Piedmont or Blue Ridge regions.
   b. Foundations are classified as unknown.
4. **Unknown foundations**
   Foundation data is not available to properly describe the type and depth of foundations. A scour code of Item 113 = U is assigned.
5. **Nondesigned Countermeasures installed**
   Nondesigned countermeasures are installed at a bridge. Since the countermeasures were not properly designed, its effectiveness is not a known quantity. A scour code of Item 113 = 7 is assigned.
   a. A countermeasure without design information is present and the bridge is already coded as Item 113 =7.
   b. A Type 1 scour study is not possible.
6. **Bridge Size Culverts**
   Culverts are not normally subject to scour unless they are bottomless. Bottomless culverts should be analyzed as bridges to determine the scour assessment type to be used. There have been cases where issues with stream degradation and abutment-like scour affects bridge-sized culverts. These cases typically occur at locations where a bridge should be used instead of a culvert. A scour code of Item 113 = 8 is assigned.
7. **Bridges over Reservoirs**
   Bridges over reservoirs are generally at low risk of scour. If the constriction is severe ($m \geq 0.75$), a Type 1 scour study should be conducted. If the constricted crossings over reservoirs with a geometric contraction ratio < 0.75, available site specific data (such as historical tape down measurements and geotechnical borings) can be used to assign a scour code of Item 113 = 5 or 8.

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1.5 Definitions, Abbreviations, and Acronyms

1.5.1 Definitions

The following terms in this Guidance Document are used as defined below:

Abrasion – Removal of streambank material due to entrained sediment or debris rubbing against the bank.

Aggradation – A general and progressive buildup of the longitudinal profile of a channel bed due to sediment deposition.

Annual Exceedance Probability (AEP) – the **probability** of a flood occurring in any year. The **probability** is expressed as a percentage. For example, a large flood that may be calculated to have a 1% chance to occur in any one year, is described as 1% AEP (commonly referred to as the 100-year flood).

Annual Flood – The maximum flow in one year may be daily or instantaneous; it is typically based on an instantaneous peak.

Approach Section –The cross section upstream of the bridge at a distance such that the flow lines are parallel, and the flow has not yet begun to contract due to the bridge constriction. For the envelope curves, this section is typically about one (1) bridge length upstream. See SIR 2016-5121:

- Page 33 paragraph 1
- Page 37 Paragraph 1
- Page 61 Paragraph 1
- Page 74 Paragraph 4
- Page 78 bullet 2

Apron – Protective material placed on a streambed to resist scour.

Apron, launching – An apron designed to protect the side slopes of a scour hole after settlement.

Armor (Armoring) – Surfacing of channel beds, banks, or embankment slopes to resist erosion and scour. a) natural process whereby an erosion-resistant layer of relatively large particles is formed on a streambed due to the removal of finer particles by streamflow; b) placement of a covering (such as riprap) to resist erosion.

Average Velocity – The velocity at a given cross section determined by dividing discharge by the cross-sectional area.

Backwater (bridge) – The increase in water surface elevation relative to the elevation occurring under natural channel and floodplain conditions. It is induced by a bridge or other structure that obstructs or constricts the free flow of water in a channel.

Backwater Area – The low-lying lands adjacent to a stream that may become flooded due to bridge backwater.

Bank – The sides of a channel between which the flow is normally confined.

Bankfull Discharge – Discharge that, on the average, fills a channel to the point of overflowing.

Bank Protection – Engineering works for the purpose of protecting streambanks from erosion.

Bank Revetment – Erosion-resistant materials placed directly on a streambank to protect the bank from erosion.

Bar – Elongated deposit of alluvium within a channel, not permanently vegetated.

Base Floodplain (FEMA) – Floodplain associated with the flood having a 1% AEP recurrence interval.

Bay - Body of water connected to the ocean with an inlet.

Bed – Bottom of channel bounded by banks.

Bed Form - A recognizable relief feature on the bed of a channel, such as a ripple, dune, plane bed, antidune, or bar. Bedforms are a consequence of the interaction between hydraulic forces (boundary shear stress) and the bed sediment.

Bed Layer - A flow layer, several grain diameters thick (usually two) immediately above the bed.

Bridge - A structure, including supports, erected over water; having a track or passageway for carrying traffic or other moving loads; and having an opening measured along the centerline of the roadway equal to or more than 20 feet between under-copings of abutments or spring lines of arches or extreme ends of openings for multiple boxes. It may also contain multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening. Any bridge meeting this definition must have a scour analysis performed and documented in the Scour Analysis Report.

Bridge Opening - The cross-sectional area beneath a bridge that is available for conveyance of water.

Bridge Scour - The erosion of sediment from around bridge abutments, piles, or piers. Scour, caused by swiftly moving water, can create scour holes, compromising the integrity of a structure. In the United States, bridge scour is one of the three main causes of bridge failure (the others being collision and overloading).

Bridge Substructure - Structural elements supporting a bridge in contact with the stream or channel bed, including bridge abutments, piers, and footings.

Bridge Waterway - The area of a bridge opening available for flow, as measured below a specified stage and normal to the principal direction of flow.

Channel - The bed and banks that confine the surface flow of a stream.

Channelization - Straightening or deepening of a natural channel by artificial cutoffs, grading, flow-control measures, or diversion of flow into an engineered channel. Channelization also occurs through natural downcutting due to changes in flow rates or regimes.

Clear Water Scour **-** Clear-water scour occurs when there is no movement of the bed material in the flow upstream of the crossing, but the acceleration of the flow and vortices created by obstructions such as piers or abutments causes the material in the crossing to move or be removed.

Confluence **-**The junction of two or more streams.

Constriction **-** A natural or artificial control section, such as a bridge crossing, channel reach, or dam, with limited flow capacity in which the upstream water surface elevation is related to downstream discharge.

Contraction Scour **-** Involves the removal of material from the bed and banks across all or most of the channel width in a natural channel or at a bridge crossing. This component of scour results from a contraction of the flow area which causes an increase in velocity and shear stress on the bed at the bridge. The contraction can be caused by a bridge or from a natural narrowing of the stream channel.

Degradation **-** A general and progressive lowering of the channel bed over time due to erosion.

Depth of Scour **-** The vertical distance a streambed is lowered by scour below a reference elevation.

Design Flow **-** The discharge that is selected as the basis for the design or evaluation of a hydraulic structure including a hydraulic design flood, scour design flood, and scour design check flood.

Discharge – Volume of water passing through a channel during a given time.

Drainage Basin **-** An area confined by drainage divides, often having only one outlet for discharge (also referred to as a catchment or a watershed).

Equilibrium Scour **-** Scour depth in a sand-bed stream with a dune bed about which live bed pier scour level fluctuates due to variability in bed material transport in the approach flow.

Erosion Control Matting **-** Fibrous matting (e.g., jute, paper, etc.) placed or sprayed on a stream-bank for the purpose of resisting erosion or providing temporary stabilization until vegetation is established.

Floodplain **-** A nearly flat, alluvial lowland bordering a stream, that is subject to frequent inundation by floods.

Freeboard **-** The vertical distance above a design stage that is allowed for waves, surges, drift, and other contingencies.

Hydraulics **-** The applied science concerned with the behavior and flow of liquids, especially in pipes, channels, structures, and the ground.

Hydraulic Model – A small-scale physical or mathematical representation of a flow condition.

Hydraulic Structures **-** The facilities used to impound, accommodate, convey, or control the flow of water, such as dams, weirs, intakes, culverts, channels, and bridges.

Invert **-** The lowest point in the channel cross section or at flow control devices such as weirs, culverts, pipes, or dams.

Item 113 - a single-digit code to identify the current status of the bridge regarding its vulnerability to scour. See Chapter 8 for details.

Live Bed Scour - Scour at a pier or abutment (or contraction scour) when the bed material in the channel upstream of the bridge is moving at the flow causing bridge scour.

Local Scour - Local scour involves removal of material from around piers, abutments, spurs, and embankments. It is caused by an acceleration of flow and resulting vortices induced by flow obstructions and is often cyclic in nature.

Longitudinal Profile - The profile of a stream or channel drawn along the length of its centerline. In drawing the profile, elevations of the water surface or the thalweg are plotted against distance as measured from the mouth or from an arbitrary initial point.

Mattress - A blanket or revetment of materials interwoven or otherwise lashed together and placed to cover an area subject to scour.

Meander Bend - a bend in the channel of a river, stream, or other watercourse. It is produced by a stream or river swinging from side to side as it flows across its floodplain or shifts its channel within a valley.

Natural Flood Plain Elevations – The reference surface for assessing multiple scour components, selected at a location representing the natural flood plain and not an existing scour hole or areas with fill.

Open Bottom Culvert - 3-sided Bridge/culvert structures with natural channel materials as the bottom.

Pavement - Streambank surface covering, usually impermeable, designed to serve as protection against erosion. Common pavements used on streambanks are concrete, compacted asphalt, and soil-cement.

Paving - Covering of stones on a channel bed or bank (used with reference to natural covering).

Pile - An elongated member, usually made of concrete, timber, or steel, that serves as a structural component of a bridge.

Plan of Action (POA) - provides guidance for inspectors and engineers that shall be implemented for scour critical bridges before, during, and after flood events to protect the structure and ultimately, the traveling public.

Reference Surface – A "Reference Surface" is used to apply scour estimates to the bridge site. This surface will show the natural topography without the effects from the roadway or sources of fill. Per USGS SIR20165121, "The reference surface can be determined by reviewing flood plain elevations from SCDOT road and bridge plans, surveyed cross sections, LIDAR, and/or site visit observations." Scour depths should be measured from the reference surface as the initial ground line. Where the flood plain slopes substantially in the lateral or longitudinal directions, judgement should be applied to select a reference surface. A similar approach can be used to determine thalweg reference elevation.

Riprap - Layer or facing of rock dumped or placed to protect a structure or embankment from erosion. In certain cases, other practices, such as wire-enclosed riprap (gabions), grouted riprap, sacked concrete, broken concrete, and concrete slabs may be used.

Roughness Coefficient - Numerical measure of the frictional resistance to flow in a channel, as in the Manning formula.

Scour - Erosion of streambed or bank material due to flowing water; often considered as being localized (see local scour, contraction scour, total scour).

Slope Protection - Any measure such as riprap, paving, vegetation, revetment, brush, or other material intended to protect a slope from erosion, slipping or caving, or to withstand external hydraulic pressure.

Spill-through Abutment - A bridge abutment having a fill slope on the streamward side. The term originally referred to the "spill-through" of fill at an open abutment but is now applied to any abutment having such a slope.

Spread Footing - A pier or abutment footing that transfers load directly to the earth.

Tape Down - The measurement from either the top of rail or top of curb to features below the bridge including, but not limited to: abutments, top of bank, water surface, channel bottom, etc.

Thalweg - The location of the channel where the main flow and velocity occur. In most cases, it is the deepest part of the channel.

Toe of Bank - That portion of a stream cross section where the lower bank terminates and the channel bottom or the opposite lower bank begins.

Total Scour - The sum of long-term degradation, general (contraction) scour, and local scour.

Ultimate Scour - The maximum depth of scour attained for a given flow condition. May require multiple flow events and in cemented or cohesive soils may be achieved over a long time period.

Vertical Abutment - An abutment, usually with wing walls, that has no fill slope on its streamward side.

Vertical Contraction Scour - Scour resulting from flow impinging on bridge superstructure elements (e.g., low chord).

Wandering Thalweg - A thalweg whose position in the channel shifts during floods and typically serves as an inset channel that conveys all or most of the streamflow at normal or lower stages.

1.5.2 Abbreviations and Acronyms

AASHTO	American Association of State Highway Transportation Officials
AEP	Annual Exceedance Probability
BrW	BridgeWatch
COVID 19	Coronavirus Disease 2019
FEMA	Federal Emergency Management Agency
FHWA	Federal Highways Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
HDSO	Hydraulics Design Support Office
HEC-18	US FHWA Hydraulic Engineering Circular No.18
HEC-RAS	USACE Hydrologic Engineering Center's River Analysis System
NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
POA	Plan of Action
PW	ProjectWise
QB	QuickBase
SCDOT	South Carolina Department of Transportation
SRH 2D	Sedimentation and River Hydraulics -Two Dimensional model
SMS	Surface-water Modeling System
USGS	United States Geological Survey
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation

1.6 References

The user is encouraged to refer to the following references for additional information when performing scour analysis of a bridge.

FHWA Publications
https://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm

FEMA Flood Map Service
https://msc.fema.gov/portal/home

HEC-18 Evaluating Scour at Bridges, Fifth Edition
https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12003.pdf

HEC-RAS 5.0 Documentation
https://www.hec.usace.army.mil/software/hec-ras/documentation.aspx

HEC-23 Volume II Bridge Scour and Stream Instability
https://www.fhwa.dot.gov/engineering/hydraulics/pubs/09111/09112.pdf

Inventory and Appraisal of the Nation's Bridges
https://www.fhwa.dot.gov/bridge/bripub.cfm

National Bridge Inspection Standards
https://www.fhwa.dot.gov/bridge/nbis.cfm

SCDOT Publications
https://www.scdot.org/business/hydraulic-design-studies.aspx

Requirements for Hydraulic Design Studies
https://www.scdot.org/business/technicalPDFs/hydraulic/requirements2009.pdf

USGS Publications
https://water.usgs.gov/osw/techniques/bs/BSDMS/

https://pubs.er.usgs.gov/publication/sir20095156

https://pubs.er.usgs.gov/publication/sir20145030

https://pubs.er.usgs.gov/publication/wri894087

https://pubs.er.usgs.gov/publication/wri924040

https://sc.water.usgs.gov/projects/scour_database/getAllDBsController.php

Clear-water Abutment and Contraction Scour in the Coastal Plain and Piedmont Provinces of South Carolina,1996-99 WRI 03-4064
https://pubs.er.usgs.gov/publication/wri034064

Development and Evaluation of Clear-Water Pier and Contraction Scour Envelope Curves in the Coastal Plain and Piedmont Provinces of South Carolina SIR 2005-5289
https://pubs.er.usgs.gov/publication/sir20055289

Development and Evaluation of Live-Bed Pier and Contraction- Scour Envelope Curves in the Coastal Plain and Piedmont Provinces of South Carolina SIR 2009-5099
https://pubs.usgs.gov/sir/2009/5099/pdf/sir20095099.pdf

The South Carolina Bridge-Scour Envelope Curves SIR 2016-5121
https://pubs.usgs.gov/sir/2016/5121/sir20165121.pdf

USGS StreamStats
https://streamstats.usgs.gov/ss/

HDB 2018-3 USGS Scour Manual and Updated Guidance on Bridge Scour Analysis
https://www.scdot.org/business/technicalPDFS/hydraulic/HDB_2019-3.pdf

HDB 2019-4 Updated Hydraulic Bridge Design Criteria
https://www.scdot.org/business/technicalPDFS/hydraulic/HDB_2019-4.pdf

NCHRP 24-20 Abutment Scour Predictions in Non-Cohesive Sediments
https://onlinepubs.trb.org/onlinepubs/nchrp/docs/nchrp24-20_fr.pdf

User's Manual and Spreadsheet Tool for Application of the South Carolina Unit Hydrograph Method
https://scdot.scltap.org/projects/completed/

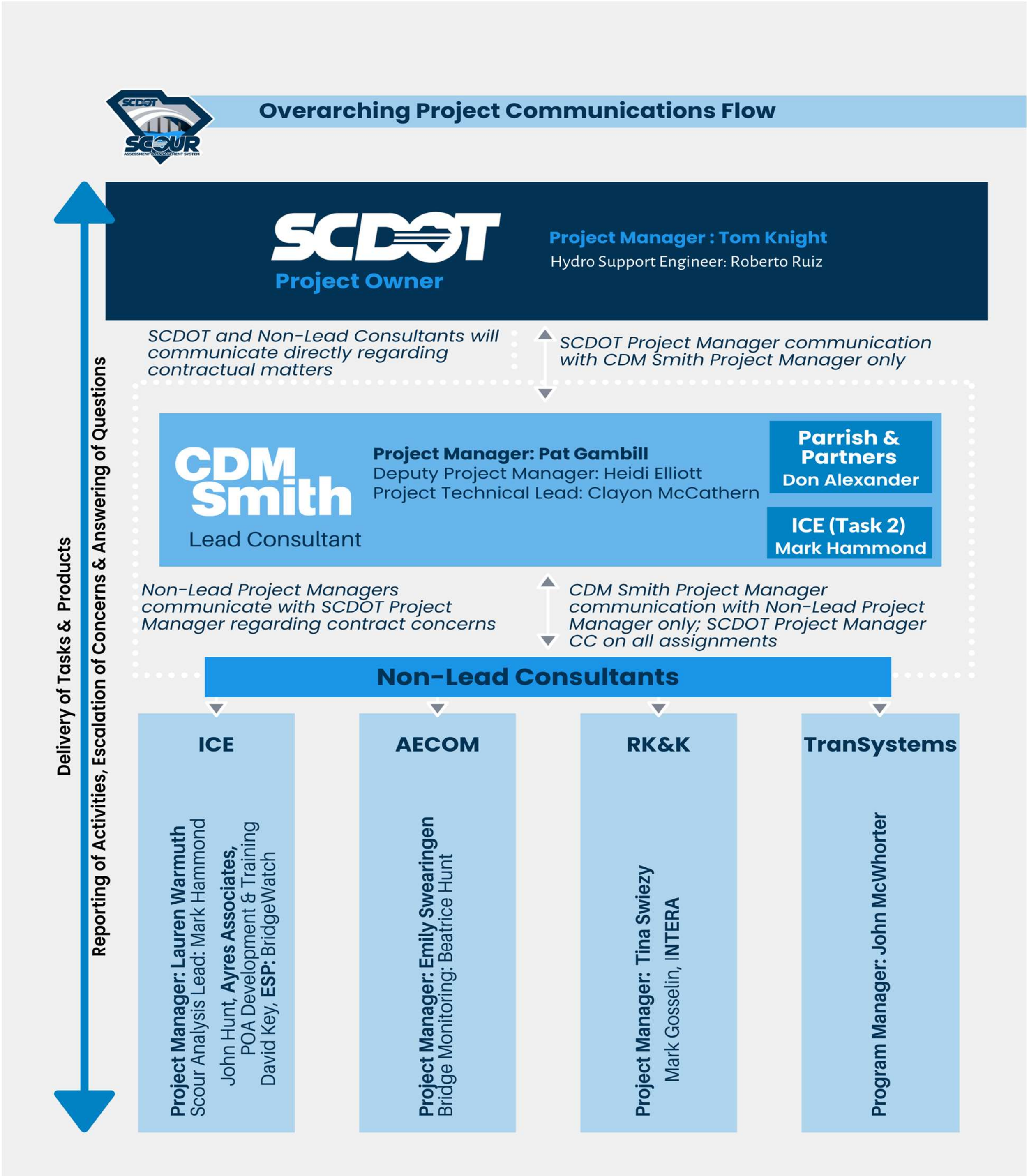
1.7 Coordination

Effective, efficient, and regular coordination amongst the SCDOT HDSO, the Lead Consultant, and the Non-Lead Consultants is a very important factor in ensuring the success of this project. The communications flow should adhere to but is not limited to the following:

- The Lead consultant will act as the point of contact with SCDOT HDSO for project related communication with HDSO copied on all email correspondance.
- All Prime Non-Lead Consultants should communicate directly with the Lead Consultant and copy SCDOT HDSO regarding all project related information
- All subconsultants should communicate directly with their respective Prime Consultant on all communications.
- All Consultants should communicate directly with HDSO for any SCDOT contract related issues.
- There will be regularly scheduled meetings (weekly or bi-weekly) held by the Lead Consultant with each Non-Lead Consultant. The SCDOT HDSO Project Team will be invited to attend these meetings.

Communications between SCDOT, the Lead Consultant, and the Non-Lead Consultants is illustrated in **Figure 2**.

Figure 2: Project Communications Flow



1.8 Technical Information Inquiry (TII)

For issues or technical questions that arise during the scour assessment effort period, a formal process will be followed in order to collect, track, and resolve any issues in a time efficient manner.

The formal process is as follows:

- The lead consultant as well as any of the the non-lead consultants shall submit the issue or technical question via the Technical Information Inquiry (TII) form (**Figure 3**) to the Lead Consultant.
- The Lead Consultant will log the TII as well as assign the TII a tracking number.
- The Lead Consultant will submit the TII with a proposed formal resolution to the SCDOT HDSO Project Manager, Tom Knight.
    - The SCDOT HDSO accepts and approves the proposed formal resolution to the TII.
        - SCDOT HDSO concludes the approval of the proposed formal resolution.
        - Lead Consultant will record and return the approved documented resolution to the originator via the TII Form.
        - Lead Consultant will post approved TII via a common project media platform.
    - The SCDOT HDSO requests further information/coordination in reference to the TII.
        - Lead Consultant requests further information/coordination from the originator to clarify the issue**.**
        - Lead Consultant submits this information to the SCDOT HDSO.
        - This process will continue until the resubmitted proposed formal solution is approved by the SCDOT HDSO.
        - Lead Consultant will record and return the approved documented resolution to the originator via the TII Form.
        - Lead Consultant will post approved TII via a common project media platform.

This formal process is illustrated in **Figure 4**.

The TII Form as well as all other forms included in this document have been provided to each of the non-lead consultants via ProjectWise.

Figure 3: Technical Information Inquiry (TII) Form

TECHNICAL INFORMATION INQUIRY

Date:

To:

From:

Project Name: SCDOT Scour Critical Assessment & Management Program

TII Number:

Technical Information Inquiry:

Signed by: Date:

Response:

Attachments:

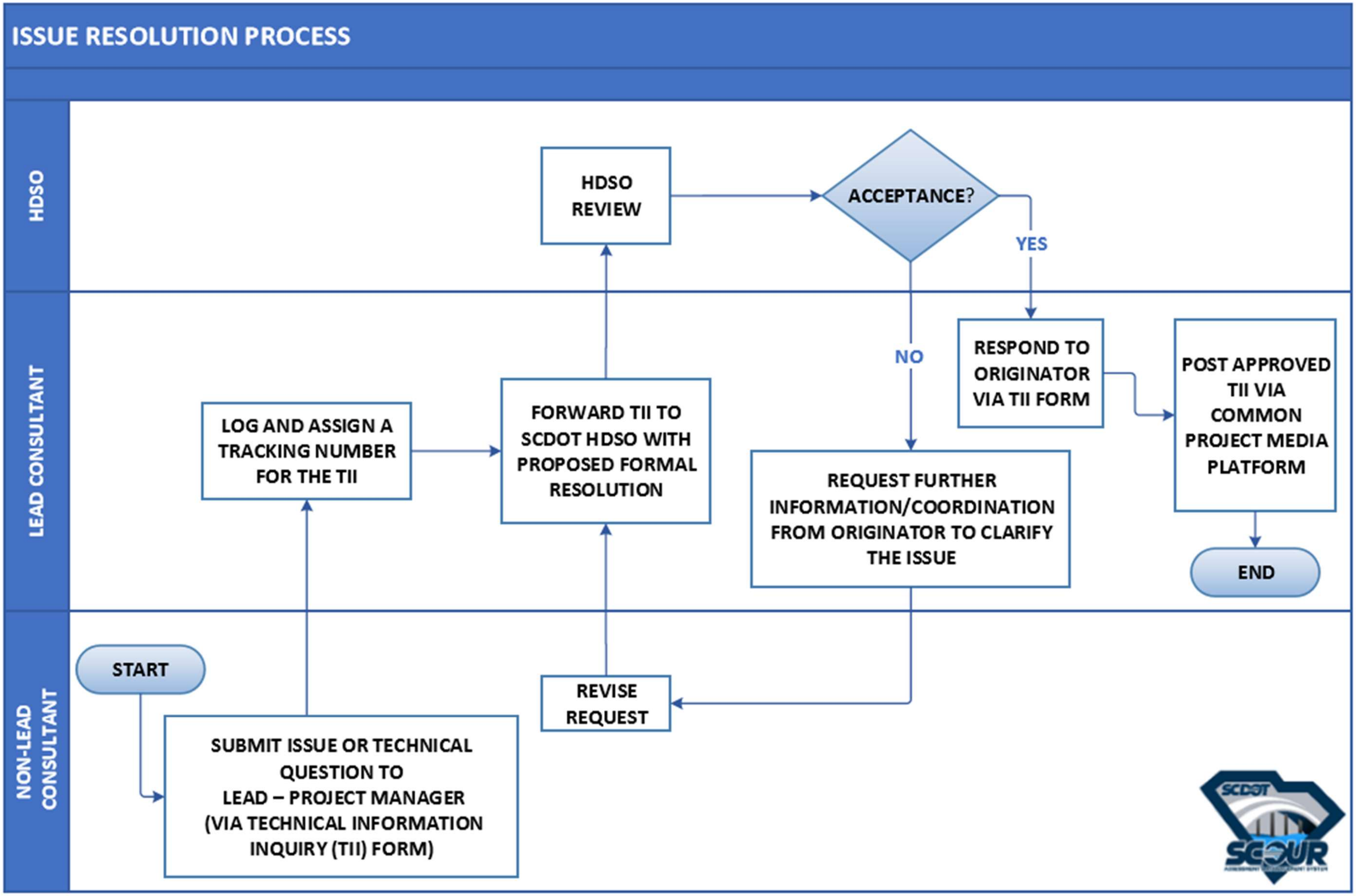
Response From: To: Date Rec'd: Date Ret'd:

Signed by: Date:

Copies to: Tom Knight, P.E., Roberto Ruiz, P.E.

PAGE 1

Figure 4: Issue Resolution Process



1.9 Revisions

Revisions to this Guidance Document may be the result of changes in SCDOT specifications, FHWA requirements, or AASHTO requirements.

Users are invited to send suggestions for revisions to this Guidance Document to the Hydraulics Design Support Office (HDSO), Tom Knight, and the Lead Consultant Project Manager, Pat Gambill. Users are to follow the Figure 5 flowchart when submitting recommendations for revisions to the Guidance Document. Suggestions need to be written with identification of the problem, the recommended revision, and the reason for the recommendation.

SCDOT will consider suggestions submitted and changes determined to be acceptable shall be submitted to FHWA for review and approval. Approved policy and editorial revisions to this Guidance Document will be indicated with a line in the margin of the applicable page. All approved revisions will be listed in **Table 2**.

Interim updates are not included in this document. Refer to posted Technical Notes for items such as text, images, photos, and appendices which may have been updated. The posted Technical Notes are contained within the SCDOT Hydraulics Design Office website.

Table 2: Revisions to Scour Analysis Guidance Document Table

Revision No.	Date	Comments/Revisions Made	Author of Revisions	Approved By	Date of Approval
1					
2					
3					
4					
5					
6					
7					
8					

Figure 5: Revisions to Scour Analysis Guidance Document Process

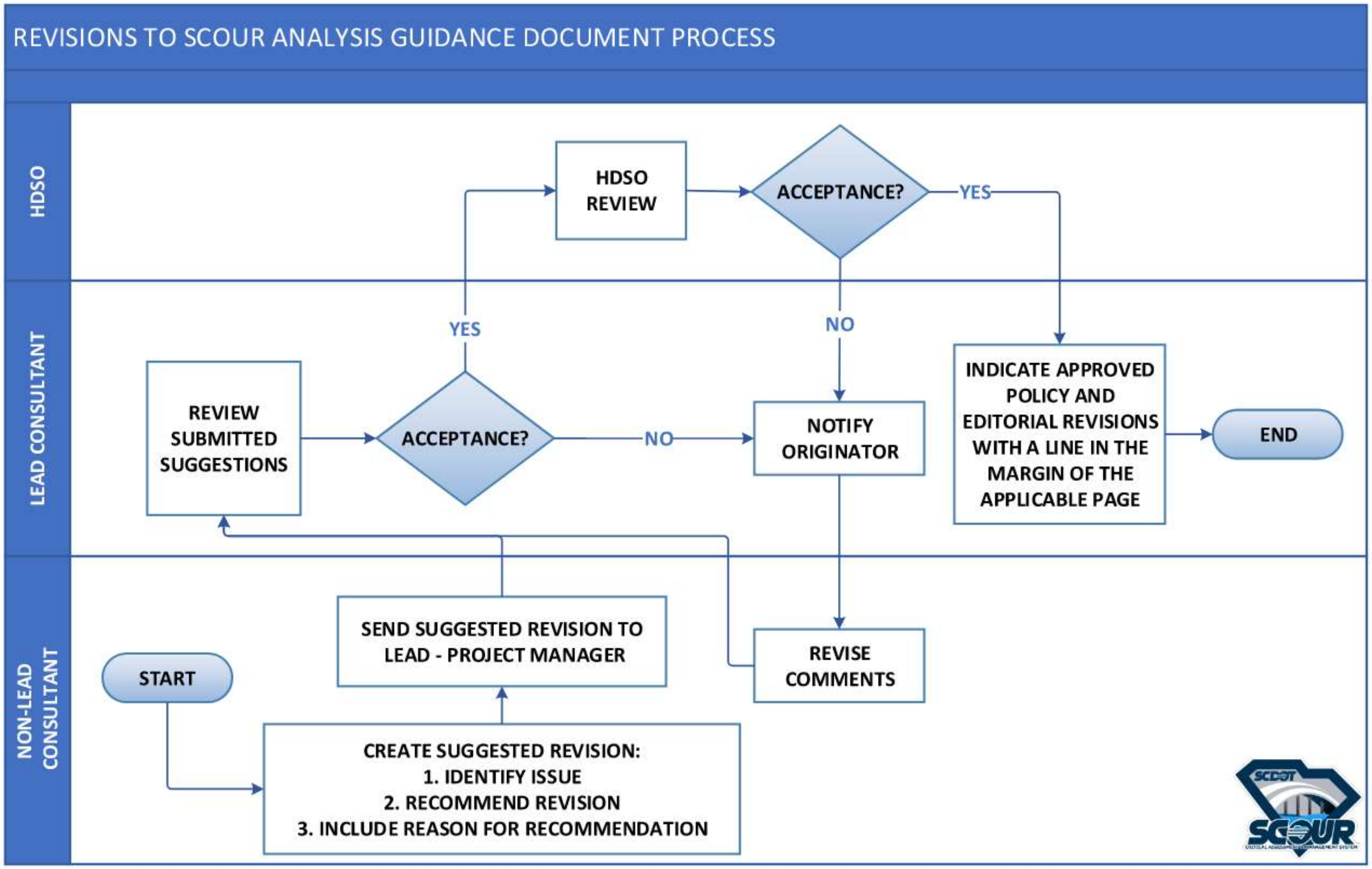


Table 3: Summary of Action Items for Chapter 1:

Action Item	Lead Consultant	Non-Lead Consultants
Identify all bridges over water that require scour analysis or a Plan of Action (POA).	X	
Develop a method of prioritizing bridges that need additional documentation.	X	
Provide a final database of prioritized bridges to each of the Non-Lead Consultants. The desired scour analysis method will be determined by the Lead Consultant and provided in the bridge list for each bridge.	X	
Communicate directly with SCDOT Project Manager regarding contract concerns following the process outlined in **Figure 2** ***Project Communications Flow***.	X	X
Direct all technical questions and questions concerning the applicability or requirements of referenced documents following the process outlined in **Figure 4.**		X

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Section 2. Desktop Data Collection

2.1 Purpose

Desktop Data Collection is a necessary component in the querry for all existing information available for each bridge included on either the scour analysis bridge list or the POA bridge list. Bridge data collection includes but is not limited to investigating SCDOT Plans Online for Final Roadway Construction plans, Final Bridge Construction plans, and As-Built bridge plans. Available data will be provided by SCDOT.

The Lead Consultant, CDM Smith, will perform extensive data collection for each of the bridges requiring a scour analysis or a POA. This data may include but is not limited to existing bridge plan sheets such as the title sheet, bridge plan and profile sheet, foundation layout sheet, pile driving logs (as-built plans), inspection reports, or any other pertinent information regarding the existing bridge substructure. For many of the bridges in the system that were constructed before 1988, bridge plans could not be located. For some of these bridges, roadway plans were found which show the foundation material and the general layout of the bridge. For the bridges that there were no construction plans (either bridge or roadway) found, a more detailed field investigation will be required in order to collect all necessary data to perform the scour analysis of the bridge.

The Lead Consultant shall transfer/copy all existing bridge documentation into each of the Non-Lead Consultants designated folders located on the SCDOT's ProjectWise. The Non-Lead Consultants will access the existing bridge documents through each of their designated Consultant folders located on the SCDOT's ProjectWise.

The Lead Consultant will provide the following to the non-lead consultants performing the required scour analysis of their assigned bridges:

- Access to the SCDOT Plan Library
- Excerpted bridge plans from the Plan Library (as available)
- Prior Bridge Inspections Reports (Including Underwater Inspections) (If available)
- Pile Records from bridges built by SCDOT Maintenance Forces
- FEMA Computer Models
- Guidance Manual for Performing Scour Studies
- SCDOT Scour Critical Assessment and Management System Form
- Prior scour reports and documentation (If available)
- Bridge Geotechnical Reports (If available)

In general, it is acceptable for the purposes of this project to utilize available data from the above mentioned sources without extensive verification of the data, however, the engineer should establish that the information is current from minimally correlating with the visual information denoted during site inspections for each bridge and correlating available data from differing sources.

Roadway plans provide a natural groundline that can be used to calculate embankment lengths and the geometric ratio. The groundline must be on an original alignment that does not reflect fill from a previous alignment. The bridge plans provide the bridge opening and geometry. Bridge As-Built plans provide pile tip elevations, drilled shaft elevations, and footing elevations. Bridge and roadway plans may also contain historical highwater elevations. These elevations can be used for bridge scour computations as long as they represent approximately a highwater elevation.

FEMA FIRMs can also provide valuable information. If FEMA maps utilize LiDAR data, they tend to be a good resource and provide embankment lengths and approach-flow widths. Approach flow-widths can also be obtained from FEMA Flood Insurance Studies. Additionally, FEMA studies can provide 1% AEP flood elevations.

2.1.1 Office Review

It is highly recommended that the field inspectors complete a review of any available bridge plans and previous inspection reports prior to performing the field inspection. Information obtained from this review provides a basis for inspecting the bridge and the stream/water body. Items for consideration in the office review include:

1. What do comparisons of streambed cross sections taken during successive inspections reveal about the streambed?
    a. Is it stable?
    b. Degrading?
    c. Aggrading?
    d. Moving laterally?
    e. Are there scour holes around piers and abutments?
2. What equipment is needed (tape, rods, poles, sounding lines, sonar, etc.) to measure streambed elevations so that a cross section diagram can be prepared?
3. Are there sketches and/or aerial photographs to indicate the planform location of the stream and determine whether the main channel is migrating or the flow direction is changing at the bridge? Make certain to look at aerials from different time periods (e.g. Google Earth Historical Imagery and USC Online Library) to capture any changes that may have occurred over time.
4. What type of bridge foundation was constructed? (Spread footings, piles, drilled shafts, etc.) Are footing and pile tip elevations known? Do the foundations appear to be vulnerable to scour? What are the sub-surface soil conditions? (sand, gravel, silt, clay, rock?)

Table 4: Data Collection Responsibilities

Action Item	Lead Consultant	Non-Lead Consultants
Arrange for non-leads to have access to SCDOT Plans Library items and other data for assigned bridges as listed in Section 2.1.	X	
Confirm that information provided for each bridge site is current based on site inspections and correlation of data from differing sources.	X	X
Complete a review of available bridge plans & inspection reports prior to performing field inspection, as described in Section 2.1.1. Determine the equipment needed and items to consider during the field inspection.	X	X

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Section 3. Field Inspections

3.1 Purpose

All bridges requiring a scour study or a Plan of Action (POA) will require a field visit. Field visits will require a minimum of two people' one being a Hydraulics Design Engineer.

Each Consultant shall submit an anticipated inspection schedule to the Lead Consultant, to be approved by the HDSO before beginning inspections. The schedule should include the bridge Asset ID and the proposed date of inspection. The Consultant's progress will be compared against this schedule.

Each consultant shall complete a Bridge Scour Inspection Form (See Section 3.4) for each bridge visited. The field visit should be primarily focused on channel stability and scour. Channel stability can be affected by aggradation or degradation, or in some cases, both at once. If the bridge is located at or near a meander bend, a build-up of sediment on the inside bend, or point bar, and scour on the outside bend will usually cause degradation.

There are two main objectives to be accomplished in inspecting bridges for scour:

1. Accurately record the present condition of the bridge and the stream, and
2. Identify conditions that are indicative of potential problems with scour and/or stream instability for further review and evaluation.

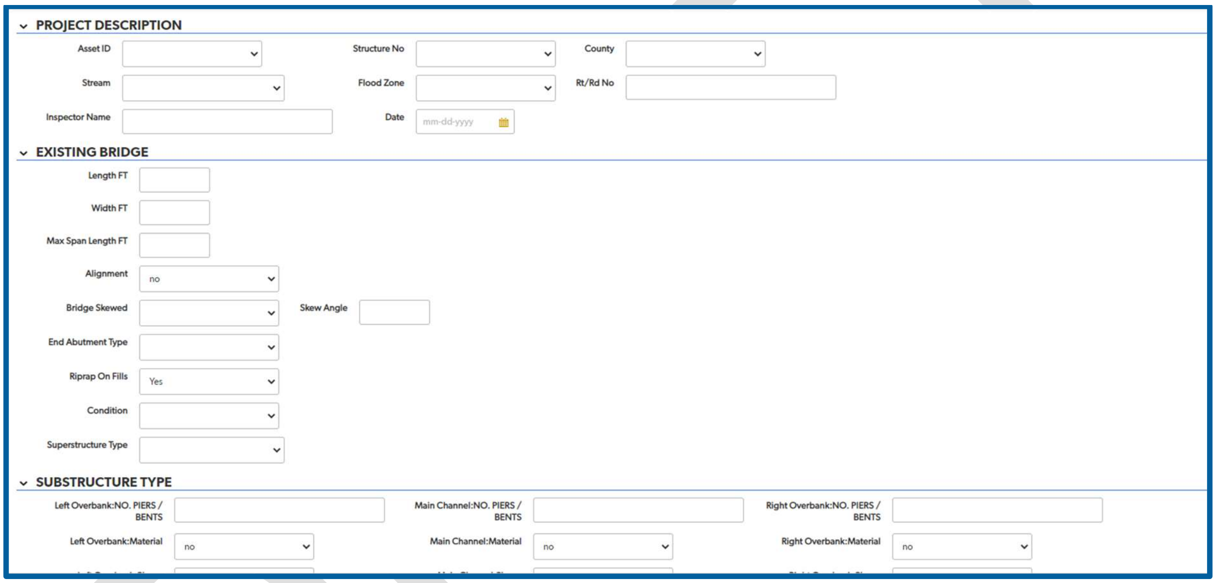
In order to accomplish these objectives, the inspection team needs to recognize, understand, and document the interrelationship between the bridge, the stream, and the floodplain. Typically, a bridge spans the main channel of a stream and perhaps a portion of the floodplain. The road approaches to the bridge are usually on embankments which obstruct flow on the floodplain. This overbank or floodplain flow must, therefore, return to the stream at the bridge, flow through relief structures (culverts or relief bridges) and/or overtop one or both approach roadways.

Where overbank flow is forced to return to the main channel at the bridge, zones of turbulence are established and scour is likely to occur at the bridge abutments. Piers and abutments may present obstacles to flood flows in the main channel, creating conditions for local scour because of the turbulence around the bridge foundations. After flowing through the bridge, the flood water will expand back to the floodplain, creating additional zones of turbulence and scour.

The number one reason for scour or channel instability is debris. The location as well as the vertical and horizontal blockage by debris should be shown and evaluated on the Site Inspection Form and accompanying sketch. The **bridge sketch** should include a plan and profile view of the existing bridge. The plan view should show the channel top of banks and if the channel is skewed to the bridge. The sketch should indicate any channel instability or locations of debris. The plan view should define land use upstream and downstream of the existing bridge and assign appropriate Manning's n values to overbanks and channel. Any utilities that are located above the existing ground or below the bridge low chord should be noted in the plan and profile view. Tape down points in the profile view shall include toe of fills, top of banks, channel thalweg, and every bent or pile location. The measurements should be taken from the same location as the Bridge Maintenance tape downs (i.e., top of rail, top of curb) so they can be compared to previous tape downs. Tape downs should only be obtained if the existing inspection reports contain data older than 2 cycles (typically 4 years).

Field inspections will be accomplished using a data collection application named QuickBase. Each Consultant will be assigned 4 accounts (to accommodate 4 teams) to use the QuickBase application. These accounts are provided by SCDOT for use on the Scour Project only, for the duration of the project. QuickBase can be used on a laptop, tablet or smartphone, uploading all collected data to a cloud-based database. QuickBase allows automated storage and tracking of inspection data. A field inspection form tailored for the project will be used for field inspection. A sample section is shown in **Figure 6**.

Figure 6: Sample Section of Field Inspection Form



PROJECT DESCRIPTION

Asset ID | Structure No | County
Stream | Flood Zone | Rt/Rd No
Inspector Name | Date mm-dd-yyyy

EXISTING BRIDGE

Length FT
Width FT
Max Span Length FT
Alignment: no
Bridge Skewed | Skew Angle
End Abutment Type
Riprap On Fills: Yes
Condition
Superstructure Type

SUBSTRUCTURE TYPE

Left Overbank:NO. PIERS / BENTS | Main Channel:NO. PIERS / BENTS | Right Overbank:NO. PIERS / BENTS
Left Overbank:Material: no | Main Channel:Material: no | Right Overbank:Material: no

If paper copies of inspection reports are created during the inspection rather than using QuickBase, the forms shall be submitted to the SCDOT HDSO by the end of the day on Friday of each week in which the inspection was performed. The submission should be submitted by sending the form to David Powers (powersdb@cdmsmith.com).

3.1.1 Suggested Field Inspection Supply Items:

- Measuring Wheel
- 25’ Steel Measuring Tape
- Engineers Hammer
- 100’ Nylon Measuring Tape with weight on the end (preferably brass)
- Roof Top Strobe Lights (Yellow & White)
- Machete
- Sharp shooter hand shovel (for soil samples)

- Heavy Duty Gallon size Ziploc Baggies (to contain soil samples)
- Hand Level
- 25’ Survey Rod (Fiberglass)
- 48” Probe Rod
- Golf Umbrella
- Cooler – 16 to 20 Quart (with Ice, Water, Gatorade, etc.)
- Sunscreen, SPF 50
- Insect Repellent, 25% DEET
- Bear Spray
- Snake Chaps and/or Snake Boots
- High Visibility Safety Vests
- First Aid Kit
- Hand Sanitizer (COVID 19)
- Sanitizing Wipes (COVID 19)
- Latex Gloves (COVID 19)
- Face Masks (COVID 19)
- Fire Extinguisher
- Field Logbook
- Field Backpack
- Writing Utensils
- Clipboards
- Personal Telephone or form of communication in case of emergency
- USB Charging Adapters

3.2 Safety Considerations

The bridge inspection team should understand and practice prudent safety precautions while conducting bridge inspections. It is expected that each company will establish a formal health and safety program that will guide their practices throughout this project. The following list of precautionary measures shall be adhered to when conducting Field Inspections:

- Park in a safe place and turn on hazard lights if visibility is impaired/lighting is poor, it is not daylight, or if the vehicle is parked on the shoulder. All vehicles are required to have white or yellow flashing strobes.

- If streambed measurements are to be taken from the bridge, extreme caution should be exercised since most of the bridges will have minimal clearance between the edge of the travelway and the parapet. Each consultant should follow their corporate Health and Safety policy in these situations.

- Each inspection team member should wear high visibility (ANSI ISEA 107) safety vests so that they are conspicuous to motorists.

- Each team member will wear appropriate closed toe shoes (preferably boots & steel toed) while performing the inspection. Maintain situational awareness when traversing slopes. Do not attempt to traverse slopes steeper than 1.5:1 - typical bridge embankment. Do not traverse unstable ground or rip rap. Keep hands free while moving over unlevel ground. Maintain secure footing when working near bridge railing.

- Team members should avoid tall brush to the extent feasible. Employees who work in tall brush should make a noise in front of them with a stick. If any snake is sighted, slowly back away and return wearing snake protection boots.

- Team members conducting inspections near open water must seek flat ground to stand on. When flat ground is not present, team members must wear flotation devices. Note: If there is a danger of falling into water that would present a danger of drowning, or a fall of > 6ft, staff should keep a minimum distance of 5ft between themselves and the leading edge of the fall area unless there is a good railing. Have a recovery plan in place (recovery line).

- While working near creeks maintain secure footing, stay out of the water unless necessary.

- The inspection team should leave word with their office regarding their schedule of work for the day. The team should also carry a cell phone with them so that they can get immediate help in the event of an emergency situation.

- The inspection team should take all necessary precautions for the COVID 19 virus. Make certain that each inspector uses the hand sanitizer regularly, wipes down all surfaces touched in the vehicle as well as all field equipment, and wears a face mask and/or latex gloves if necessary.

3.3 General Site Considerations

In order to evaluate the relationship between the bridge and the water body it is crossing, observations should be documented of the conditions of the river, both upstream and downstream of the bridge. These should include conditions such as:

- Take numerous photos at each bridge site to include but not limited to:
  - Typical substructure units (bents).
  - Existing Superstructure.
  - The channel section at the bridge, upstream from the bridge (approx. 100 feet), and downstream from the bridge (approx. 100 feet).
  - Existing vegetation around/near any of the substructure units as well as the banks.
  - Existing debris around any of the substructure units (bents).
  - Any signs of erosion, displaced riprap, sloughing banks, migrating channel, sandbars.
  - Profile view of the Bridge (if possible; oblique view okay).
  - The Bridge number (located inside the barrier parapet).

- Walk or observe (take photos) the natural creek section upstream as well as downstream.

- Observe (take photos) of existing vegetation and debris. Make notes of any potential vegetation and debris.
- Is there evidence of general degradation or aggradation of the river channel resulting in unstable bed and banks? Confirm with historical tape downs.
- Is there evidence of on-going development in the watershed and particularly in the adjacent floodplain that could be contributing to channel instability?
- Are there active gravel or sand mining operations in the channel near the bridge?
- Are there confluences with other streams? How will the confluence affect flood flow and sediment transport conditions?
- Is there evidence at the bridge or in the up and downstream reaches that the stream carries large amounts of debris? Are the bridge superstructure and substructure elements streamlined to pass debris, or is it likely that debris will be caught on the bridge and create adverse flow patterns with resulting scour?
- The best way of evaluating flow conditions through the bridge is to look at and photograph the bridge from the up- and downstream channel. Is there a significant angle of attack of the flow on a pier or abutment?
- Evaluate the riprap materials. Riprap should be angular and interlocking quarried stone. Flat sections of broken concrete paving do not make good riprap.
- Riprap should have a granular or geotextile filter between the rock and the subgrade to prevent loss of the finer subgrade material, whether on the bed or the bank.
- Riprap should be well graded (a wide range of rock sizes).
- When inspecting riprap, the following would be strong indicators of problems:
  - Riprap stones that have been displaced downstream.
  - The riprap blanket has slumped down the slope.
  - Angular riprap material has been replaced by smoother river run material.
  - Riprap material physically deteriorated, disintegrated, or showing signs of having been abraded over time.
  - Holes in the riprap blanket where the filter has been exposed or breached.
  - Riprap layer not thick enough.
  - Geotextile ripped.

3.4 Bridge Scour Inspection Form

BRIDGE SCOUR SITE INSPECTION FORM

PROJECT DESCRIPTION

County: ______________ Rt. / Rd. No.: ______________

Stream: ______________ Asset ID: ______________

Structure No: ______________ Flood Zone: ______________

By: Date:

Note: All references to left and right are looking in the direction of flow.

EXISTING BRIDGE

Length: ______ ft. Width: ______ ft. Max. Span Length: ______ ft.

Alignment: Tangent ☐ Curved ☐

Bridge skewed: Yes ☐ No ☐ Skew Angle: ______ degrees

End Abutment Type: ______________

Riprap on Fills: Yes ☐ No ☐ Condition: ______________

Superstructure Type: ______________

Substructure Type: FILL OUT TABLE 1 BELOW

TABLE 1	MATERIAL				SHAPE				SIZE	
LOCATION	NO. PIERS / BENTS	CONCRETE	STEEL	TIMBER	SQUARE	ROUND	TRIANGULAR	OTHER	LENGTH	DIAMETER
LEFT OVERBANK										
MAIN CHANNEL										
RIGHT OVERBANK										

Utilities Present: Yes ☐ No ☐ Describe: ______________

Debris Accumulations on Bridge: Percent Blocked (Horizontal): ______ %

Percent Blocked (Vertical): ______ %

Draw Sketch of Representative Pier/Bent

BRIDGE SCOUR SITE INSPECTION FORM

PROJECT DESCRIPTION

County: ______________________ **Rt. / Rd. No.:** ______________________

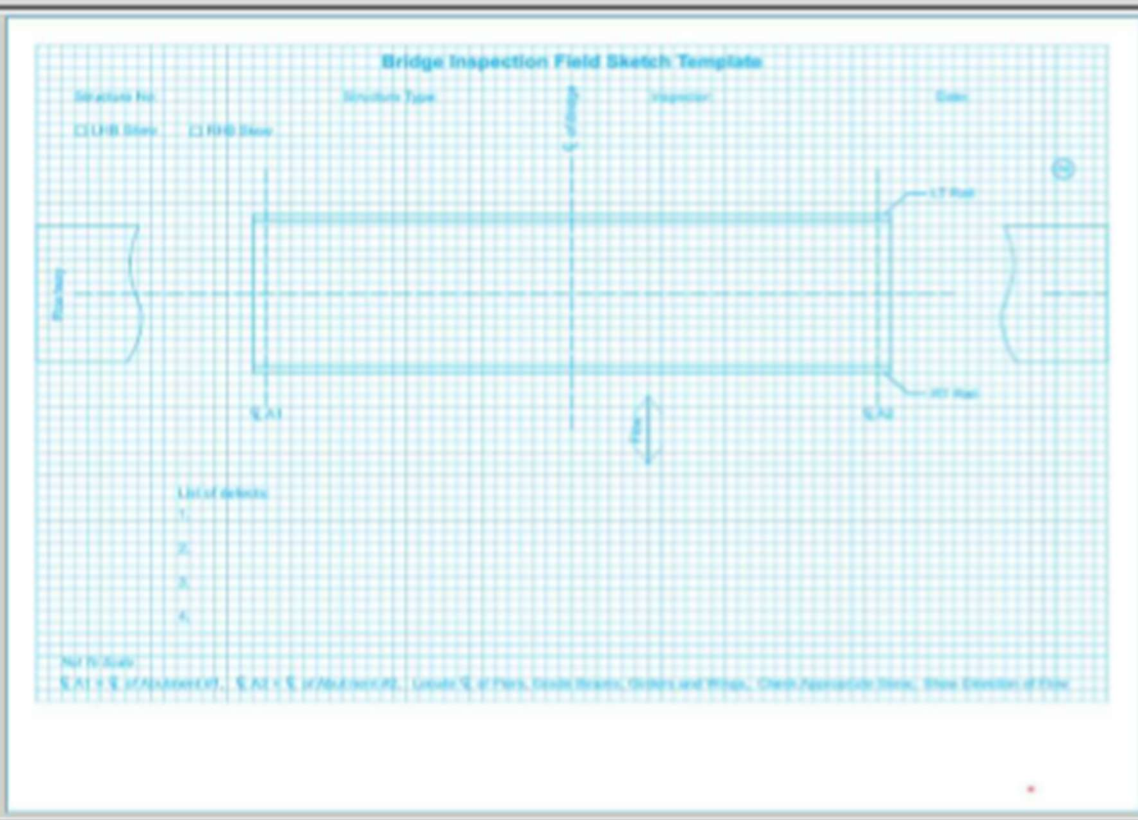
Stream: ______________________ **Asset ID:** ______________________

Structure No: ______________________ **Flood Zone:** ______________________

By: ______________________ **Date:** ______________________

Note: All references to left and right are looking in the direction of flow.

EXISTING BRIDGE PLAN VIEW SKETCH



PLAN VIEW SKETCH CHECKLIST

☐	North Arrow	☐	Mid-Channel Bars (extent, vegetation)
☐	Flow Direction	☐	Downstream Blow-Hole (banks impacted, dimensions)
☐	Streambanks	☐	Debris (accumulation, type, horiz & vert pos, trapping potential)
☐	Bridge Deck	☐	Location of Cross Sections
☐	Angle of Approach	☐	Scour Holes
☐	Piers & Columns	☐	Riprap (note quality & gradation)
☐	Footings or Encasements	☐	Filter fabric or geotextile
☐	Abutments	☐	Photo/Video Locations & Directions
☐	Wing Walls	☐	Countermeasures (type, dimensions, locations, condition)
☐	Tributary Confluences	☐	
☐	Meander Impacts/Cutbanks	☐	
☐	Bank Erosion	☐	
☐	Point Bars (extent, vegetation)	☐	

BRIDGE SCOUR SITE INSPECTION FORM

PROJECT DESCRIPTION

County: ____________________ Rt. / Rd. No.: ____________________

Stream: ____________________ Asset ID: ____________________

Structure No: ____________________ Flood Zone: ____________________

By: ____________________ Date: ____________________

Note: All references to left and right are looking in the direction of flow.

DESCRIPTION OF FLOODPLAIN

Describe General Topography of FloodPlain

Floodplain conditions at Bridge Site:

Floodplain	Developed				Forest/Wetlands			Undergrowth/Shrubs			Planted/Cultivated		Other
	Open	Low	Medium	High	Thin	Moderate	Thick	Thin	Moderate	Thick	Pasture	Crops	
Upstream/Left													
Upstream/Right													
Downstream/left													
Downstream/right													

Other Floodplain Comments:

COMMENTS

COUNTERMEASURES

IN THE UPSTREAM CHANNEL

IN THE DOWNSTREAM CHANNEL

UNDER THE BRIDGE

Is there Evidence of Roadway Over-Topping?	☐	YES	☐	Is pressure flow indicated by debris or waterline located higher than the low chord of the bridge?	NO ☐	YES ☐	
Bend in Channel at Bridge:	☐ None	☐ Mild-30°	☐ Moderate - 30° to 60°	☐ Severe - over 60°			
Describe:							
Debris Accumulaton:	NO ☐	YES ☐		Debris Trapping Potential:	Low ☐	Medium ☐	High ☐
Describe Type & Location:							

REQUIRED PHOTOS	FILE NAME/NUMBER
• UpStream Left Bank	
• UpStream Right Bank	
• Bridge opening from UpStream side	
• Bridge Profile	
• Representative Pier/Bent	
• Left Abutment	
• Right Abutment	
• DownStream Left Bank	
• DownStream Right Bank	
• Bridge opening from DownStream side	
• Under bridge looking UpStream	
• Under bridge looking DownStream	
• Bed Material from Bridge	
• Piers	
• Abutments	
• Roadway Approach - Right	
• Roadway Approach - Left	
• Floodplain Surface Cover	
• Tributary Confluences	
• Meander impacts / cutbanks	
• Point Bars	
• Mid-Channel Bars	
• Bank Erosion	
• Downstream Blow Hole	
• Debris	
• Countermeasures	
• RipRap	

3.5 Tape Downs (Upstream & Downstream) Forms

UPSTREAM PROFILE & SCOUR NOTES FOR BRIDGE/CULVERT PROJECTS

Structure No. ____________ Road ________________ Watercourse _____________Asset ID __________

Location __________________GPS Lat/Long _______________________________Date_____________

County____________________ Inspection Team ____

TAPE DOWNS

Bridge Station (left to right)	Tape Down (ft)	High Steel Elev. (ft)	Ground Elev. (ft)	Remarks

DOWNSTREAM PROFILE & SCOUR NOTES FOR BRIDGE/CULVERT PROJECTS

Structure No. ____________ Road ________________ Watercourse _____________Asset ID _________

Location __________________GPS Lat/Long _______________________________Date_____________

County____________________ Inspection Team ____

TAPE DOWNS

Bridge Station (left to right)	Tape Down (ft)	High Steel Elev. (ft)	Ground Elev. (ft)	Remarks

Table 5: Field Inspection Responsibilities

Action Item	Lead Consultant	Non-Lead Consultants
Establish a formal health and safety program that will guide practices throughout this project, including but not limited to the precautionary measures listed in Section 3.2.	X	X
Submit an anticipated inspection schedule to the Lead Consultant, to be approved by the HDSO before beginning inspections as described in Section 3.1.	X	X
Perform site inspections and complete Bridge Scour Inspection Forms for each bridge following the guidelines and forms set forth in this chapter, as applicable.	X	X
Bridge Scour inspection forms shall be submitted to the SCDOT HDSO by the end of the day on Friday of each week in which the inspection was performed.	X	X

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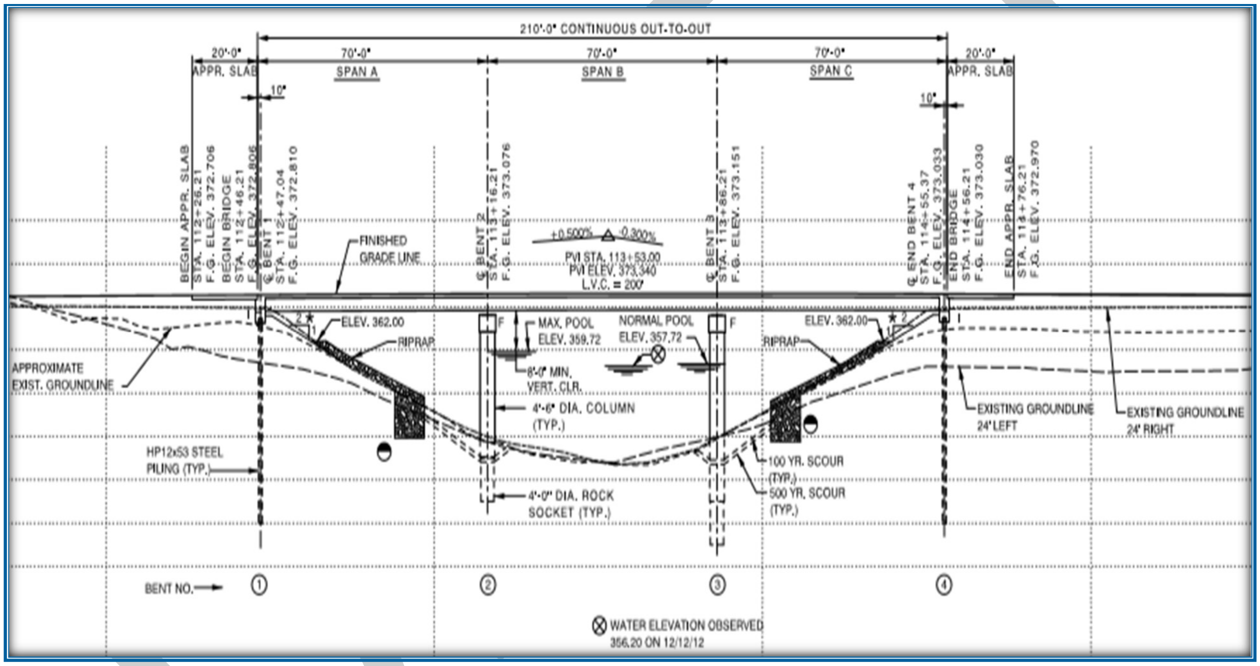
Section 4. Field Surveys

4.1 Purpose

Field surveys will be required when records of existing groundline, bridge geometry, or flood plain data do not exist or are not sufficient to perform a scour study. Field Surveys for riverine bridges will require the following minimum items of information, if not otherwise available.

- Triple profile
  - Cross section upstream of the bridge face beyond the toe of fill (including floodplain)
  - Cross section downstream of the bridge face beyond the toe of fill (including floodplain)
  - A groundline cross section under the existing bridge

Figure 7: Example of Bridge Profile Showing Triple Profile



- The survey will also require:
  - Cross section of floodplain at start of contraction in flow (approach)
  - Cross section of floodplain at end of the effect of the contraction in flow (exit)

- The bridge cross section shall include:
  - Pile or pier locations and geometry
  - Bridge low chord elevation
  - Bridge finished grade elevation profile

- Channel cross sections shall include
  - Top of banks
  - Toe of banks
  - Channel thalweg location

When possible, utilize existing mapping data (LiDAR), tape downs, FEMA model data, etc. to develop the required information needed for modeling the scour analysis. If the available data is not sufficient, supplement with a field survey by obtaining additional information as needed to complete the items as noted above. It is acceptable for purposes of this project to interpret tape down information for both the upstream and downstream bridge faces as well as to inform the channel shape at the approach and exit cross sections where channel uniformity can be reasonably established. Overbank LiDAR can be joined with tape downs or channel field surveys to complete the approach and exit cross sections for modeling and analysis.

When utilizing data from different sources, it is imperative to correlate the vertical datums. Field survey for this project should be obtained using the North American Vertical Datum (NAVD88) and other data should be corrected to that datum. Similarly, mapping data from different sources should be corrected to a common vertical datum for each bridge analysis. It is not necessary to utilize NAVD88 if no field survey is obtained for a given bridge, for this project.

All field surveys shall include, where available, collection of the High Water Marks (HWM's). See the following page(s) for appropriate forms. Refer to modeling Chapters (5 & 6) for domain information.

Refer to the USGS *Field Manual for Identifying and Preserving High-Water Mark Data*: https://pubs.usgs.gov/of/2017/1105/ofr20171105.pdf

For additional guidance refer to I*dentifying and Preserving High-Water Mark Data, Techniques and Methods 3-A24* https://pubs.usgs.gov/tm/03/a24/tm3a24.pdf

All field surveys collected for this project should be provided to SCDOT HDSO with the individual bridge file submittals in MicroStation format with the appropriate naming convention.

Figure 8: High Water Mark (HWM) Field Form

High Water Mark (HWM) Field Form

SCDOT Structure number: ______________________ **Road**: _________

Date: ___________________ **Field party**: ___________________________

Stream: ______________________________ **County**: _____________________

Structure Latitude: **N**____________________ **GPS unit**: __________________
(make, model)

Structure Longitude: **W**__________________ **GPS serial #**: _______________

(horizontal datum is NAD83)

Location: ____________________________ **Accuracy**:____________________

SITE MAP

Stream: ____________________ **Road:** ____________________

HWM No. ______________ **Photo No.** ____________________

HWM Latitude: N ____________________ **Longitude: W** ____________________

Accuracy: __________

HWM identified with (colored flagging, marker, nail, stake, disc, spray paint, other__________)

Type of mark (debris line, mud line, seed line, wash line, cut line other______________)

Inside or outside mark: ____________ **Approx. height above ground (ft):** ________

Quality of mark: Excellent (+/- 0.05 ft) **Good** (+/- 0.10 ft) **Fair** (+/- 0.25 ft) **Poor** (>0.25 ft)

Still Water: (Yes / No) **Environment:** Urban / Rural

Mark Description

(Include such details as physical description, distance from bridge and embankment, address if in structure and available, etc.)

HWM No. ______________ **Photo No.** ____________________

HWM Latitude: N ____________________ **Longitude: W** ____________________

Accuracy: __________

HWM identified with (colored flagging, marker, nail, stake, disc, spray paint, other__________)

Type of mark (debris line, mud line, seed line, wash line, cut line other______________)

Inside or outside mark: ____________ **Approx. height above ground (ft):** ________

Quality of mark: Excellent (+/- 0.05 ft) **Good** (+/- 0.10 ft) **Fair** (+/- 0.25 ft) **Poor** (>0.25 ft)

Still Water: (Yes / No) **Environment:** Urban / Rural

Mark Description

(Include such details as physical description, distance from bridge and embankment, address if in structure and available, etc.)

Table 6: Field Survey Responsibilities

Action Item	Lead Consultant	Non-Lead Consultants
Conduct a field survey following guidance in Section 4.1 when records of existing groundline, bridge geometry, or flood plain data do not exist or are not sufficient to perform a scour study.	X	X
Field survey for this project should be obtained using the North American Vertical Datum (NAVD88) and other data should be corrected to that datum.	X	X
All field surveys collected for this project should be provided with the individual bridge file submittals in MicroStation format with the appropriate naming convention.	X	X

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Section 5. Hydrologic & Hydraulic Modeling

5.1 Purpose

This section provides guidance on the acceptable methods for determining the design hydrology and hydraulics for bridge scour analyses associated with this project. Project partners are encouraged to use design discharges, (found on plans or in reports) that have previously been approved by SCDOT if they are deemed reasonable and valid. When warranted, and where the USGS river network lines are available, new hydrology will be developed using the USGS StreamStats website to provide consistency throughout the project. It is assumed that riverine boundary conditions will primarily use steady state conditions.

For each analyzed bridge, flood hydraulic characteristics are required and shall be estimated for the bridge scour analysis. In this project, the required inputs and parameters of the bridge scour methodologies, envelope curve equations and HEC-18, will be prepared using USACE HEC-RAS(1D) or USBR SRH-2D (2D) computer programs in SMS.

5.2 Design Hydrology

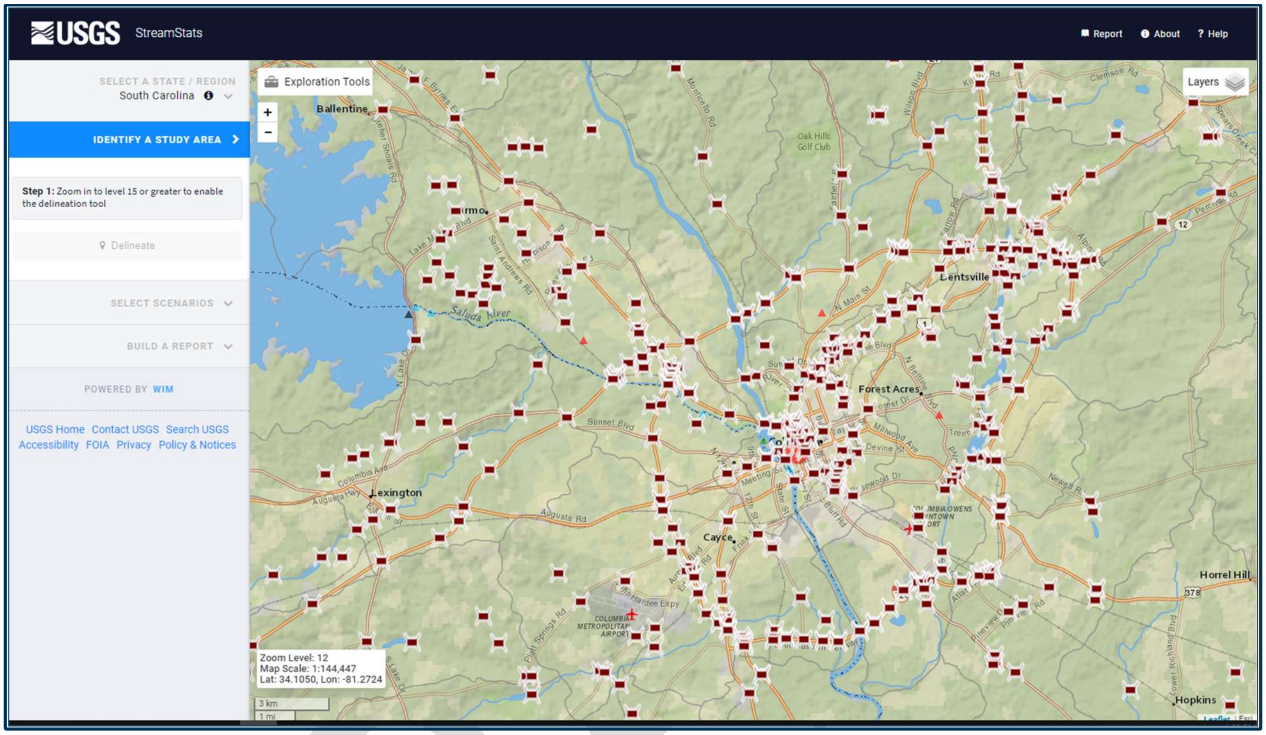
5.2.1 USGS StreamStats

StreamStats is a web application that provides streamflow statistics, drainage-basin characteristics, and other information for USGS stream gage and user-selected ungaged sites on streams. When users select the location of a stream gage, StreamStats will provide links to previously published information pertaining to that gage. When users select a site on an ungaged stream, StreamStats will determine the drainage-basin boundary for the site, compute a variety of drainage-basin characteristics, and solve regression equations using USGS hydrographic information to estimate streamflow statistics for the site based on one of two approaches: 1) Peak-Flow Statistics or 2) Urban Peak Flow Statistics.

It is anticipated that most analyses will use the Peak-Flow Statistics, which are based on "Magnitude and Frequency of Rural Floods in the Southeastern United States, 2006: Volume 3, South Carolina" (SIR-2009-5156) and "Methods for estimating the magnitude and frequency of floods for urban and small, rural streams in Georgia, South Carolina, and North Carolina" (SIR-2014-5030), depending on the contributing drainage area. If it is determined that the Urban Peak-Flow Statistics are more representative of the study area, the justification for this should be documented and the design discharges will be based on "Methods for estimating the magnitude and frequency of floods for urban and small, rural streams in Georgia, South Carolina, and North Carolina" (SIR2014-5030). This is not necessary for small rural sites.

The StreamStats Report, including all applicable parameters, and GIS files including the watershed polygons should be submitted with the study documentation. In circumstances where it is reasonable to do so (e.g. sites that are on the border between two regions), the regression parameters may be manually modified. If parameter modifications are deemed necessary, the justification and calculations should be fully documented.

Figure 9: Streamstats Web Interface



All discharges developed for scour analyses will be calculated using USGS StreamStats in combination with any USGS gauges that may be available. All bridges will be analyzed using the 1% AEP and the 0.2% AEP discharges as the design events. Historical flood elevations, if well documented, may be used to analyze bridges for scour if they meet or exceed the 1% AEP flood elevations.

The references of regression methodologies used by USGS StreamStats for South Carolina are:

- Feaster, T.D., Gotvald, A.J., and Weaver, J.C.,2009, Magnitude and Frequency of Rural Floods in the Southeastern United States, 2006: Volume 3, South Carolina: U.S. Geological Survey Scientific Investigations Report 2009-5156, 226 p.

- Feaster, T.D., Gotvald, A.J., and Weaver, J.C.,2014, Methods for estimating the magnitude and frequency of floods for urban and small, rural streams in Georgia, South Carolina, and North Carolina, 2011 (ver. 1.1, March 2014): U.S. Geological Survey Scientific Investigations Report 2014–5030, 104 p.

For the bridges that are not located along the default river network of USGS StreamStats, engineers should estimate the frequency flood peak discharges in accordance with these two USGS publications.

The regression equations are valid as long as the parameters are within the data collected. These limitations can be found in the publications referenced above. For larger drainage areas, it is often safe to use the rural regressions, as the urban influences are typically less significant in larger drainage areas. For drainage areas smaller than 0.1 mi^2, it is safe to use the urban and small rural regression equations, due to the inclusions of gage data from small rural sites. Note that a basin is considered to be "urban" if the impervious area is 10 percent or greater. Rural regression equations are suitable for basins with less than 10 percent impervious areas.

For drainage areas with special circumstances, the discharge may be determined using SCDOT approved methods, such as the procedures described in the South Carolina Unit Hydrograph Method Applications Manual (SCDOT No.: SPR 738), which is available from the SC Local Technical Assistance Program website. There may be occasions when the USGS regression equations are not applicable. In such cases, the Rational Method (0 to 100 acres), the SC Unit Hydrograph Method in Section 3.2.16 (References 65), or other methods approved by SCDOT HDSO may be used, if deemed appropriate.

5.2.2 Tidal Hydrographs

The methodology for developing a tidal and surge hydrograph can be found in Part 2 of Requirements for Hydraulic Design Studies (Draft 2019). It is assumed that tidal and surge hydraulics will be combined with steady state riverine flows for bridges analyzed in tidal areas of the State. Storm surge design hydrographs are to be based on Hurricane conditions, as these tend to produce the most intense conditions.

The 1% AEP and the 0.2% AEP surge heights for the South Carolina ADCIRC stations can be found in the First Edition of Tidal Hydrology, Hydraulics, and Scour at Bridges (FHWA-NHI-05-077), along with the other hydrograph variables required for developing a tidal and surge hydrograph boundary condition. It should be noted that the ADCIRC data and the NOAA data are for stillwater heights, only (i.e. they do not consider waves). FEMA FIS may include wave heights, so the modeler should be careful to use the stillwater heights.

If it is considered necessary to use a riverine input in conjunction with a tidal and surge hydrograph, the applicable design storm shall be used for both inputs (e.g. 1% AEP discharge from the upstream source and a 1% AEP surge on the downstream boundary condition).

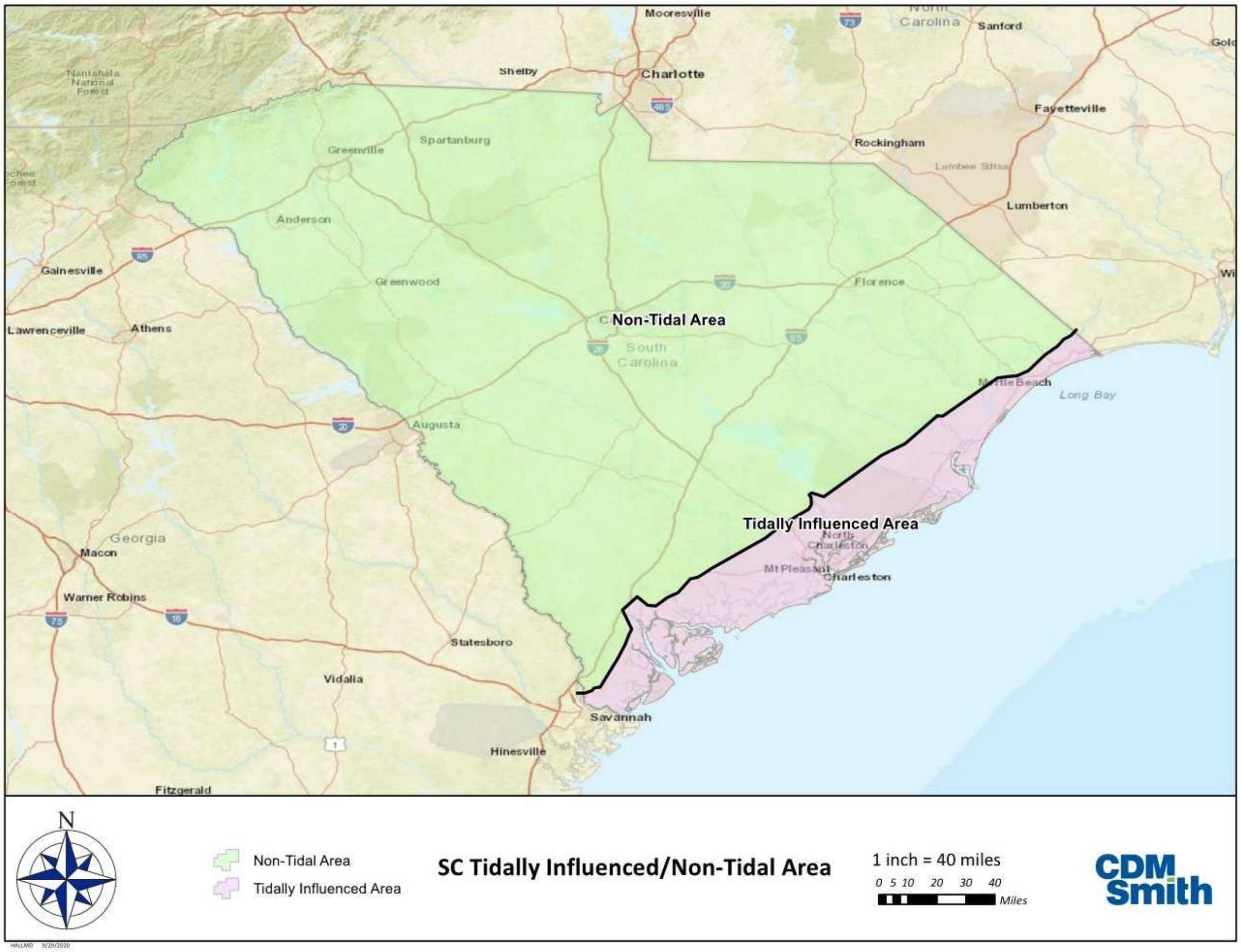
5.3 Bridge Scour Hydraulics

Flow hydraulics are significantly dominated by flow obstructions when channel flow runs through bridge structures, such as piers and abutment, or is restricted by bridge embankments. The disturbance from bridge structures will alter the hydraulic characteristics. In accordance with the state bridge scour envelope curve equations and HEC-18, flow velocity, depth, top width, and other flow characteristics are generally required inputs for bridge scour estimation. For the purposes of this project, these flow characteristics will be computed using either USACE HEC-RAS (1D) program or USBR SRH-2D (2D) program in SMS.

The bridge sites shall be divided based on whether they fall within the tidal impact areas or not, to determine if a HEC-RAS or SRH-2D analysis is appropriate. Flood profiles available from the Flood

Insurance Studies for the coastal counties were studied for streams draining to the Atlantic Ocean to determine how far inland the tidal impacts extend. A demarcation line was established by connecting the boundary points. (**Figure 10**)

Figure 10: Demarcation Boundary Line to distinguish between tidally affected sites and riverine sites



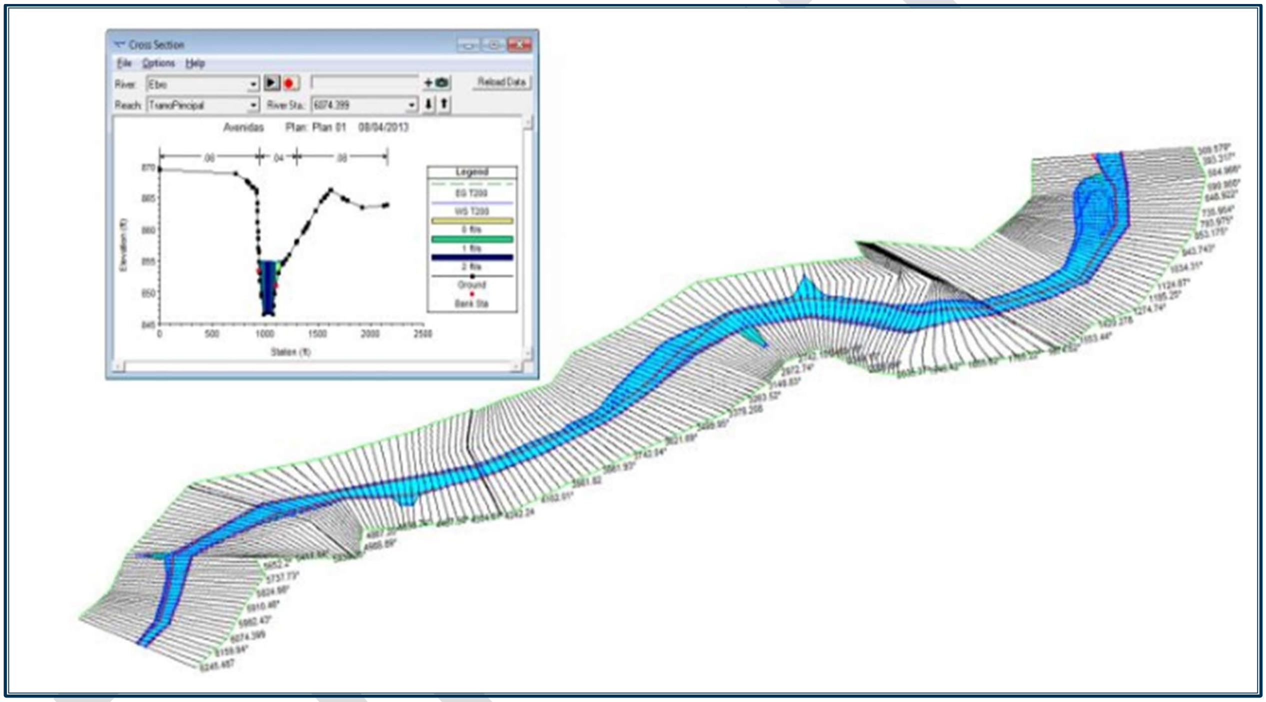
5.3.1 1D HEC-RAS Models

The USACE HEC-RAS (River Analysis System) is a commonly used hydraulic model capable of conducting one-dimensional (1D) steady and unsteady flow hydraulic modeling to aid hydraulic engineers in channel flow analyses and floodplain delineations. The results of the model simulations/computations are typically applied in floodplain management, flood insurance studies, sedimentation studies, and bridge scour analyses. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage, and management capabilities, graphics, and reporting facilities.

All 1D hydraulic models, whether riverine or tidal, are to be analyzed utilizing HEC-RAS (v.5.0.7 or later). Detailed documentation for the development of HEC-RAS models can be found in the HEC-RAS User's Manual and Hydraulic Reference Manual. For bridges that are located within FEMA studied areas or that have the original bridge design hydraulic models, it may be recommended that these models are reviewed (even if they were performed in other computer models) to see if the information can be imported into HEC-RAS or inform the development of new models. Previously developed models should be updated based on the most current data and revised to produce reasonable inputs for the bridge scour analysis.

A riverine model consists of adequate downstream cross-sections to establish a stable flow regime, multiple bridge cross sections (see **Figure 11)**, and a reasonable number of cross sections upstream of the structure. Cross sections should be developed from LiDAR data along with any channel points that may be available. Additional channel points, if needed, can be located from old plans or bridge inspections to help define the channel geometry. The bridge cross section(s) may be a combination of old plan data, bridge inspection reports, or data gathered from the field review.

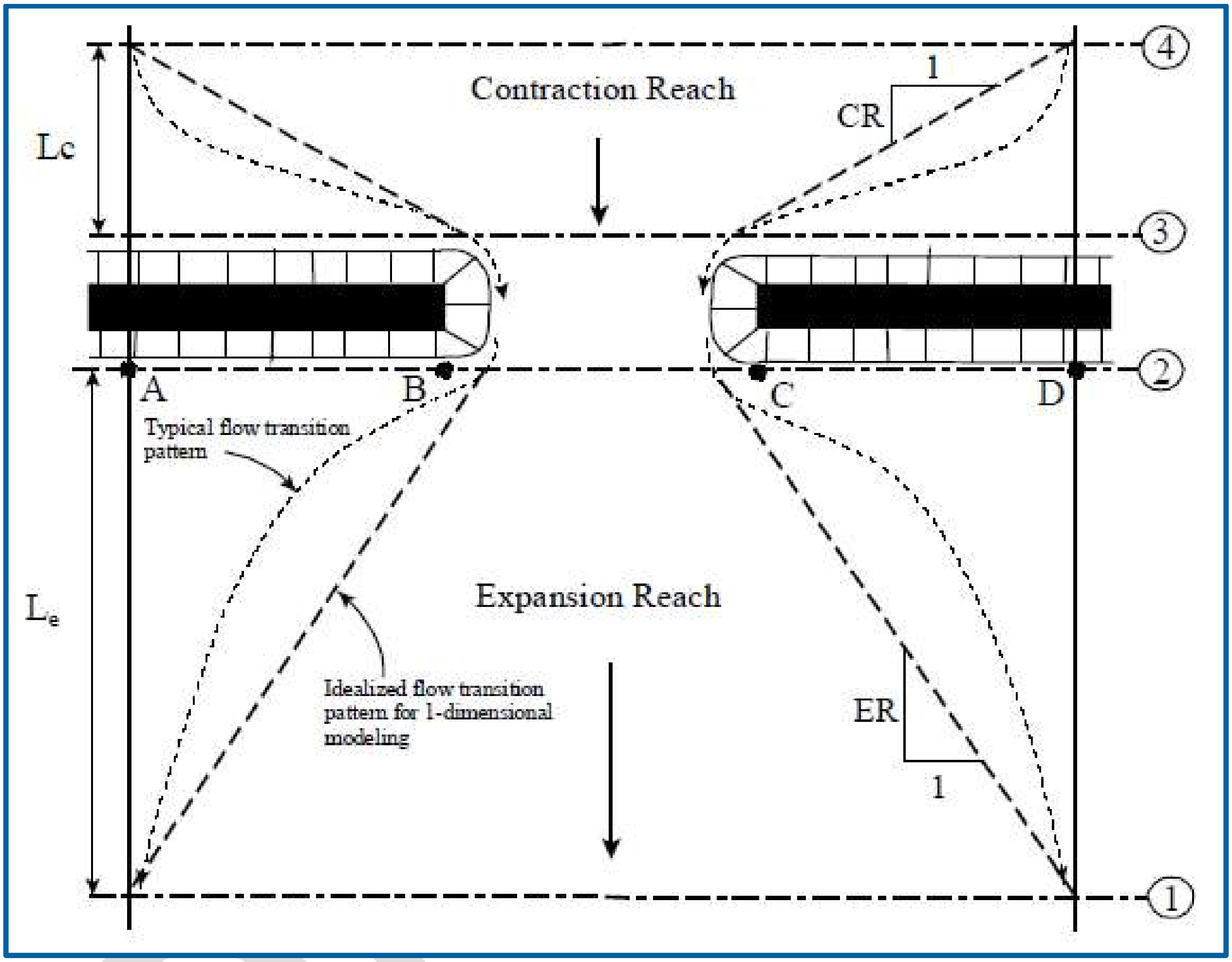
Figure 11: HEC-RAS 1D Model Layout



The dimensions, skew, shape factors of the bridge (e.g. piers, abutments, embankments, etc.) and contraction and expansion coefficients shall be used and included in the geometric data of HEC-RAS models. Flow transitions for bridge backwater analyses need to be performed in a manner consistent with the guidance found in Appendix B of the HEC-RAS Hydraulic Reference Manual. Specific areas of concern that have been noted when using FIS information for SCDOT applications are the angles of the ineffective regions upstream and downstream of a bridge, and the location of the bounding cross-sections (see **Figure 12**) The bridge structure information should be obtained based on field surveys, which may be supplemented with: as-built drawings, design documents, or previous hydraulic models. In this study, engineers shall verify if the bridge elements built in the HEC-RAS model agree with the existing conditions.

For tidal hydraulic simulations, the HEC-RAS models will consist of downstream boundary conditions controlled by tidal levels and upstream boundary conditions controlled by riverine flows and channel geometries that represent both surge and tidal influences and the combined impacts from both tidal and riverine floods. Engineers should document the selected flood scenarios, model setup, and assumptions.

Figure 12: Typical Bridge Cross Section Layout for 1D Model



Bridge scour analyses will **not** be performed using HEC-RAS tools. Instead, the output of the HEC-RAS hydraulic model will be used in the bridge scour estimation utilizing the methodologies described in Section 6.

5.3.2 2D SRH 2D Models

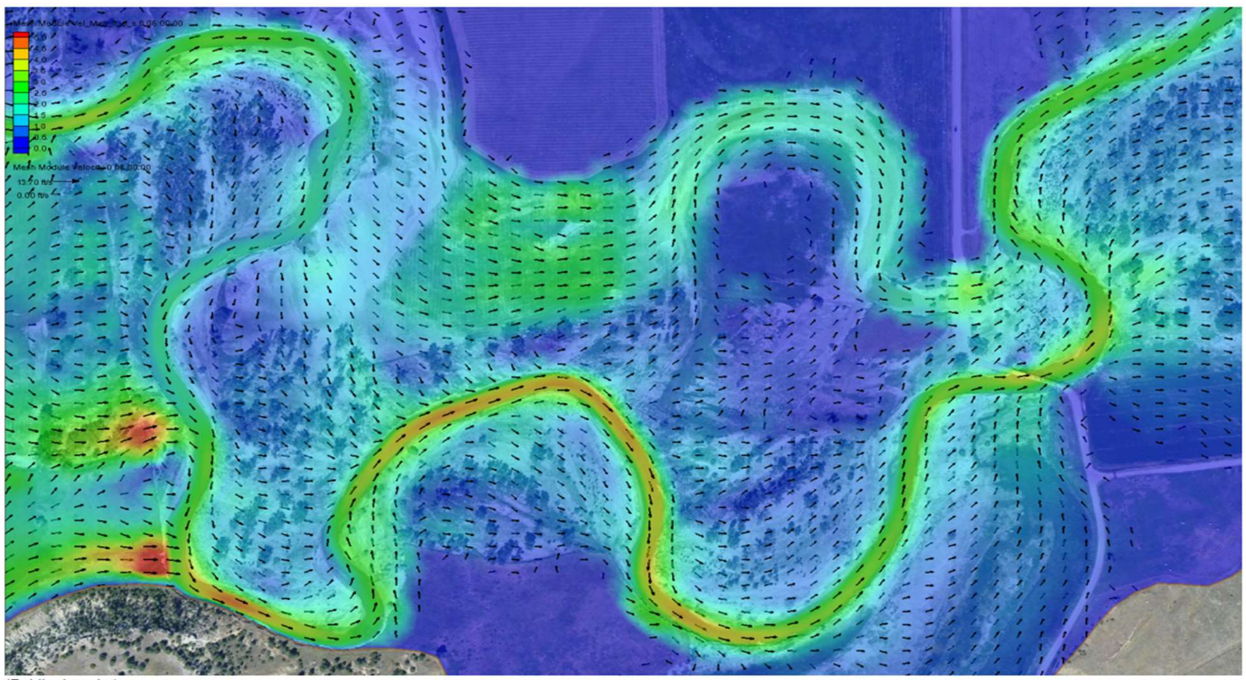
The USBR SRH 2D program is recommended for 2D flood hydraulic modeling by FHWA. SRH 2D can model the complicated flow conditions when flows are not dominated by a single flow direction (See **Figure 13**) as well as when they are disturbed by bridge structures. The SRH-2D program was integrated into the Surface Water Modeling System (SMS, by Aquaveo) with a user-friendly interface.

For this project, all required 2D flood hydraulic models, whether riverine or tidal, will be analyzed utilizing the SRH 2D program. The use of 2D models for riverine bridges should be limited to bridges located in wide floodplains with adverse skews. For tidal bridges, a 2D model will only be required in large estuaries or bays with complex hydraulics and complex flow patterns.

All SRH 2D hydraulic models must be run as unsteady flow routing. When preparing a 2D model, it is also important to keep in mind that 2D models have much longer run times than 1D models. Generally, previously developed 2D models that used different computer programs will not be compatible with SRH-2D. Therefore, if the required flow hydraulic characteristics for bridge scour analysis cannot be obtained from the previous 2D model outputs, a new SRH-2D model will need to be created to replace the previous 2D model and generate new model outputs.

Figure 13: Example of a USBR SRH-2D Model

Sample output from the SRH-2D model



(Public domain.)

Where available, existing 2D models may be utilized and modified as necessary to develop an acceptable model for individual bridges. The model domain must be developed to include spatial coverage upstream and downstream of the bridge. Where storm surge will be included in the model, the domain should extend downstream to the open coast. Other means of transposing the downstream boundary conditions are acceptable as approved by the HDSO.

The new version of SMS 13 ,version 13.1, released in March 2021 includes new features to directly export many of the needed variables to the FHWA Hydraulic Toolbox for a scour analysis from the SRH-2D model outputs. This provides another option to allow engineers to prepare a bridge scour analysis using an SRH-2D model and HEC-18 methodology through the FHWA Hydraulic Toolbox program.

Table 7: Hydrologic & Hydraulic Modeling Responsibilities

Action Item	Lead Consultant	Non-Lead Consultants
Use design discharges that have previously been approved by SCDOT if they are deemed reasonable and valid. When warranted, and where the USGS river network lines are available, new hydrology should be developed using the USGS StreamStats website.	X	X
For the bridges that are not located along the default stream network of USGS StreamStats, peak discharges should be estimated using regression equations in accordance with the two USGS publications referenced in section 5.2.1.	X	X
If deemed necessary, a riverine hydrograph should be developed for the peak discharge values using methodology as described in Section 5.2.2.	X	X
Tidal and surge hydraulics should be combined with steady state riverine flows for bridges analyzed in tidal areas of the state. Use methodology for developing a tidal and surge hydrograph found in Requirements for Hydraulic Design Studies (Draft 2019).	X	X
All 1D hydraulic models, whether riverine or tidal, are to be analyzed utilizing HEC-RAS (v.5.0.7 or later) using guidance from Section 5.3.1.	X	X
All required 2D flood hydraulic models, whether riverine or tidal, will be analyzed utilizing the SRH 2D program using guidance from Section 5.3.2. The use of 2D models for riverine bridges should be limited to bridges located in wide floodplains with adverse skews. For tidal bridges, a 2D model will only be required in large estuaries or bays with complex hydraulics and complex flow patterns. All SRH-2D hydraulic models must be run as unsteady flow routing.	X	X

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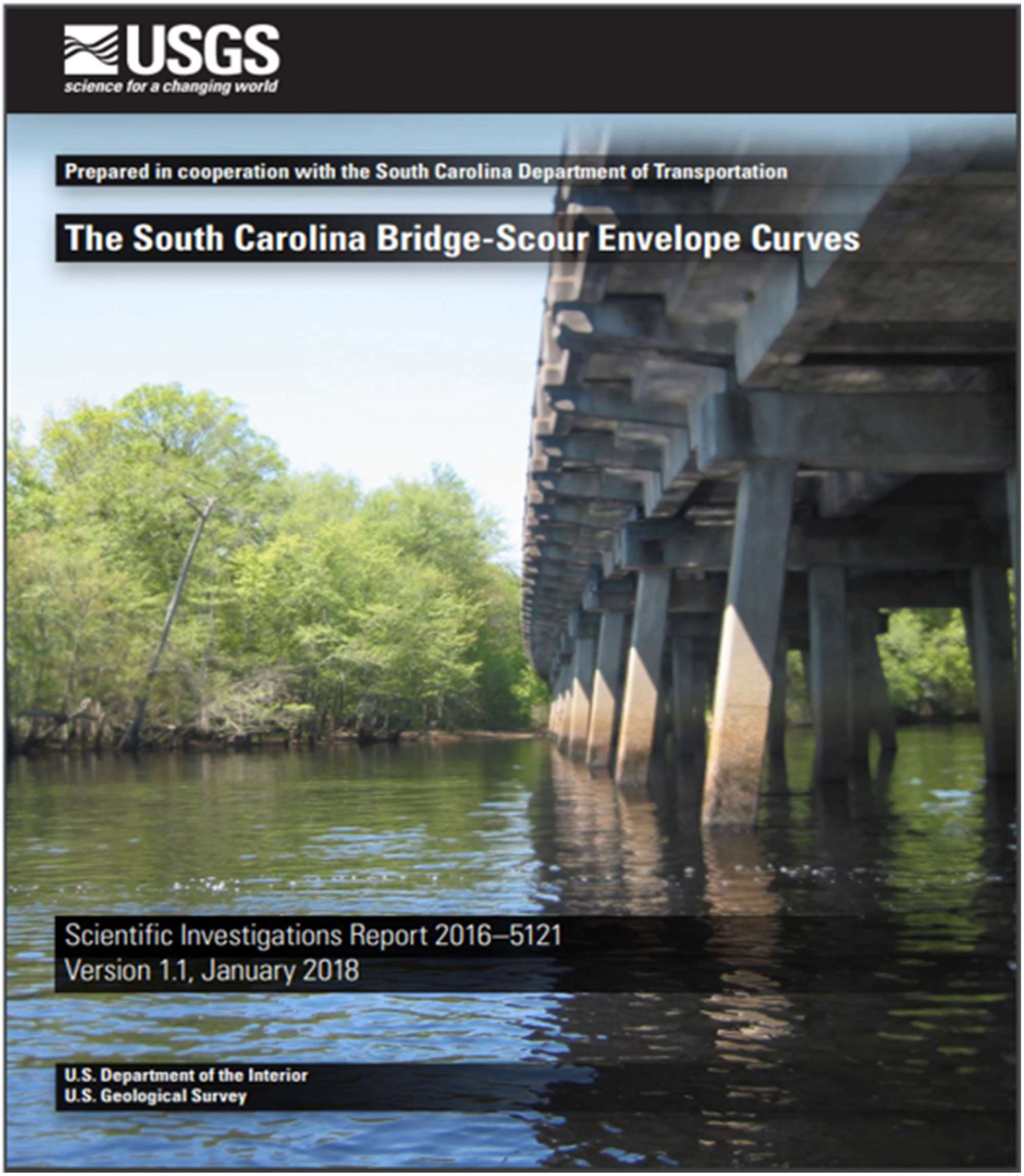
Section 6. Scour Assessments

6.1 USGS Envelope Curves



6.1.1 Introduction

The U.S. Geological Survey, in cooperation with the South Carolina Department of Transportation, conducted a series of three field investigations to evaluate historical, riverine bridge scour in the Piedmont and Coastal Plain regions of South Carolina. These investigations included data collected at 231 riverine bridges, which led to the development of bridge-scour envelope curves for clear-water and live-bed components of scour. The application and limitations of the South Carolina bridge-scour envelope curves were documented in four reports, each report addressing selected components of bridge scour. The current investigation (2016) synthesizes the findings of these previous reports into a guidance manual providing an integrated procedure for applying the envelope curves. Additionally, the investigation provides limited verification for selected bridge-scour envelope curves by comparing them to field data collected outside of South Carolina from previously published sources. Although the bridge-scour envelope curves have limitations, they are useful supplementary tools for assessing the potential for scour at riverine bridges in South Carolina.

6.1.2 Purpose

All riverine bridges will first utilize the South Carolina Bridge-Scour Envelope Curves Template to compute the likely maximum scour potential in accordance with the calculation guidance and limitations of the envelope curves. The information required to use the envelope curves can come from multiple sources including a hydraulic model, SCDOT plans, topographic data (LiDAR), or FEMA data. Key data includes High Water Marks, the elevation of the bridge low chord, and the elevation of the low point in the roadway profile (especially if it's offset from the bridge and lower than the bridge deck). If discrepancies exist between sources, evaluate these discrepancies and use engineering judgment in the final selection of these variables. Links to the South Carolina Bridge-Scour Envelope Curves are as follows (https://pubs.er.usgs.gov/publication/sir20165121):

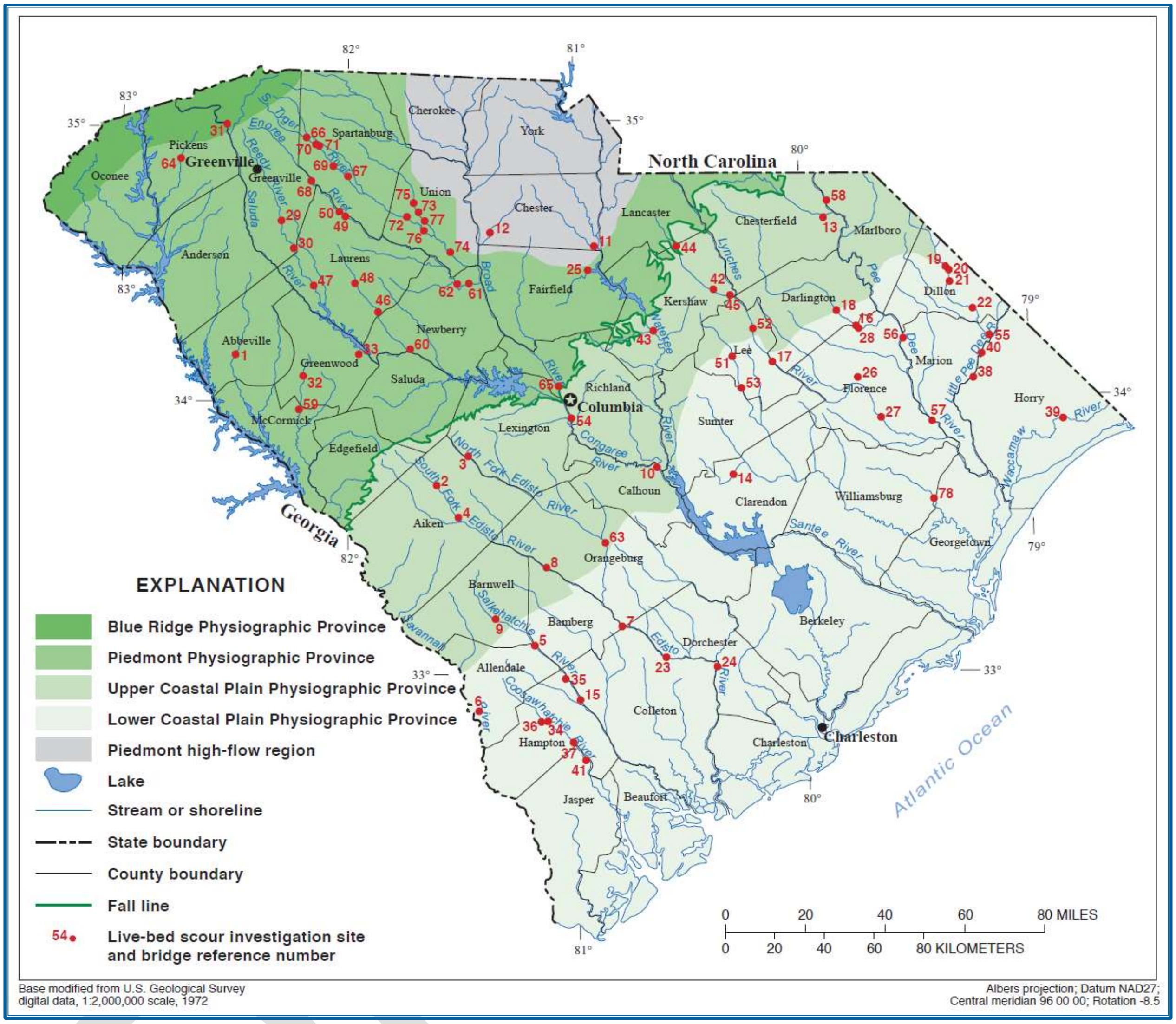
- Document:
  https://pubs.usgs.gov/sir/2016/5121/sir20165121.pdf
- Scour Envelope Curve Template
  https://pubs.usgs.gov/sir/2016/5121/sir20165121_template-scour-envelope-curve-042418.xlsx
- South Carolina bridge-scour study sites and reference numbers for Figure 1
  https://pubs.usgs.gov/sir/2016/5121/sir20165121_app1.xlsx
- Estimate of maximum historic flows at selected bridge crossings in South Carolina
  https://pubs.usgs.gov/sir/2016/5121/sir20165121_app2.xlsx
- Related Work: - Assessing Potential Scour Using the South Carolina Bridge-Scour Envelope Curves https://pubs.er.usgs.gov/publication/fs20163065

To use the Envelope Curve Template, engineers must first determine the Physiographic Region location of the bridge (see **Figure 14**).

In general, bridge scour potentials include long-term scour and local scour. The magnitude of long-term aggradation or degradation at a bridge can be determined from historical records and observational data. Bridge inspection records can be used to identify long-term trends in vertical stability by comparing streambed tape (measure) downs at the bridge over a period of years. Using all available information, estimate the long-term bed elevation change at the bridge site for the design life of the bridge (usually 100 years). If the estimate indicates that the stream will degrade, the elevation after long-term degradation should be used as the base elevation for contraction and local scour. If the estimate indicates that the stream will aggrade, then this should be noted in the report, but not included in the total scour assessment. In cases of aggradation or where long-term elevation changes are not obvious, original ground elevations (from the plans) should be used as the base elevation for contraction and local scour.

Local scour means that the potential channel invert scours due to flow area contraction from a bridge, the dominant channel flow conditions, and channel bed materials and is commonly classified as Live-Bed Scour and Clear-Water Scour. Clear-water scour means that normally there is no sediment transport along the channel bed and is often found at the channels with coarse bed materials such as gravels. Live-bed scour means active sediment transport is occurring along the channel in normal flow conditions. Moving sand riffles, dunes, and cumulative channel degradation could be commonly seen and indicate the evidence of live-bed scour, especially for channels with fine materials (sand and silt). In practice, local scour describes the scour potential around the bridge structures during the design flood events or flow conditions. Consequently, the maximum scour potential is considered as the sum of the long-term scour and local scour.

Figure 14: South Carolina Physiographic Regions



It must also be determined where or if clear-water and live-bed scour exist in the bridge opening, see **Figure 15**. Live-bed scour and clear-water scour can occur in the channel region although clear-water scour only exists in undefined, swampy channels, or floodplain bridges. According to the information above, the correct envelope curves need to be applied to the bridge opening. The following subsections summarize the limitations and criteria for assessing the USGS envelope curves. For a complete list, see Scientific Investigations Report 2016-5121, Version1.1. Non-Lead Consultants shall contact the Lead Consultant if the envelope curves appear to not be applicable. The Lead Consultant will discuss these sites with the SCDOT HDSO.

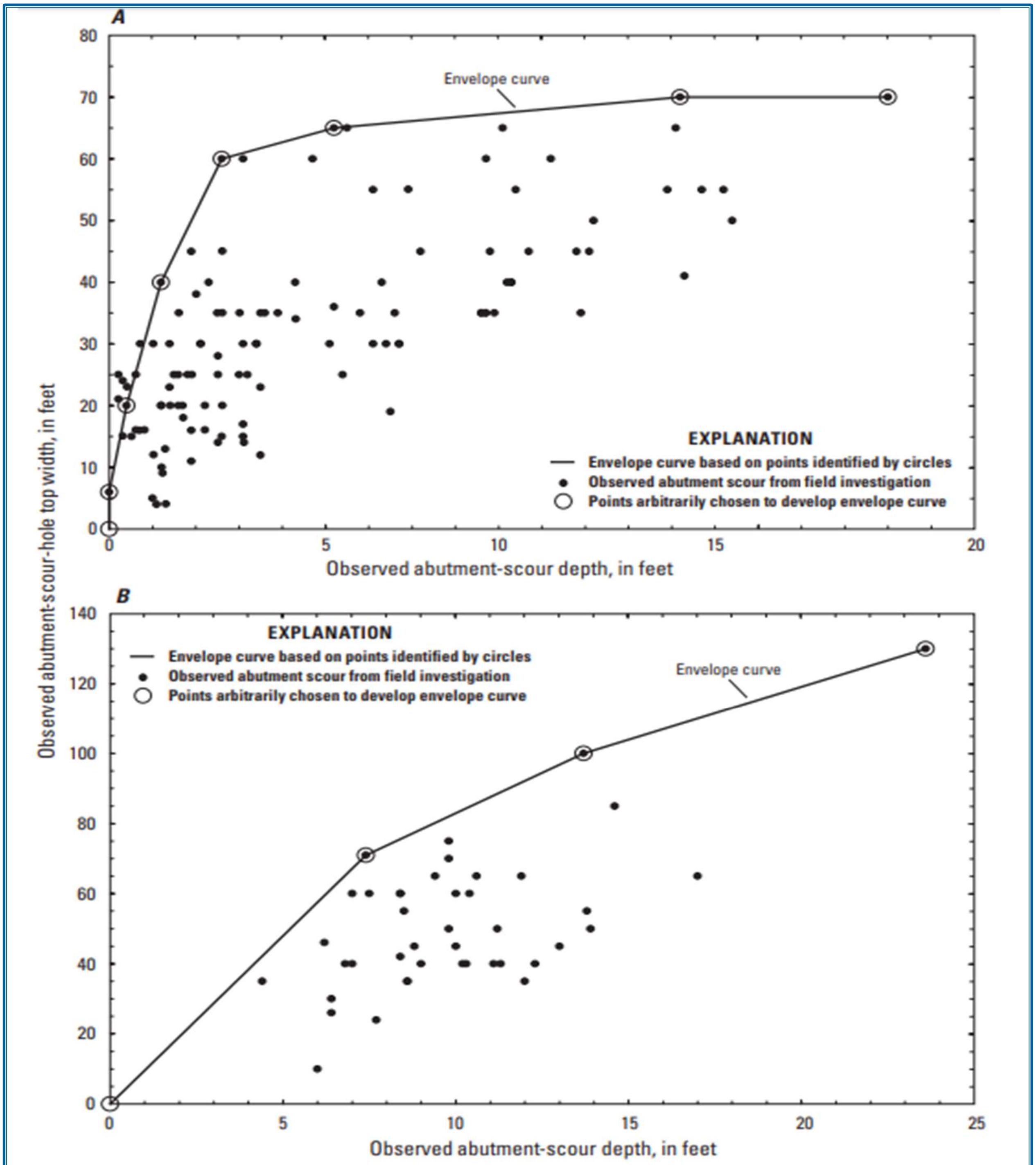
Limitations associated with the USGS envelope curves for bridge scour in South Carolina should be kept in mind when using them to assess scour potential. These envelope curves were developed based on investigations of bridges in the Piedmont and Coastal Plain Physiographic Regions. Therefore, the applicability of the envelope curves generally excludes the tidally influenced area of the Coastal Plain. It should be understood that uncertainty associated with the envelope curves increases near the limits of the data range.

6.1.3 Abutment Scour

- Bridges over swampy channels, as well as bridges located in the Piedmont regions of flood plain relief areas approximately 240 feet or less in length, tend to form a large, single scour hole that encompasses the entire bridge opening from abutment toe to abutment toe.
- When assessing bridges with swampy poorly defined channels, with bridge lengths 240 feet or less, it is recommended using the longer of the left or right embankment lengths in the assessment.
- Bridges greater than 240 feet in length generally form separate abutment scour holes at the left and right abutments.
- To avoid overestimation of the upper bound of abutment-scour depth, it may be reasonable to use the embankment-length envelope curve as the primary tool for estimating abutment-scour potential in the Piedmont and Coastal Plain.
- To assure that abutment-scour potential is not underestimated at a multiple-bridge crossing, it is recommended that the modified abutment-scour envelope curves not be used to assess multiple bridge openings.
- It is recommended that only the original geometric-contraction ratio envelope curves be used to assess abutment-scour potential at a multiple-bridge crossing rather than the original embankment length curves.
- The exception to this recommendation is for multiple-bridge openings in the Coastal Plain where the embankment length is greater than or equal to 426 ft. In this case, both curves (original embankment length or geometric contraction ratio) can be used to assess the upper bound of abutment-scour potential.
- Contraction scour should not be considered a contributing component to total scour in the abutment scour region.
- The modified abutment-scour envelope curves can be used to provide refined estimates of the upper bound of abutment scour potential for smaller embankment lengths. The modified envelope curves are limited to embankment lengths less than or equal to 500 ft. and geometric-contraction ratios should not exceed 0.85 and 0.9 for the Piedmont or Coastal Plain, respectively.
- Multiple-column bents and piers 2.3 feet or less and minimal skew in the abutment-scour region should not be included for total scour depth.
- For bents or piers over 2.3 feet and minimal skew in the abutment-scour regions, compare the depth of scour for the abutment and the pier and used the largest depth for the scour depth in this region.
- In the Piedmont region, if the estimated abutment scour is 5 feet or less, then judgment should be used to account for the effect of pier scour within the abutment region regardless of the pier width.

See **Figure 15** below to obtain a conservative estimate of the top width of abutment scour to define the abutment scour region.

Figure 15 : Relation of Abutment Scour-Hole Top Width and Abutment-Scour Depth At Bridges

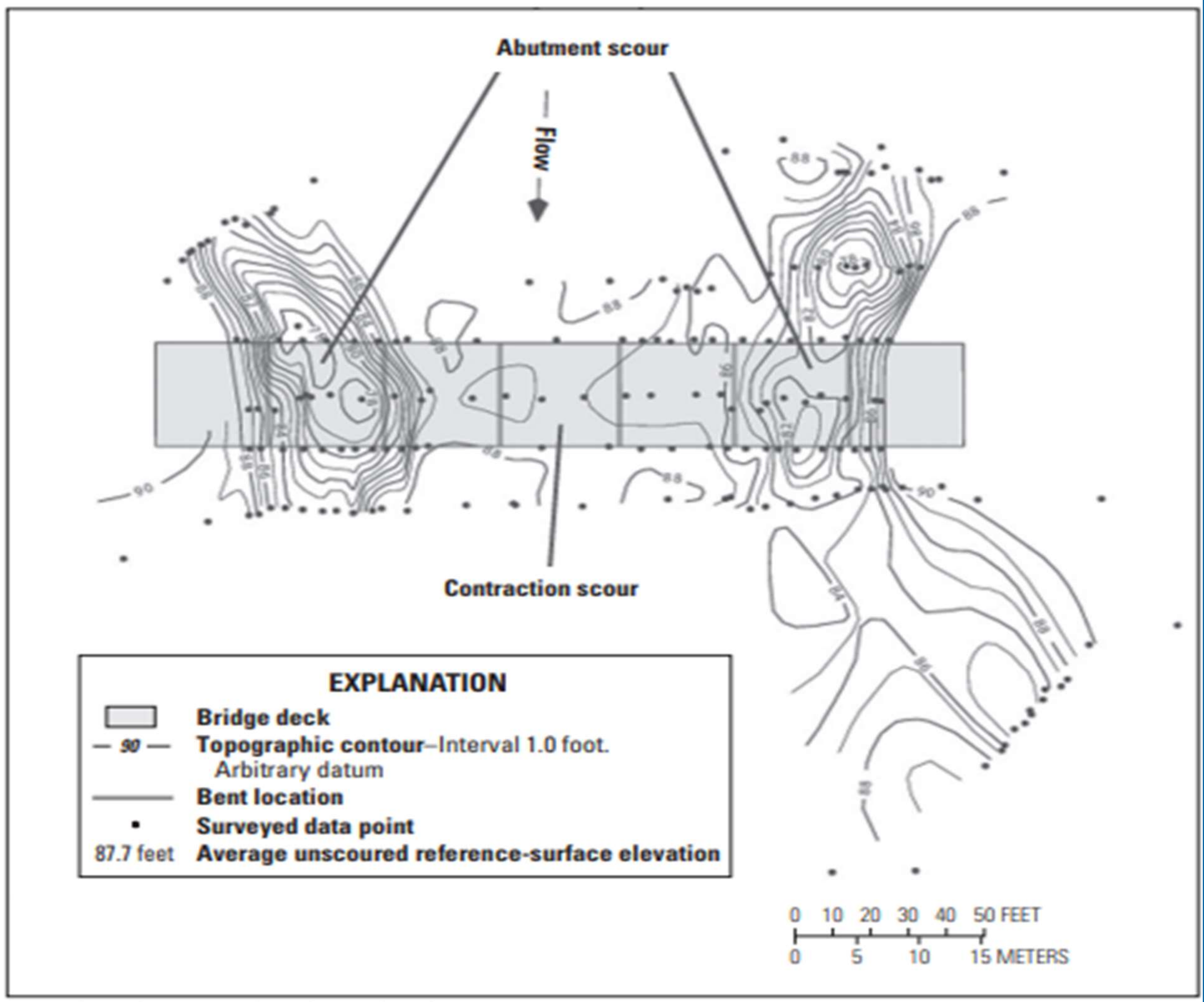


Notes: (A) bridges greater than 240 feet in length and (B) swampy and flood plain relief bridges. 240 feet or less in length, in the Piedmont and Coastal Plain of South Carolina

Source: Benedict, 2001

6.1.4 Clear-Water Contraction Scour

Figure 16: Example of Clear-Water Abutment and Contraction Scour Areas



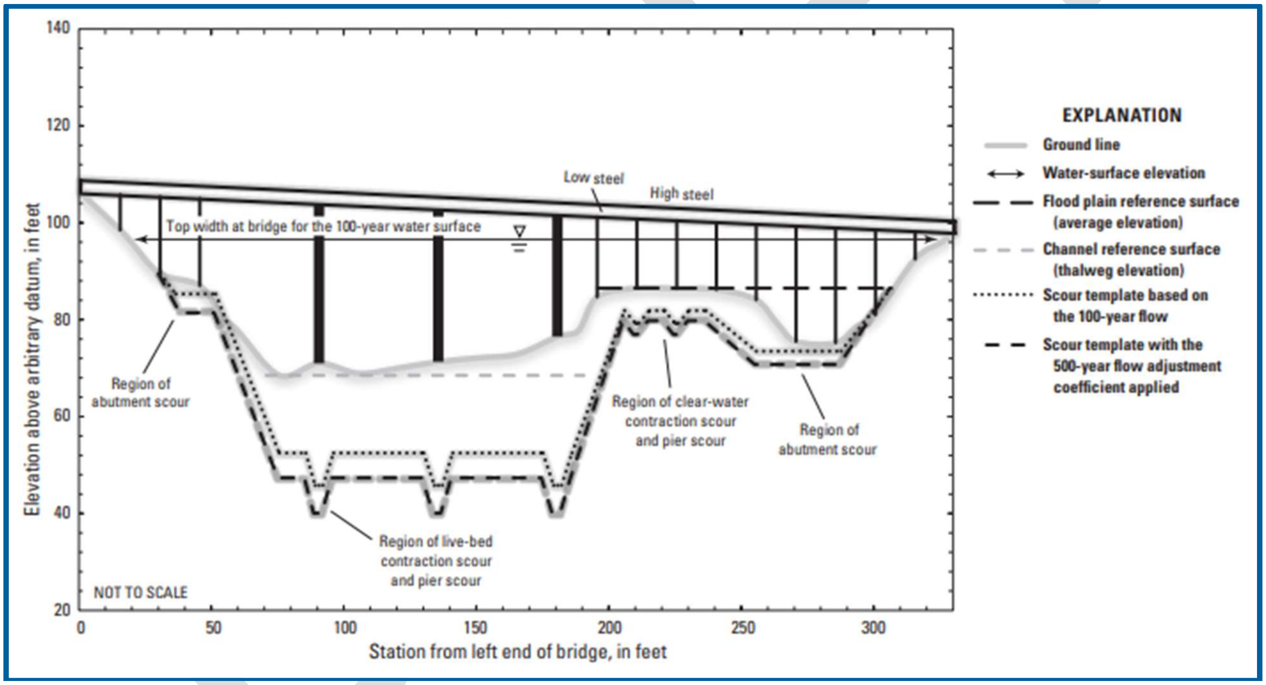
Notes: Depicts structure 274000300200 on S.C. Route 3 crossing Cypress Creek in Jasper County (December 9, 1996).
Source: Benedict and /Caldwell, 2006

- The undisturbed floodplain elevation is used as a reference surface to determine the clear-water contraction scour depth.
- Since the edge of the abutment-scour hole is a limiting boundary for clear-water contraction scour, abutment scour at the bridge should be evaluated first.
- Clear-water contraction scour in the Coastal Plain and Piedmont overbanks represents contraction scour only and not total scour. Scour created by piers and pile bents must be evaluated and added to predict total scour.
- If the top width of the potential abutment-scour hole as determined from Figure 42 extends to the channel, use the largest scour depth from the clear-water abutment-scour and contraction scour estimates.

6.1.5 Live-Bed Contraction Scour

- Live-bed contraction scour typically occurs in the main channel where there are sufficient velocities to transport bed sediments.
- The field envelope curve for live-bed scour in the Piedmont and Coastal plain uses the geometric contraction ratio as the explanatory variable. Both the Piedmont and Coastal plain is limited to a geometric ratio of 0.82. Extending the application of this equation beyond this limit should be used with caution.
- The modified live-bed contraction-scour curves can be used for bridges with drainage areas less than or equal to 100 square miles and sites with drainage areas greater than 100 square miles but less than or equal to 200 square miles. The modified live-bed envelope curves are limited to a geometric contraction ratio of 0.9.

Figure 17: Region of Potential Scour Determined from South Carolina Bridge-Scour Envelope Curves



Notes: Shown for Enoree River at Road S-87 in Newberry County, South Carolina, with the 500-year flow adjustment coefficient applied.

6.1.6 Clear-Water Pier Scour

- The clear-water pier scour equation is limited to a nominal pier width of 6 feet or less and is not recommended outside these limits.
- Clear-water pier scour is added to clear-water contraction scour to obtain total scour. Clear-water pier scour is not added to abutment scour for total scour calculation.

6.1.7 Live-Bed Pier Scour

- The live-bed pier scour equation is limited to a nominal pier width of 6 feet or less.

6.1.8 PSDb-2014 Pier Scour

- The PSDb equation is for both live-bed and clear water computations and limited to nominal pier widths less than 15 feet.

6.1.9 Simplified Level 1 Analysis

The information needed to perform a scour analysis using the USGS Envelope Curves can potentially be derived without developing a hydraulic model. Old roadway plans can provide the information needed.

If a high water mark, design water surface elevation (1% AEP), or roadway low point elevation are available, along with the natural cross section geometry from the roadway or bridge plans, then a water surface top width and/or embankment length can be determined. It is important to note that a high water mark associated with known overtopping should not be used with this method. Alternately, a top width associated with the 1% AEP could be measured from a FEMA Flood Insurance Rate Map (FIRM) or taken directly from the cross section table in the study. Using the water surface top width, the embankment length can be determined, and the contraction scour equation can be applied to determine live bed scour depth. With either method, the top width estimates should be checked with other available information. Older FEMA studies that did not use LIDAR data for mapping are often too crude for this method, so the study should be checked to determine if the mapping was prepared with LIDAR ground data.

Also in many cases, a simple comparison of scour depths to bridge foundation depths (with remaining post-scour pile penetration) can be made. By comparing the computed scour depth to pile lengths, the remaining pile length can be determined, and an Item 113 code can be assigned. For multiple column/pile bents, the average pile tip elevation for each bent should be used.

Examples of where to obtain data for these simplified calculations are shown in **Figure 18** and **Figure 19**.

Figure 18: Example of Topwidth and Embankment Measurement

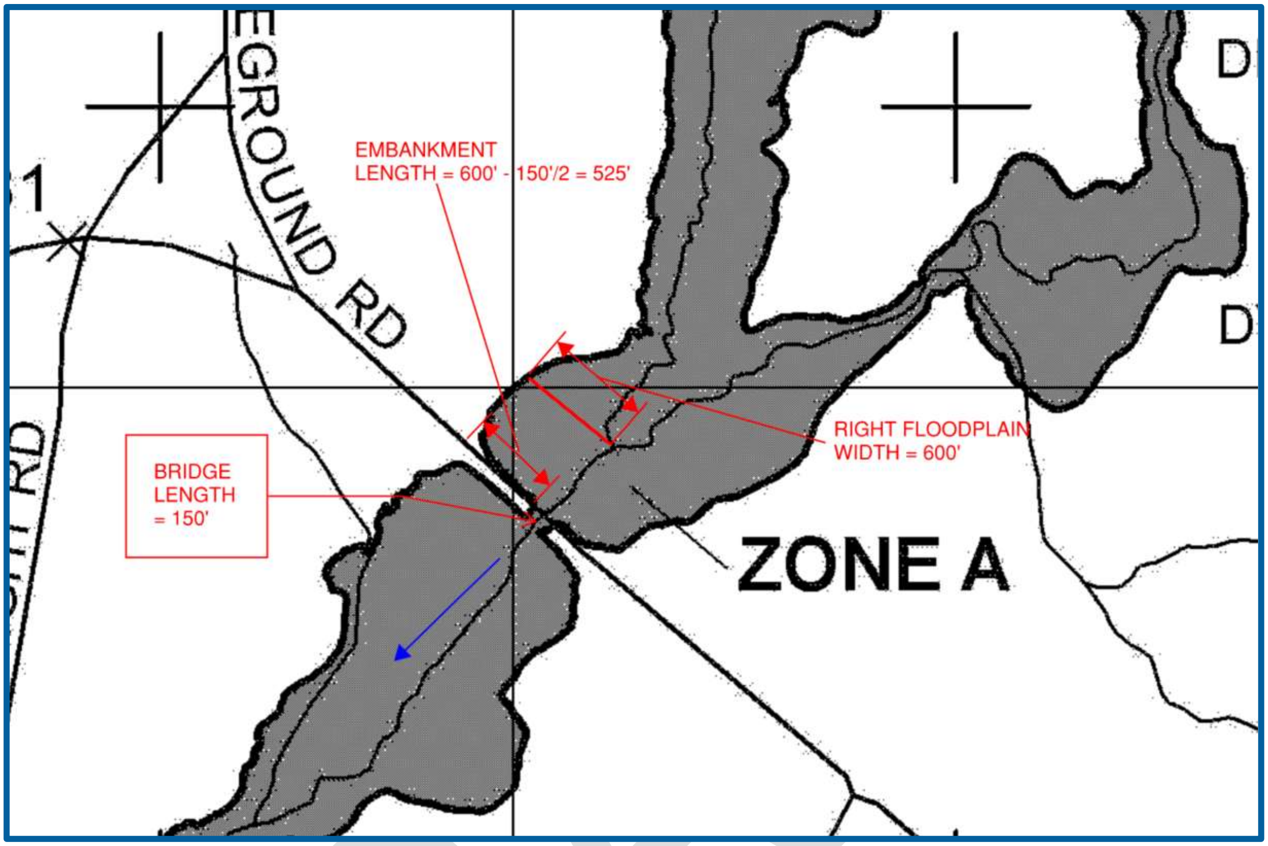
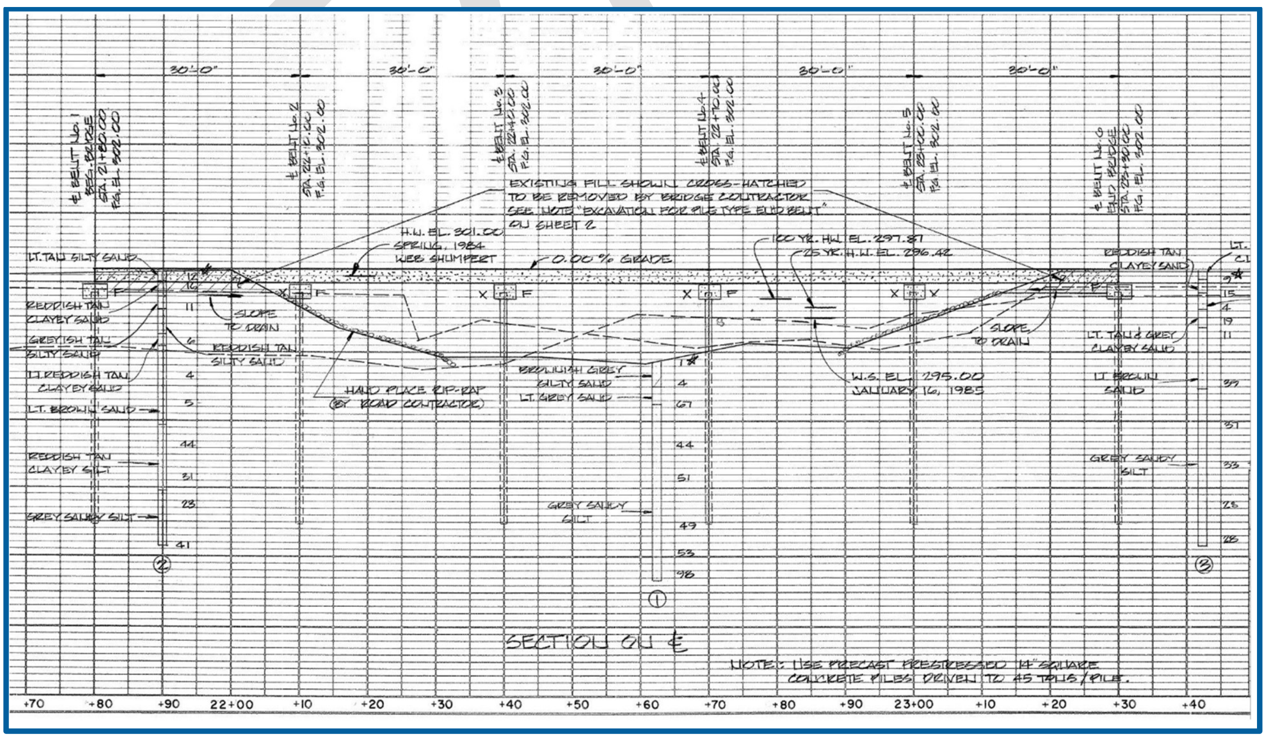
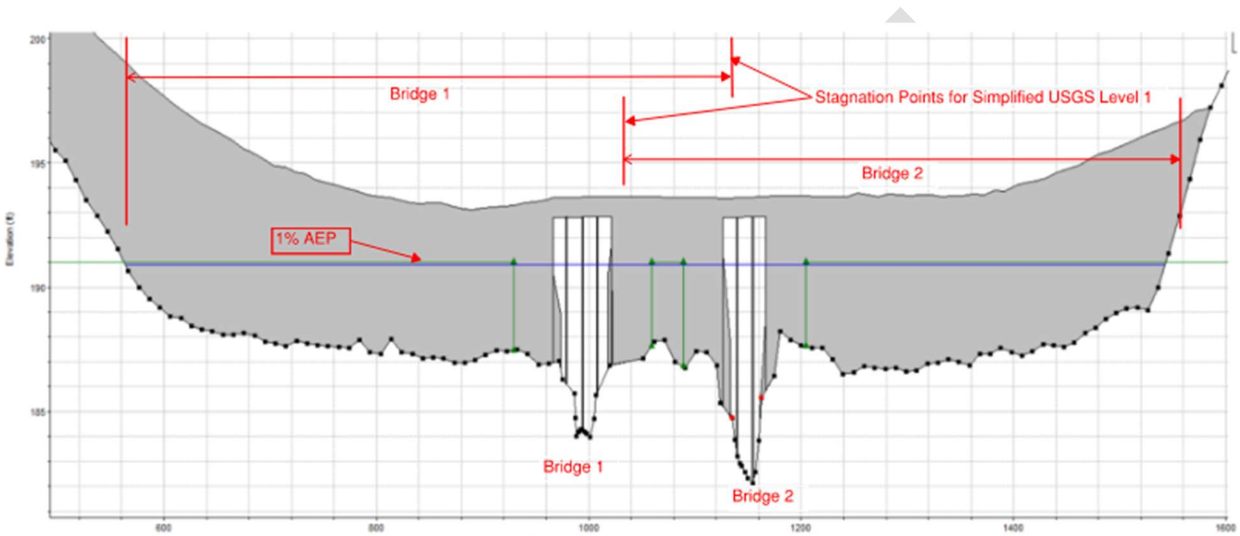


Figure 19: Example of High Water Data and Cross Section Geometry



This method may also be suitable for multiple openings. The embankment lengths should be estimated by establishing stagnation points between the bridges. The stagnation points are provided in output from hydraulic modeling, however, if a conservative result is acceptable, use the adjacent bridge end as the stagnation point. See **Figure 20** for a typical example for multiple opening stagnation points.

Figure 20: Example Multiple Opening Stagnation Points



6.1.10 Envelope Curves Example

A Level 1 analysis will be performed on bridges with sufficient foundation information available for the existing structure using the USGS_sir20165121 template spreadsheet based on the USGS publication for South Carolina bridge-scour envelope curves. Several checks that are built into the spreadsheet will be utilized on a case by case basis, especially for the lower limits of the drainage area.

- Site Info
  - The site info tab is populated by the user based on data available through various sources such as the FEMA for the hydraulic model, SCDOT for As-Built/As-Let plans, LIDAR DEM for the Topography etc. Priority of the source used for the analysis is based on the order in which the sources are listed in the spreadsheet as shown below.

    1. Hydraulic Model
    2. SCDOT Road Plans
    3. Topographic Map
    4. FEMA Map

  - Measurements for the embankment length, unconstricted approach cross-section width, abutment lengths, and channel width shall be measured per the source available. An overlap of information from one source to the other should be strictly avoided to maintain the exclusivity of the Geometric Contraction Ratio (m) associated with the information from each source.

- Scour Depth Calculation

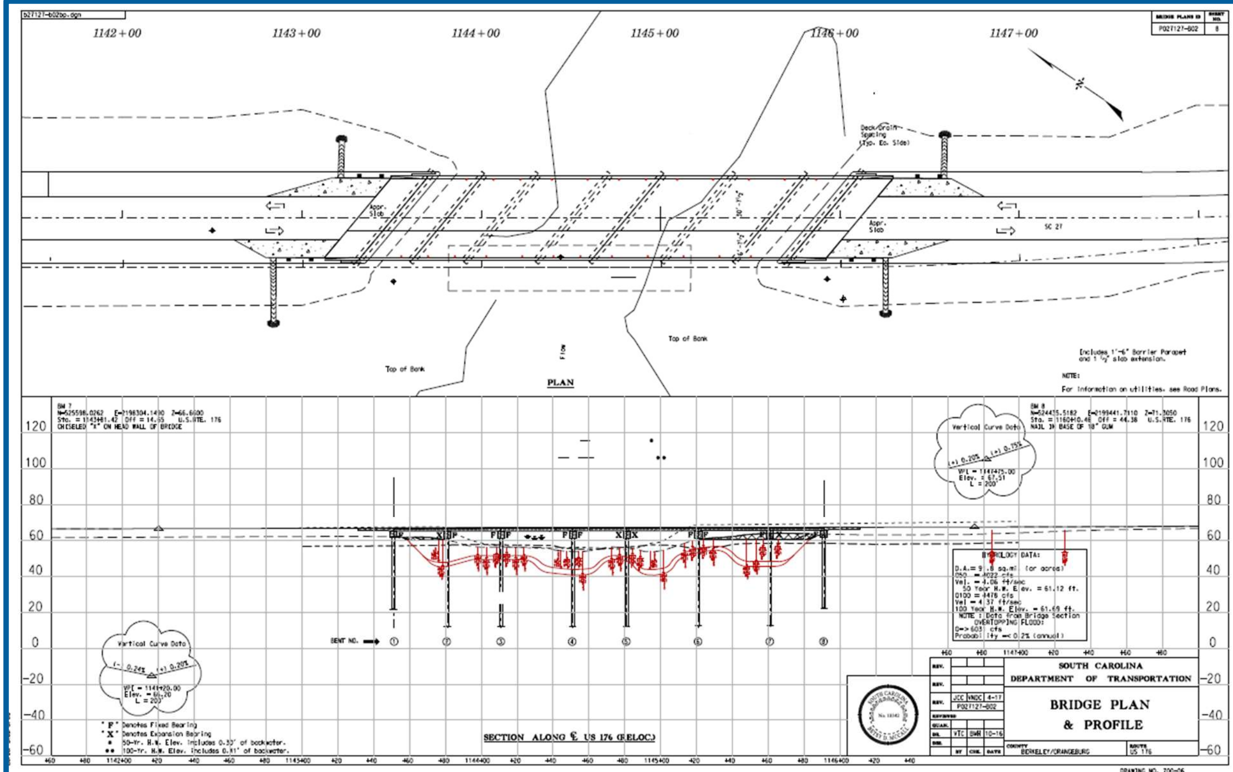
    The scour depths should be automatically calculated for the values measured, as explained above, and then verified against the checks coded in the spreadsheet. Pier measurements shall be entered in the Pier Scour spreadsheet separately.

- Embedment depths are obtained from the as-built drawings and pile logs and shall be entered in the penetration table tab to determine the stability of the structure based on the scour calculations.

For instances where the spreadsheet calculates the pier scour for abutments as well, the work case scour (pier or abutment) should be plotted on the scour map.

Separate scour analysis spreadsheets shall be prepared for the 100 year and High-Water elevation scenario as appropriate.

The following six (6) pages provide a detailed example of a Level 1 analysis using the USGS_sir20165121 template spreadsheet based on the USGS publication for South Carolina bridge-scour envelope curves.



Site Information

1

Use a blank template when starting new assessments
(Fill in gray shaded cells; leave blank if data not available.)

Bridge Number:		Stream:	Dean's Swamp	Date of Analysis:	01/23/17
County:	Berkeley	Road:	US 176		
Physiographic Region (for scour):	Coastal Plain	Multiple Bridge?	Yes	Bridge Length:	240 ft
		Relief Bridge?	No		
Latitude:	33.2759 DMS	Swampy, Poorly Defined Channel?	No	Drainage Area:	91.8 sq mi
Longitude:	-80.3508 DMS				

Hydraulic Model Data (Stations for bridge cross section are based on unconstricted approach section station with bridge projected on to approach)

Data Available?	Yes
Quality of Model Data:	Good

LEW station at unconstricted approach cross section; OR left stagnation point for multiple bridge (if no data, leave cell empty):	9877.73 ft
REW station at unconstricted approach cross section; OR right stagnation point for multiple bridge (if no data, leave cell empty):	10134.47 ft
Unconstricted cross-section topwidth from model data (approach before cross-section):	257 ft
CHECK (Single bridge data): Do embankment lengths and toe-to-toe distance equal unconstricted cross-section topwidth? (approach before cross-section)	N/A

LEW station at bridge (based on approach):	9877.73 ft
REW station at bridge (based on approach):	10134.47 ft
Left abutment toe station (based on approach):	9900.92 ft
Right abutment toe station (based on approach):	10102.92 ft
LTB station at bridge (if relief bridge or swampy, poorly defined channel, leave cell empty):	9886.1 ft
RTB station at bridge (if relief bridge or swampy, poorly defined channel, leave cell empty):	10126.1 ft
Channel topwidth (model):	240 ft
Distance from toe to toe (model):	202 ft
Left embankment length (model):	312 ft
Right embankment length (model):	551 ft
M(g) (model):	0.78

SCDOT Plan Data (Be sure to check for tie equalities)

Data Available?	Yes
Quality of Plan Data:	Good

SCDOT Road Plan number:	
Use HWM or average flood-plain flow depth for WSEL?**	High Water
WSEL on SCDOT datum:	62.12 ft
LEW station at unconstricted cross section from plans (if no data, leave cell empty):	9877.73 ft
REW station at unconstricted cross section from plans (if no data, leave cell empty):	10134.47 ft
Unconstricted cross-section topwidth from plans:	257 ft
CHECK (Single bridge data): Do embankment lengths and toe-to-toe distance equal unconstricted cross-section topwidth?	N/A
CHECK (Multiple bridge data): Does sum of embankment and bridge lengths equal approach flood-plain topwidth?	Yes

LEW station at bridge:	9737.76 ft
REW station at bridge:	10274.44 ft
Left abutment toe station:	9900.92 ft
Right abutment toe station:	10102.92 ft
LTB station at bridge (if relief bridge or swampy, poorly defined channel, leave cell empty):	9909.6 ft
RTB station at bridge (if relief bridge or swampy, poorly defined channel, leave cell empty):	10077.1 ft
Channel topwidth (plans):	168 ft
Distance from toe to toe (plans):	202 ft
Left embankment length (plans):	312 ft
Right embankment length (plans):	551 ft
M(g) (plans):	0.78

**NOTE: Average flood-plain flow depth in Coastal Plain and Piedmont is approximately 7 ft.

Topographic Map Data

Data Available?	Yes
Quality of Map Data:	Poor

Does topo indicate wide, flat floodplain?	Yes	
Does topo indicate severe meander just upstream?	No	
Bridge length as provided by SCDOT (verify with topo map if possible):	240	ft
Approach flood-plain topwidth (topo map):**	3189.73	ft
Left embankment length (topo map):	No Data	ft
Right embankment length (topo map):	No Data	ft
M(g) (topo map):	No Data	

CHECK (Single bridge data):

Does sum of embankment and bridge lengths equal approach flood-plain topwidth?	N/A

CHECK (Multiple bridge data):

Does sum of embankment and bridge lengths equal approach flood-plain topwidth?	N/A

**NOTE: The approach cross section should represent the unconstricted natural cross section located approximately one bridge-width upstream of the bridge of interest.
**NOTE: The HWM from the SCDOT plans, HWM from flood documentation, or the average flood-plain flow depth should be used to approximate the flood-plain topwidth.

FEMA/Other Map Data

Data Available?	
Quality of Map Data:	
If "Other Map," describe:	

Bridge length as provided by SCDOT (verify with FEMA/Other map if possible):	240	ft
Approach flood-plain topwidth (FEMA/Other map):**	3189.73	ft
Left embankment length (FEMA/Other map):	No Data	ft
Right embankment length (FEMA/Other map):	No Data	ft
M(g) (FEMA/Other map):	No Data	

CHECK (Single bridge data):

Does sum of embankment and bridge lengths equal approach flood-plain topwidth?	N/A

CHECK (Multiple bridge data):

Does sum of embankment and bridge lengths equal approach flood-plain topwidth?	N/A

**NOTE: The approach cross section should represent the unconstricted natural cross section located approximately one bridge-length upstream of the bridge of interest.
**NOTE: The inundated areas on the FEMA/Other map should be used to approximate the flood-plain topwidth.

2

Comparison of Geometric-Contraction Ratios [M(g)]

Select Source for M(g): Source Used: Hydraulic Model

	M(g) Value	Quality of Source Data
M(g) from model:	0.78	Good
M(g) from road plans:	0.78	Good
M(g) from topographic map:	No Data	Poor
M(g) from FEMA/Other map:	No Data	No Data
USE M(g):	0.78	

**NOTE: The "USE M(g)" value is automatically selected, but can be overridden by typing in another value. If the originally selected value of M(g) is overridden, justification should be provided in the comments below.
**NOTE: In most cases, the model data should provide a reasonable estimate of M(g) and should be given strong consideration in the selection of the final M(g). The other sources of data (road plans and maps) should be used to confirm the M(g) estimate based on the model data. The road plans are based on an actual survey, likely providing a better data source for confirming the M(g) determined from the model data. The details associated with the topographic and FEMA/Other maps will often be limited, causing discrepancies in the estimate of M(g). When significant discrepancies in the estimate of M(g) exist between the four data sources, the user should determine the reason for the discrepancy and then select a reasonable, but conservative estimate of M(g). As a general rule, the selected M(g) and embankment lengths should come from the same data source.

Comparison of Embankment Lengths

Select Source for Embankment Length: Source Used: Hydraulic Model

	Left: Embankment Length (ft)	Left: Quality of Source Data	Right: Embankment Length (ft)	Right: Quality of Source Data
Embankment length from model:	312	Good	551	Good
Embankment length from road plans:	312	Good	551	Good
Embankment length from topographic map:	No Data	Poor	No Data	Poor
Embankment length from FEMA/Other map:	No Data	No Data	No Data	No Data
USE embankment length:	312 ft		551 ft	

CHECK:

Is this a relief or swampy bridge with a poorly defined channel and a bridge length less than or equal to 240 ft? If so, use the maximum embankment length from the selected "Source Used" for left and right embankment length.	No

**NOTE: The "USE embankment length" value is automatically selected, but can be overridden by typing in another value. If the originally selected value of embankment length is overridden, justification should be provided in the comments below.
**NOTE: In most cases, the model data should provide a reasonable estimate of embankment lengths and should be given strong consideration in the selection of the final embankment lengths. The other sources of data (road plans and maps) should be used to confirm the embankment length estimates baed on the model data. The road plans are based on an actual survey, likely providing a better data source for confirming the embankment lengths determined from the model data. The details associated with the topographic and FEMA/Other maps will often be limited, causing discrepancies in the estimate of embankment length. When significant discrepancies in the estimate of embankmnent lengths exist between the four data sources, the user should determine the reason for the discrepancy and then select a reasonable, but conservative estimate of embankment length. As a general rule, the selected M(g) and embankment lengths should come from the same data source.

Comparison of Overbank Widths underneath Bridge

Select Source for Overbank Width: Source Used: SCDOT Plans

	Left Overbank Width (Left abutment toe to left top of bank)**	Right Overbank Width (Right top of bank to right abutment toe)**
Overbank width (Old SCDOT plans if available):	8.68 ft	25.82 ft
Overbank width (Hydraulic Model):	8.68 ft	25.82 ft
USE overbank width:	8.68 ft	25.82 ft
CHECK: Is overbank width greater than or equal to 10 feet?**	No	Yes

**NOTE: The overbank width information is compared with the topwidth of the abutment-scour hole to determine how much of the overbank width will be covered by the abutment-scour hole and how much will remain for overbank scour.
**NOTE: If the site is a relief bridge or has a swampy, poorly defined channel, then the overbank width will be determined by splitting the toe-to-toe width between the left and right overbanks.
**NOTE: The SCDOT Requirements Manual recommends for new and replacement bridges that there be a minimum 10 foot setback distance from the top of bank to the abutment toe (written commun., S.T. Benedict, South Carolina Department of Transportation, September 12, 2016).

1

Clear-Water Abutment-Scour Estimate

(occurs in the abutment region)

(Option to fill in/modify gray shaded cells. Other cells are selected/calculated automatically.)

Bridge Number:	0	**Stream:**	Dean's Swamp	**Date of Analysis:**	01/23/17
County:	Berkeley	**Road:**	US 176		
Physiographic Region:	Coastal Plain	**Multiple Bridge?**	Yes	**Bridge Length:**	240 ft
		Relief Bridge?	No		
		Swampy, Poorly Defined Channel?	No	**Drainage Area:**	91.8 sq mi
Latitude:	33.2759 DMS				
Longitude:	-80.3508 DMS				

Drainage Area Check -- Original Curve (Benedict and others, 2016; Benedict, 2003): DA IN RANGE

Drainage Area Check -- Modified Curve (Benedict and others, 2016; Benedict and Caldwell, 2012): DA IN RANGE

Comparison of Geometric-Contraction Ratios [M(g)]

	M(g) Value	Quality of Source
M(g) from model:	0.78	Good
M(g) from road plans:	0.78	Good
M(g) from topographic map:	No Data	Poor
M(g) from FEMA/Other map:	No Data	No Data
USE M(g): (from "Site Info" Sheet)	0.78	

M(g) range check -- Original Curve (Benedict and others, 2016; Benedict, 2003): OK

M(g) range check -- Modified Curve (Benedict and others, 2016; Benedict and Caldwell, 2012): OK

**NOTE: The "USE M(g)" value is automatically pulled from the Site Info Sheet.

Guidance:

Original Clear-Water Abutment-Scour Curves
(Benedict and others, 2016; Benedict, 2003)
Limits:
1) For Piedmont sites the maximum M(g) =0.82, but 0.86 could be justified with caution.
2) For Coastal Plain sites the maximum M(g) =0.98, but use caution when greater than 0.9.
3) Drainage area should fall within range of measured data and caution should be used as drainage area approaches limits of data.

Modified Clear-Water Abutment-Scour Curve
(Benedict and others, 2016; Benedict and Caldwell, 2012)
Limits:
1) For Piedmont sites the maximum M(g) =0.85.
2) For Coastal Plain sites the maximum M(g) =0.9.
3) Drainage area should fall within the range of measured data and caution should be used as drainage area approaches limits of data.

2

Comparison of Embankment Lengths

	Left		Right	
	Embankment Length (ft)	Quality of Source Data	Embankment Length (ft)	Quality of Source Data
Embankment length from model:	312	Good	551	Good
Embankment length from road plans:	312	Good	551	Good
Embankment length from topographic map:	No Data	Poor	No Data	Poor
Embankment length from FEMA/Other map:	No Data	No Data	No Data	No Data
USE embankment length *(from Site Info Sheet)*:	**312**		**551**	
Embankment length range check -- Original Curve (Benedict and others, 2016; Benedict, 2003): *(from "EQUATIONS" Sheet)*	OK		OK	
Embankment length range check -- Modified Curve (Benedict and others, 2016; Benedict and Caldwell, 2012): *(from "EQUATIONS" Sheet)*	OK		OUTSIDE RANGE	

**NOTE: The "USE embankment length" value is automatically pulled from the Site Info Sheet.

CHECK:

Is this a relief or swampy bridge with a length less than or equal to 240 ft? If so, use the maximum embankment length from the selected "Source Used" (see "Site Info" Sheet) for left and right embankment lengths.	**No**

Guidance:

Original Clear-Water Abutment-Scour Curves
(Benedict and others, 2016; Benedict, 2003)
Limits:
1) If the bridge is a relief or swampy bridge with a length of 240 ft or less, the longest embankment length for the left or right embankments should be used at both abutments.
2) For Piedmont sites the maximum embankment length = 950 ft.
3) For Coastal Plain sites the maximum embankment length = 7,440 ft, but most of the data is for lengths of about 2,000 ft or less. Caution must be used when values exceed 2,000 ft.
4) Drainage area should fall within the range of measured data and caution should be used as drainage area approaches limits of data.

Modified Clear-Water Abutment-Scour Curve
(Benedict and others, 2016; Benedict and Caldwell, 2012)
Limits:
1) If the bridge is a relief or swampy bridge with a length of 240 ft or less, the longest embankment length for the left or right embankments should be used at both abutments.
2) For Piedmont and Coastal Plain sites, the maximum embankment length = 500 ft.
3) Drainage area should fall within the range of measured data and caution should be used as drainage area approaches limits of data.

3

Clear-Water Abutment-Scour Depth from Envelope Curves

	Left Abutment		Right Abutment	
Original Clear-Water Abutment-Scour Curves (Benedict and others, 2016; Benedict, 2003):				
Abutment-scour depth by embankment length:	10.6	ft	14.6	ft
Abutment-scour depth by geometric-contraction ratio M(g):	12.3	ft	12.3	ft
Original abutment-scour curve selection:	Automatic Calculation		Automatic Calculation	
Selected original abutment-scour depth:	12.3	ft	12.3	ft
Modified Clear-Water Abutment-Scour Curve (Benedict and others, 2016; Benedict and Caldwell, 2012):				
Abutment-scour depth by embankment-length category:	11.5	ft	N/A	ft
Abutment-scour depth by interpolation:	9.0	ft	N/A	ft
Modified abutment-scour curve selection:	Automatic Calculation		Automatic Calculation	
Selected modified abutment-scour depth:	11.5	ft	N/A	ft
Final Selected Clear-Water Abutment-Scour Depth:				
Final abutment-scour curve selection:	Automatic Selection		Automatic Selection	
Final selected clear water abutment-scour depth:	12.3	ft	12.3	ft
Relative Increase in Theoretical Clear-Water Abutment-Scour from the 100- to 500-Year Flows (Benedict and others, 2016):				
500-yr flow coefficient:	1.21		1.21	
Abutment-scour by 500-year flow coefficient:	14.9	ft	14.9	ft

Guidance:

Original Clear-Water Abutment-Scour Curves
(Benedict and others, 2016; Benedict, 2003)

1) If the bridge is a relief or swampy bridge with a length of 240 ft or less, the scour depth determined by embankment length for the left and right abutments should be based on the longest embankment length.
NOTE: The "Use embankment length" from above should reflect the maximum embankment length from the left or right embankment if the bridge meets the criteria in item 1. Check to verify.
2) For single bridge, the spreadsheet will select the larger of two original envelope curves (embankment length or M(g) curves). However, there are cases when it may be appropriate to select the smaller value. Refer to Benedict and others (2016) for additional discussion.
3) For multiple bridge in Piedmont, use M(g) envelope curve.
4) For multiple bridge in Coastal Plain, for embankment length < 426 ft use M(g) envelope curve.
5) For multiple bridge in Coastal Plain: for embankment length >= 426 ft, the spreadsheet will select the larger of the two envelope curves. However, there are cases when it may be appropriate to select the smaller value. Refer to Benedict and others (2016) for additional discussion.
6) If the M(g) and (or) embankment lengths are near the limits or beyond the range of the envelope data a caution or warning message, respectively, will appear in the "M(g) range check" and (or) "Embankment length range check" cells above. For these cases judgment must be used to assess the best estimate of clear-water abutment scour.

Modified Clear-Water Abutment-Scour Curve
(Benedict and others, 2016; Benedict and Caldwell, 2012)

1) If the bridge is a relief or swampy bridge with a length of 240 ft or less, the scour depth determined by embankment length for the left and right abutments should be based on the longest embankment length.
NOTE: The "Use embankment length" from above should reflect the maximum embankment length from the left or right embankment if the bridge meets the criteria in item 1. Check to verify.
2) Use for single bridges only. Use original curve (Benedict and others, 2016; Benedict, 2003) for multiple bridges.
3) If the estimate of scour using the original envelope curves is less than that using the modified curve, then use the scour depth associated with the original curve.
4) If the M(g) and (or) embankment lengths are near the limits or beyond the range of the envelope data a caution or warning message, respectively, will appear in the "M(g) range check" and (or) "Embankment length range check" cells above. For these cases judgment must be used to assess the best estimate of clear-water abutment scour.

Relative Increase in Theoretical Clear-Water Abutment-Scour from the 100- to 500-Year Flows
(Benedict and others, 2016)

1) The 500-year flow adjustment coefficient (K_{500}) is used to calculate the relative abutment scour increase from 100- to 500-year flows.
2) The K_{500} is a helpful tool for gaining perspective on the relative increase of theoretical scour associated with the 100- to 500-year abutment-scour depth. However, the adjusted envelope curve values should not be considered a definitive estimate of the abutment scour associated with the 500-year flow.

Scour-Hole Topwidths

(Benedict and others, 2016; Benedict, 2003)

	Left Abutment		Right Abutment	
Use Abutment Scour-Hole Topwidth Curve (select from 1 or 2 below): (1) Any length bridge with a well defined channel or any bridge longer than 240 feet (2) Flood-plain relief or swampy bridge with length of 240 ft or less	1		1	
Abutment scour-hole topwidth:	69.4	ft	69.4	ft
Is scour depth outside range of graph?	No		No	

NOTE: The "Abutment scour-hole topwidth" is automatically calculated. The scour-hole topwidth equations coded in the spreadsheet limit the abutment-scour depth to 25 feet, which is beyond the range of the original graphs. The cell below the scour-hole topwidth will indicate if the abutment-scour depth exceeds the graph range and judgment must be used with regard to utilizing the estimated value.

Clear-Water Contraction-Scour Estimate

1

(occurs in the overbank region)

(Option to fill in/modify gray shaded cells. Other cells are selected/calculated automatically.)

Bridge Number:	0	**Stream:**	Dean's Swamp	**Date of Analysis:**	01/23/17
County:	Berkeley	**Road:**	US 176	**Bridge Length:**	240 ft
Physiographic Region:	Coastal Plain	**Multiple Bridge?**	Yes	**Drainage Area:**	91.8 sq mi
		Relief Bridge?	No		
Latitude:	33.2759 DMS	**Swampy, Poorly Defined Channel?**	No	**Drainage Area Check:**	DA IN RANGE
Longitude:	-80.3508 DMS				

Comparison of Geometric-Contraction Ratios [M(g)]

	M(g) Value	Quality of Source Data
M(g) from model:	0.78	Good
M(g) from road plans:	0.78	Good
M(g) from topographic map:	No Data	Poor
M(g) from FEMA/Other map:	No Data	No Data
USE M(g): (from "Site Info" Sheet)	0.78	
M(g) range check: (from "EQUATIONS" Sheet)	OK	

**NOTES: If the geometric-contraction ratio is greater than 0.95 message is OUTSIDE RANGE.
If the geometric-contraction ratio is between 0 and 0.85 message is OK.
If the geometric-contraction ratio is between 0.85 and 0.95 message is CAUTION.

**NOTE: The "USE M(g)" value is automatically pulled from the Site Info Sheet.

Guidance:

(Benedict and others, 2016; Benedict and Caldwell, 2006)

1) For the Piedmont data the maximum M(g) for clear-water overbank contraction scour was 0.85.
2) For the Coastal Plain data the maximum M(g) for clear-water overbank contraction scour was 0.95 with data sparse for M(g) greater than 0.9.
3) Caution must be used when M(g) nears or exceeds the upper limits of the data and the "M(g) range check" cell above should be used to help evaluate the final selection of M(g).

Clear-Water Contraction-Scour Depth from Envelope Curves

	Left Overbank	Right Overbank
Clear-Water Contraction-Scour Curve (Benedict and others, 2016; Benedict and Caldwell, 2006)		
Clear-water contraction-scour depth by geometric-contraction ratio M(g):	4.8 ft	4.8 ft
Final Selected Clear-Water Contraction-Scour Depth:	4.8 ft	4.8 ft
Relative Increase in Theoretical Clear-Water Contraction Scour from the 100- to 500-Year Flows (Benedict and others, 2016):		
500-yr flow coefficient:	1.46	1.46
Clear-water contraction-scour by 500-year flow coefficient:	6.9 ft	6.9 ft

**NOTE: The "Selected clear-water overbank-contraction-scour depth" value is automatically selected, but can be overridden by typing in another value. If the originally selected value of overbank-contraction-scour depth is overridden, justification should be provided in the comments below.

Guidance:

Clear-Water Contraction-Scour Curve

(Benedict and others, 2016; Benedict and Caldwell, 2006)

1) If the M(g) is near the limits or beyond the range of the envelope data a caution or warning message, respectively, will appear in the "M(g) range check" cell above. For these cases judgment must be used to assess the best estimate of clear-water overbank-contraction scour.

Relative Increase in Theoretical Clear-Water Contraction-Scour from the 100- to 500-Year Flows

(Benedict and others, 2016)

1) The 500-year flow adjustment coefficient (K_{500}) is used to calculate the relative abutment scour increase from 100- to 500-year flows.
2) The K_{500} is a helpful tool for gaining perspective on the relative increase of theoretical scour associated with the 100- to 500-year clear-water contraction-scour depth. However, the adjusted envelope curve values should not be considered a definitive estimate of the scour associated with the 500-year flow.

Live-Bed Contraction-Scour Estimate

1

(occurs in the channel region)

(Option to fill in/modify gray shaded cells. Other cells are selected/calculated automatically.)

Bridge Number:	0	**Stream:**	Dean's Swamp	**Date of Analysis:**	01/23/17
County:	Berkeley	**Road:**	US 176	**Bridge Length:**	240 ft
Physiographic Region:	Coastal Plain	**Multiple Bridge?**	Yes	**Drainage Area:**	91.8 sq mi
		Relief Bridge?	No		
Latitude:	33.2759 DMS	**Swampy, Poorly Defined Channel?**	No		
Longitude:	-80.3508 DMS				

Drainage Area Check -- Original Curve (Benedict and others, 2016; Benedict and Caldwell, 2009):	DA IN RANGE
Drainage Area Check -- Modified Curve (Benedict and others, 2016; Benedict and Caldwell, 2012):	DA IN RANGE

Comparison of Geometric-Contraction Ratios [M(g)]

	M(g) Value	Quality of Source Data
M(g) from model:	0.78	Good
M(g) from road plans:	0.78	Good
M(g) from topographic map:	No Data	Poor
M(g) from FEMA/Other map:	No Data	No Data
USE M(g): (from "Site Info" Sheet)	0.78	

M(g) range check -- Original Curve (Benedict and Caldwell, 2009) (M(g) <=0.82):	OK
M(g) range check -- Modified Curve (Benedict and Caldwell, 2012) (M(g) <=0.90):	OK

**NOTE: The "USE M(g)" value is automatically pulled from the Site Info Sheet.

Guidance:

Original Live-Bed Contraction-Scour Curve:

(Benedict and others, 2016; Benedict and Caldwell, 2009)

NOTE: Only the field envelope curve for live-bed contraction scour is used in the spreadsheet template. The user may refer to Benedict and others (2016) for application of the dimensionless envelope curve, if deemed appropriate.

Limits:
1) For Piedmont and Coastal Plain sites the maximum M(g) =0.82.
2) Limited clear-water scour data suggests that it may be appropriate to extend the live-bed curve beyond a value of 0.82; however caution and judgment must be used.
3) Drainage area should fall within range of the measured data and caution should be used as drainage area approaches limits of data.
4) Because of uncertainty associated with the live-bed contraction-scour data, caution and judgment must be used in the final estimate of live-bed contraction scour.

Modified Live-Bed Contraction-Scour Curve:

(Benedict and others, 2016; Benedict and Caldwell, 2012)

Limits:
1) For Piedmont and Coastal Plain sites the maximum M(g) =0.9.
2) Drainage area should be 200 square miles or less.
3) Because of uncertainty associated with the live-bed contraction-scour data, caution and judgment must be used in the final estimate of live-bed contraction scour.

Pier Scour Estimate

1

(Fill in gray shaded cells. Other cells are selected/calculated automatically.)

Bridge Number:	0	**Stream:**	Dean's Swamp	**Date of Analysis:**	01/23/17
County:	Berkeley	**Road:**	US 176		
Physiographic Region:	Coastal Plain	**Multiple Bridge?**	Yes	**Bridge Length:**	240 ft
		Relief Bridge?	No		
Latitude:	33.2759 DMS	**Swampy, Poorly Defined Channel?**	No	**Drainage Area:**	91.8 sq mi
Longitude:	-80.3508 DMS				

Guidance:

Use of Pier Scour Table below
- See cell comments for guidance on using the Pier Scour Table below.

Pier Scour Computations
- If a pier or bent falls anywhere on the overbank, pier scour will be computed for both the abutment and overbank regions.
- If there are piers or bents of varying geometries on the same overbank, use the worst case pier geometry in both the abutment and overbank areas.
- When a pier is on the floodplain, but near the channel bank, the user must decide if the pier should be considered to be a channel pier or not; in addition to the proximity of the pier to the bank, the user should consider other factors such as bends that may increase potential for scour.

Pier Scour Table

(Benedict and others, 2016; Benedict and Caldwell, 2009; Benedict and Caldwell, 2006)

	Left Abutment	Left Overbank	Channel	Right Overbank	Right Abutment
Location of pier	LABUT	LOB	CH	ROB	RABUT
Type of pier or bent (choose from list)	Concrete Pile Bent	Concrete Pile Bent	Concrete Pile Bent	Concrete Pile Bent	Concrete Pile Bent
Envelope curve used (choose from list)	Automatic Calculation	Automatic Calculation	Automatic Calculation	Automatic Calculation	Automatic Calculation
Pier width (feet)		2	2	2	
Pier length (feet) (should not be less than pier width)		2	2	2	
Angle of attack (degrees) (should not exceed 90)		0	0	0	
Multiple column pier or bent? (choose from list)		Yes	Yes	Yes	
Estimate of minimum spacing between columns (feet)		10	10	10	
Column spacing to width ratio (should be between 2 and 10)	N/A	5.0	5.0	5.0	N/A
Skew coefficient (single pier - HEC-18)	N/A	1.00	1.00	1.00	N/A
Skew coefficient (selected value)	N/A	1.00	1.00	1.00	N/A
Envelope curve used in pier scour estimate	N/A	PSDb-2014	SC Live Bed	PSDb-2014	N/A
Pier scour from envelope (feet) (no adjustment)	0.00	3.92	3.92	3.92	0.00
Pier scour adjusted for skew (feet)	0.00	3.92	3.92	3.92	0.00
Final selected pier scour depth (feet)	**0.00**	**3.92**	**3.92**	**3.92**	**0.00**
500-yr flow coefficient:	1.09	1.09	1.09	1.09	1.09
Relative Increase in Theoretical Pier-Scour from the 100- to 500-Year Flows (Benedict and others, 2016):	**0.00**	**4.30**	**4.30**	**4.30**	**0.00**

**NOTE: The K_{500} is a helpful tool for gaining perspective on the relative increase of theoretical scour associated with the 100- to 500-year clear-water contraction-scour depth. However, the adjusted envelope curve values should not be considered a definitive estimate of the scour associated with the 500-year flow.

Pile Penetration Table

1

Scour analysis using USGS Bridge-Scour Envelope Curves

(Fill in gray shaded cells. Other cells are selected/calculated automatically.)

Bridge Number:	0	**Stream:**	Dean's Swamp	**Date of Analysis:**	01/23/17
County:	Berkeley	**Road:**	US 176		
				Bridge Length:	240 ft
Physiographic Region:	Coastal Plain	**Multiple Bridge?**	Yes		
		Relief Bridge?	No	**Drainage Area:**	91.8 sq mi
Latitude:	33.2759 DMS	**Swampy, Poorly Defined Channel?**	No		
Longitude:	-80.3508 DMS				

NOTE: Bents are listed from left to right looking downstream

GUIDANCE FOR LEFT AND RIGHT ABUTMENT SCOUR:

Refer to Benedict and others (2016) and Benedict (2003) for additional guidance.

1) Do not include clear-water overbank scour depth in abutment-scour area.
2) If site is in the Piedmont region and the abutment-scour depth is less than or equal to 5 feet then add pier-scour depth for determining total scour.
3) If the pier in the abutment area is a multiple column bent/pier with minimal skew or a solid, long pier with no skew, and the pier width is less than or equal to 2.3 ft, then do not add pier scour to total scour. (NOTE: The exception to this guidance is for sites in the Piedmont with abutment-scour depths less than or equal to 5 ft as noted in item 2 above.)
4) The spreadsheet assumes that abutment scour will always occur at the left and right abutments. The spreadsheet will automatically make an initial determination regarding the inclusion of pier scour in the total scour estimate. The user should review this initial determination and if appropriate override the automated value by typing "Yes" or "No" (case sensitive) in the "Use pier scour?" column. If the pier is skewed, the user should apply judgment to determine if pier scour should be included in the total scour estimate, especially for long solid piers where a pier skew can cause large scour depths.
5) If the site is a relief or swampy bridge that is 240 ft or less, the abutment-scour depth will be applicable from toe-to-toe; if the relief or swampy bridge is greater than 240 ft, the abutment scour-hole depths will be limited to the abutment scour-hole topwidths and the clear-water overbank contraction scour will be applied to the remaining overbank area. The spreadsheet will automatically determine if there is any overbank area on which overbank contraction scour will occur.

GUIDANCE FOR LEFT AND RIGHT OVERBANK CONTRACTION SCOUR:

Refer to Benedict and others (2016) and Benedict and Caldwell (2006) for additional guidance.

1) If the abutment-scour hole topwidth is greater than the overbank width then it will be assumed that the abutment-scour depth will cover the entire overbank area and there will be no clear-water overbank scour applied to the bridge overbank. However, if the abutment-scour hole topwidth is less than the overbank width then it will be assumed that clear-water overbank scour occurs in the overbank area not affected by the abutment scour hole.
2) The spreadsheet will automatically determine if clear-water overbank scour should be applied or not.
3) If clear-water overbank scour is determined to be applicable to the overbank area, then the spreadsheet will automatically apply the calculated pier scour to the overbank as well.

GUIDANCE FOR LIVE-BED CHANNEL SCOUR:

Refer to Benedict and others (2016) and Benedict and Caldwell (2009) for additional guidance.

1) If the main channel is well defined and considered to be live-bed in nature, it will be assumed that the live-bed contraction scour and channel pier scour will be included in the estimate for total scour in the main channel. The spreadsheet will automatically determine if these scour components are to be included in the estimate of total scour in the main channel.
2) Live-bed contraction scour will not be applied to a relief bridge or to a bridge with a swampy, poorly defined channel; at such bridges, it will be assumed that clear-water scour conditions prevail and the procedures for applying clear-water abutment and contraction scour, as noted previously, will be used. The spreadsheet will automatically determine if live-bed scour should or should not be applied to the channel.

GENERAL GUIDANCE:

1) Drainage area should fall within the range of measured data and caution should be used as drainage area approaches limits of the data or exceeds the data range.
2) If the M(g) and (or) embankment lengths are near the limits or beyond the range of the envelope data caution should be used.
3) User should review automatically determined values to assure that selected values are reasonable.

	Pier location	Use clear-water abutment scour?	Clear-water abutment scour from USGS curves (feet)	Use clear-water overbank contraction scour?	Clear-water overbank contraction scour from USGS curves (feet)	Use live-bed channel contraction scour?	Live-bed channel contraction scour from USGS curves (feet)	Use pier scour?	Pier scour (feet)	Total scour at bent (feet)	Computed embedment of pile from consultant (feet)	Remaining pile penetration (feet)	Embedment below thalweg from consultant (feet)	Remaining pile penetration (at thalweg) (feet)
Left Abutment	LABUT	Yes	12.29	No	0.00	No	0.00	No	0.00	12.29		-12.29		-12.29
Left Overbank	LOB	No	0.00	No	0.00	No	0.00	No	0.00	N/A		N/A		N/A
Channel	CH	No	0.00	No	0.00	Yes	9.80	Yes	3.92	13.72		-13.72		-13.72
Right Overbank	ROB	No	0.00	No	0.00	No	0.00	No	0.00	N/A		N/A		N/A
Right Abutment	RABUT	Yes	12.29	No	0.00	No	0.00	No	0.00	12.29		-12.29		-12.29

6.2 FHWA HEC-18

For bridges not falling within the limitations of the South Carolina Bridge-Scour Envelope Curves, FHWA HEC-18 methodology should be utilized to compute scour. The latest version of HEC-18 *Evaluating Scour at Bridges* is the Fifth Edition dated April 2012. The link to the document is:

https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12003.pdf

The most recent tech brief from FHWA is:

https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif19007.pdf

In accordance with HEC-18, the bridge scour estimations will require different inputs and materials from the South Carolina Bridge-Scour Envelope Curves. These required inputs could be taken from the flood hydraulic model outputs (1D/2D), the relevant materials (design drawings and documentation, site observations, gauged flow and sediment data, and samples). FHWA's Hydraulic Toolbox Version 4.4.1 (https://www.fhwa.dot.gov/engineering/hydraulics/software/toolbox44.zip) provides the calculators of bridge scour analysis per HEC-18 methodologies, including:

- Abutment Scour
- Contraction Scour
- Long-Term Degradation
- Pier Scour
- Special Conditions, such as pressurized flow conditions.

It also provides a function of importing geometry data from a HEC-RAS project. For this project, FHWA's Hydraulic Toolbox program will be used to perform the bridge scour analysis per HEC-18 and to produce constant analysis structure and outputs. HEC-18 provides multiple methods for evaluating each of the above scour components. It is important that engineers use engineering judgment to decide which methodology is most appropriate for a given bridge and well document the site conditions, method selections, and assumptions.

The input bridge structure data must agree with the existing bridge conditions and the flood hydraulic models. Acceptable sources for channel bed materials (sediment particle sizes) could be:

- Measured sediment data from:
  - Nearby USGS gage stations
  - On-site sediment sampling from the previous works for the given bridges or the bridges which have similar channel sediment conditions near the analyzed bridge.
- Boring information from bridge construction plans
- SCDHEC soil distribution tables or
- NRCS Web soil survey, which mainly shows large scale topsoil information in a watershed basis.

If necessary, a request may be made for the LEAD and HDSO to approve the collection of a site specific grab sample from the streambed and stream banks. **No geotechnical borings are required for this project.**

6.3 Tidal Scour Analysis

Scour at bridges over tidal waterways is a combination of long-term degradation, contraction scour, local scour, and waterway instability. Evaluation of scour for tidal bridges should follow HEC-18 methodology. USGS envelope curves are not applicable to coastal areas.

Scour events at tidally influenced waterways may be associated with normal tidal flow, tidal surge associated with a hurricane, or a combination of riverine and tidal flows, all of which are governed by unsteady flow. Development of design scour for these events should identify maximum conditions from a model-generated time series as input hydraulic parameters for scour calculation. Time dependent scour methodologies should not be considered for tidal design.

The degree to which tidal fluctuations influence the discharge at the river crossing depends on such factors as the relative distance from the ocean to the crossing, riverbed slope, cross-sectional area, storage volume, and hydraulic resistance. As the distance from the crossing to the ocean is reduced, the influence of the tidal fluctuations increases. Consequently, the degree of tailwater influence on flow hydraulics at the crossing increases. A limiting case occurs when the magnitude of the tidal fluctuations is large enough to reduce the discharge through the bridge crossing to zero at high tide. River crossings located closer to the ocean than this limiting case have two directional flow at the bridge crossing, and because of storage of the river flow at high tide, the ebb tide will have a larger discharge and velocities than the flood tide.

Extreme events associated with inland floods and storm tides should be used in determining the hydraulics at the bridge to evaluate local and contraction scour. Difficulty arises in determining whether the storm tide, inland flood, or the combination of both should be considered controlling. The effect of the inland flood discharges (if any), would be most significant during the period when storm tide floodwaters recede (ebb), as those discharges would likely add to, and increase the storm tide associated discharges.

Because the assessment of scour requires engineering judgment, the engineer evaluating tidal scour should be familiar with the FHWA's HEC-18 Evaluating Scour at Bridges, HEC-20 Stream Stability at Highway structures, HEC-25 (1st Edition) Tidal Hydrology, Hydraulics and Scour at Bridge, HEC-25 (2nd Edition) Highways in the Coastal Environment, HDS6 River Engineering for Highway Encroachment and HDS7 Hydraulic Design of Safe Bridges.

6.4 Scour Profiles

A scour profile should be plotted for each bridge for which a hydraulic model (HEC-RAS or SRH-2D) is developed, and scour computations are performed, using either the USGS Envelope Curves or HEC-18 methods. The profile should reflect the total cumulative depths of each of the scour components (contraction and local scour) computed at the bridge site.

Scour profiles are unnecessary for bridges which are lacking accurate bridge profile drawings. For these bridges, a simple comparison of scour depths to bridge foundation depths (with remaining post-scour pile penetration) can be made.

The scour profile should be plotted on an existing bridge centerline profile drawing. The bridge profile should be developed based on the best available information, which could include:

- Stream/bridge surveys (as described in Chapter 4)
- Existing bridge plans
- Microstation files
- Tape down/bridge geometry field measurements
- HEC-RAS scour computation plots

The bridge/scour profile plot should be drawn to scale, and should include the following information (at a minimum):

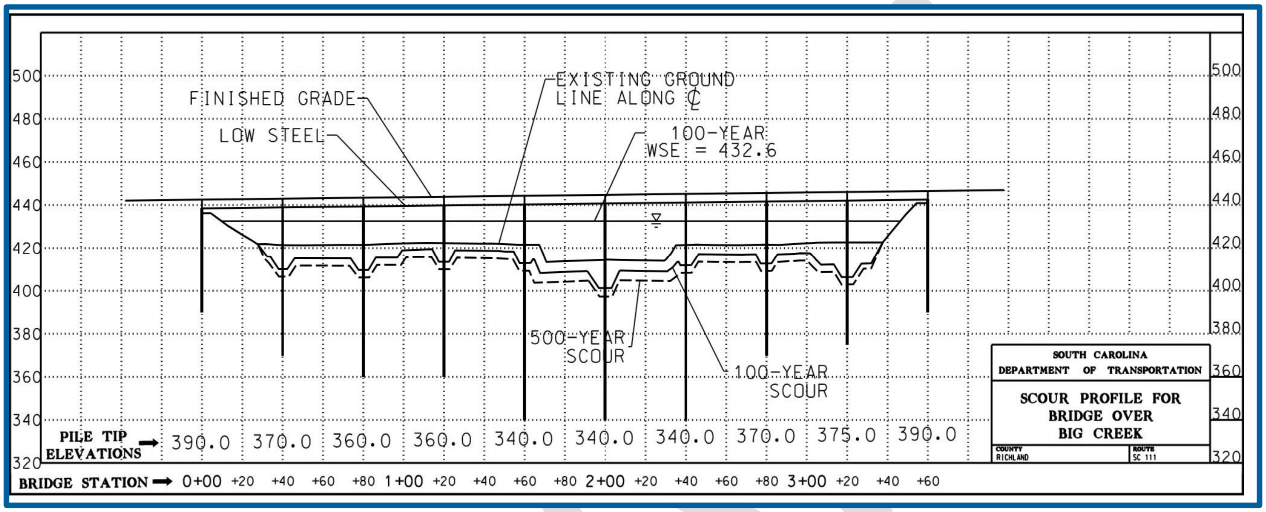
- Bridge geometry (including bridge finished grade and low chord/steel profiles).
- Pier/bent locations.
- Centerline ground/channel profile geometry is shown within the bridge opening.
- 1% AEP (100-year) and 0.2% AEP (500-year) scour profile plots.
- 1% AEP (100-year) water surface elevation.
- Foundation depths (pile tip, drilled shaft bottom, or spread footing elevations) are shown for each pier. For multiple column/pile bents, the maximum tip elevation for each bent should be shown.

Abutment and pier scour hole top widths should follow guidance presented in the HEC-18 and USGS Envelope Curve manuals, depending on which method is used.

Side slopes for abutment and pier scour holes should be plotted as 2:1 or flatter in sandy soils or 1.5:1 or flatter in cohesive soils. If these scour holes are near an adjacent abutment and there is potential undermining of the abutment, judgment should be used as to the quality and effectiveness of riprap protection on the abutment. In some cases, it may be determined that riprap would sufficiently protect the abutment from scour. In these situations, it may be suitable to show a slightly steeper scour hole side slope in order to indicate that abutments would not be prone to undermining.

Once a total scour profile has been drawn for 1% AEP (100-year) and 0.2% AEP (500-year) floods, it should be saved and submitted in PDF format. An example scour profile is shown in **Figure 21**. On the scour profile plot, indicate the pile tip elevations. Do not rely on the drawing to indicate this since the foundation is not consistently drawn to scale. Use a rectangle or an arrow label to indicate the average pile tip elevation for each bent.

Figure 21: Example Scour Profile Plot



6.5 Metric 18 Scour Assessment Report Template

See the following pages for the Metric 18 Scour Assessment Report Template.

METRIC 18
SCOUR ASSESSMENT REPORT

_______ over _______________, ________________ County, SC

Asset ID: _ _ _ _ _

Structure Number: _ _ _ _ _ _ _ _ _ _ _ _ _

CRITICAL ASSESSMENT & MANAGEMENT SYSTEM

Item 113	**#**	**POA?**	**Y/N**	Prepared By: <Consultant Logo>
COA		Hydraulic Engineer		*Version. 1.0* *20210301*

Certification: *This assessment was performed in accordance with SCDOT Scour Analysis for Existing Structures, Jan 2021.*

Consultant Certification	Signature:	Date:
QA Acceptance:	Signature:	Date:
HDSO Acceptance:	Signature:	Date:

1

I. Basis of Study

a. FHWA Requirements

The Federal Highway Administration requires that "Every bridge over a waterway, whether existing or under design, should be evaluated as to its vulnerability to scour in order to determine the prudent measures to be taken for its protection (Technical Advisory T5140.23, October 21, 1991; 23 CFR 650.313 (e), (e3)). Bridges that are deemed vulnerable to scour are classified as scour critical in the National Bridge Inventory Database (see NBI, Item 113). Plans of Action (POA) that implement safety measures during a specified flood event must be developed for each bridge deemed scour critical or to have unknown foundations.

Compliance with the Federal Highway Administration's policy regarding bridges over water requires that supporting documentation (such as the scour critical assessment, POA, and history of POA implementation during flood events) be on file and readily accessible for all bridges over water in the Bridge File System, which is housed in SCDOT's ProjectWise Explorer V8i. SCDOT's Bridge File System is organized by asset ID and houses all bridge-related files.

b. Scour Assessment Guidance:

Scour Assessment will be completed in accordance with the guidance provided in SCDOT *Scour Analysis for Existing Bridges*, January 2021, prepared specifically for the Scour Critical Assessment and Management System project.

BRIDGE DATA	
Asset ID	
Structure Number	
County	
Facility Carried	
Waterbody	
Skew Angle	
Bridge Length	
Bridge Width	
FEMA Flood Map Number	
FEMA Flood Zone	
Year Built	
Span Arrangement	
Latitude	
Longitude	
Representative Pier	
Pier Shape	
Abutment Type	
Roadway Alignment	

LOCATION MAP *(include enough definition with nearest Major Road / Intersection)*

AERIAL IMAGE

BRIDGE PLAN or SCHEMATIC

II.Data Collection

a. Records (please check all that apply)

Roadway Plans		Routine Inspect	
Bridge Plans		Pile Log	
FEMA Maps		FIS Study	
USGS StreamStats			
As-builts		Soils Data	
b. Site Inspection and QuickBase Report		**Date of Inspection:**	
Tapedowns		Soil Samples	
Photos			

c. Other Measurements	
d. Existing Model Data	**Source:** **Type:**

e. Scour and Inspection History:

(Include any items such as Rip Rap Condition, waterway adequacy, debris, erosion and scour issues)

Hydrologic Summary

Drainage Area:		sq mi			
High Water Mark (ft):		**Source:**		**Datum:**	

	10% AEP (10-Yr.)	4% AEP (25-Yr.)	2% AEP (50-Yr.)	1% AEP (100-Yr.)	0.5% AEP (500-Yr.)
Turkey Creek Design Flow Rate (StreamStats) (cfs)					
Design Flow (from Plan)(cfs)					
Water Surface Elevation					
Velocity (from plans) (fps)					

f. Field Conditions from Inspection Notes:

(Include items such as Confirmation of Bent Configuration, Abutment Type and Condition, Abutment Protection Condition, Channel/Waterway Condition, Utility Obstructions, Debris Accumulation, Channel Bank Stability, other Erosion or Scour Issues)

g. Notes and Assumptions on Data Collected			
Datum Conversion		Soil Type	
Pile Tip Elev/Embedment		D50	
General Terrain (hilly/flat/etc)			
Other Notes:			

III. Scour Assessment

a. Scour Estimate

Summary of Results

Bent #	Geometric Contraction Ratio (m)	Pier Scour (ft)	Clear Water Contraction Scour (ft)	Live Bed Contraction Scour (ft)	Abutment Scour (ft)	Total Scour (ft)	Ground Elevation (ft)	Scour Hole Topwidth (ft)	Pile Embedment (ft)
1									
2									
3									
4									
	<Insert additional rows as needed for total number of bents>								

b. Pile Embedment/Foundation Stability

c. Scour Profile Plot

<Insert scour plot here (show scour depths, side slopes, top widths, AEP, bent designations consistent with Bridge diagram)>

IV. Conclusions

a. Assumptions and Triggers

<Include any assumptions or triggers that should be considered where the scour code could change due to changes in existing site conditions>

b. Item 113 Code Recommendation

APPENDICES

A. Available Plan Excerpts
B. Available Mapping
C. Other Relevant Data
D. QuickBase Inspection Report
E. USGS Spreadsheets
F. Hydraulic Model
G. HEC-18 Calculations
H. QC Checklist

(Reports should include all appendices, mark "not applicable" as required.)

APPENDIX A. Available Plan Excerpts

APPENDIX B. Available Mapping

APPENDIX C. Other Relevant Data

APPENDIX D. QuickBase Inspection Report

APPENDIX E. USGS Spreadsheets

APPENDIX F. Hydraulic Model (HEC-RAS, SRH2D)

APPENDIX G. HEC-18 Calculations

APPENDIX H. QC Checklist

- End of Metric 18 Scour Assessment Report -

Table 8: Scour Assessment Responsibilities

Action Item	Lead Consultant	Non-Lead Consultants
All riverine bridges should utilize the South Carolina Bridge-Scour Envelope Curves Template to compute the likely maximum scour potential in accordance with the calculation guidance and limitations of the envelope curves, as described in Section 6.1.	X	X
For bridges not falling within the limitations of the South Carolina Bridge-Scour Envelope Curves, FHWA HEC-18 methodology should be utilized to compute scour. FHWA's Hydraulic Toolbox program will be used to perform the bridge scour analysis per HEC-18 methodologies using guidance from Section 6.2.	X	X
If necessary, a request may be made for the LEAD and HDSO to approve the collection of a site specific grab sample from the streambed and streambanks.		X
If necessary, approve requests for the collection of a site specific grab sample from the streambed and streambanks, after consultation with the HDSO.	X	

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Section 7. QC & QA Procedures

7.1 Purpose

The purpose of this chapter is to specify the exact steps to be performed for the Quality Control and Quality Assurance tasks. Quality Management team members are responsible for the overall quality of each of the deliverables for the project. *Quality Control* is the process of checking that all computations are correct, complete, and in compliance with requirements, while *Quality Assurance* looks at the overall quality process to ensure that it is being followed. Calculations, spreadsheets, and other documentation should be checked by a person independent of the work.

7.2 Quality Control

The Quality Control process entails checking that all computations are correct, complete, and in compliance with the project requirements. Implementation of quality control should be in accordance with the following guidelines as a minimum, in addition to any procedures required by each Consulting Firm's internal QA/QC processes.

1. Conformance of design documents for internal QC:
    a. Submitted documents conform to the internal QC checklist of required documents (see Figures 21 & 22).
    b. Method of scour analysis agrees with direction from lead consultant/HDSO.
    c. Hydraulics model/methodology (if applicable) agrees with direction from lead consultant/HDSO.

2. Unless hydrology is accepted from a previous study, confirm hydrology using the appropriate QC spreadsheet.

3. Unless hydraulics are accepted from a previous study, confirm hydraulic analysis using the appropriate QC spreadsheet.

4. Confirm scour analysis using the appropriate QC spreadsheet.

5. Check the report to confirm all values shown to agree with analyses.

6. Confirm item 113 coding based on the guidance document (Chapter 8).

7.2.1 File Naming Convention

In order to facilitate the efficiency of reviews and for establishing a permanent record of the analyses that are done for this project, it will be important that all files conform to the DOT's established naming convention. Where naming conventions do not currently exist, file names should conform to the guidance outlined in this section.

The standard format for file naming should conform to the following convention:

AssetID_Document Type_Description_YYYY-MM-DD.extension

Where:

- Asset ID is the five digit identifier that will start each file name (noted by "#####" below)
- Document Type will be one of the following:
  - "ScourAssessment" for scour analysis documentation (i.e. narrative description of calculations and results).
  - "Model 1D" files within
  - "Scour Input" for supporting information such as computer model files or spreadsheet files.
  - "ScourSuppCalcs" for supplementary calculations.
- Date shall be in the format YYYY-MM-DD and should be the date the scour analysis was completed.
- The file extension will be based on the type of file submitted. (**Table 9**) Quality Assurance reviews will be conducted using Bluebeam review sessions, so the primary documentation should be submitted in pdf format. Supporting documentation can be submitted in its original format.

Table 9: File Naming Convention

File Type	File Name
Item 113 Re-evaluation Form	#####-A4.2_113ReEval-YYYY-MM-DD
Scour Profile (Stream and/or Ground)	#####-A5.7_Scour_Profile-YYYY-MM-DD
Scour Assessment (Narrative Report)	#####-Scour_Assess-YYYY-MM-DD.pdf
Detailed Channel Profile	#####-Scour_DetChannelProf-YYYY-MM-DD
Drainage Area File (Shape)	#####-Scour_DrainageArea-YYYY-MM-DD.shp
Input Files (Excel Files)	#####-Scour_Input-FREEFORM-YYYY-MM-DD
HEC-2 (zip file for all model files)	#####-Scour_Model1D-HEC2-YYYY-MM-DD.zip
HEC RAS (zip file for all model files)	#####-Scour_Model1D-HECRAS-YYYY-MM-DD.zip
HY-8	#####-Scour_Model1D-HY8-YYYY-MM-DD.hy8
WSPRO (zip file for all model files)	#####-Scour_Model1D-WSPRO-YYYY-MM-DD.zip
ADH (zip file for all model files)	#####-Scour_Model2D-ADH-YYYY-MM-DD.zip
ADCIRC (zip file for all model files)	#####-Scour_Model2D-ADCIRC-YYYY-MM-DD.zip
FESWMS (zip file for all model files)	#####-Scour_Model2D-FESWMS-YYYY-MM-DD.zip
FLOW2D (zip file for all model files)	#####-Scour_Model2D-FLOW2D-YYYY-MM-DD.zip
HECRAS-2D (zip file for all model files)	#####-Scour_Model2D-HECRAS2D-YYYY-MM-DD.zip
RMA2 (zip file for all model files)	#####-Scour_Model2D-RMA2-YYYY-MM-DD.zip
SRH2D (zip file for all model files)	#####-Scour_Model2D-SRH2D-YYYY-MM-DD.zip
Scour Monitoring Plan (Document Responsible Entity)	#####-Scour_MonitorPlan-YYYY-MM-DD
Monitoring Device Output	#####-Scour_MonitorDeviceOutput-FREEFORM-YYYY-MM-DD
Plan of Action	#####-Scour_POA-YYYY-MM-DD
Re-Assessments for Item 113 Re-Evals	#####-Scour_ReAssess-YYYY-MM-DD
Summary Coversheet Form	#####-Scour_SummaryCoverSheet-YYYY-MM-DD
Supplemental Calculations	#####-Scour_SuppCalcs-YYYY-MM-DD

7.2.2 Checklist of Required Documents for Internal QC

- ☐ Cover sheet identifying bridge asset number, crossing roadway, and waterbody name.
- ☐ Copy of this checklist indicating the inclusion of all documents and files submitted.
- ☐ Documentation from the Lead consultant regarding recommended hydraulic and scour methodology.
- ☐ Summary sheet documenting sources of all geometry data used and datum.
- ☐ Documentation of hydrology source or computations.
- ☐ Documentation of model calibration (if applicable).
- ☐ HEC-RAS files (if applicable).
  - Project file
  - Terrain data (If applicable, in *.hdf format including the projection file)
  - Geometry file (one geometry file per site)
  - Flow file (one flow file per site with each recurrence interval included and clearly named)
  - Plan file (one plan file per site)
  - Output file
  - Scour Report (pdf format) should include:
    - Schematic layout:
      - Profile showing 1% (100 Year) & 0.2% (500 Year) AEP WSE
      - Output table (Standard Table 1)
      - Bridge table (1% & 0.2% AEP)
      - Cross sections – 2 per page showing 1% & 2% AEP WSEL
- ☐ SMS SRH-2D files
  - Project file
  - Base mapping
  - Terrain Data
  - Flow Data (hydrograph)
  - PDF Report including: Schematic showing flow vectors
  - Scour Report (pdf format) should include:
    - Computation spreadsheets
    - PDF report

Figure 22: Bridge Scour Report Quality Control Checklist

BRIDGE SCOUR REPORT QUALITY CONTROL CHECKLIST

PROJECT DETAILS

Bridge Asset ID: ______________________
Route: ______________________
Stream crossing: ______________________
County: ______________________

Company: ______________________

QA Certification: ______________________

CHECKLISTS

Checklists Completed:	Designer(s):	Reviewer(s):	Date:
_____ Hydrology			
_____ Terrain			
_____ HEC-RAS			
_____ SRH 2D			
_____ Env. Curves			
_____ HEC-18			

Instructions:

1. For all applicable spreadsheets, reviewer shall indicate status of each item and provide comments if necessary.
2. Originator shall make corrections as indicated by comments, provide comment if necessary and resubmit the scour study to reviewer.
3. Reviewer shall update status of resubmitted items, and provide additional comments as needed.
4. If additional comments or corrections are necessary, originator shall make corrections and resubmit until all items have a status of 4 (N/A) or 5 (Closed)
5. These checklists are intended to provide documentation that a quality control review was performed. All applicable checklists must be completed and included, along with this summary sheet, for Scour Study Report submission.

Figure 23: Hydrology Quality Control Checklist

Bridge Asset ID: 0

Hydrology QC Checklist

SCDOT Scour Critical Assessment and Management System

Originator:

Technical Review By:

Date QC Certified for Submittal:

instructions:

1. Populate "originator" & "review by" cells to left
2. Provide comments below per instructions on the Summary Sheet.
3. For each round of comment, add additional lines.
4. When all comments are satisfied, reviewer fills in date certified for submittal

ID	QC Check and Description	Quality Control Review		
		Status*	QC Review Comment	Originator Response
	General			
1	If a previously accepted model is used as the source for peak discharge(s),the source model is identified			
2	If peak discharge(s) are from a previously accepted model, discharges used agree with the source			
3	If 0.2% AEP discharge is extrapolated from 1% AEP discharge, confirm correct methodology			
	Stream Stats			
4	Basin delineation			
5	Confirm rural vs. urban regression scenario			
6	Basin characteristics			
7	Peak-flow report appears reasonable			
	Unsteady Flow Hydrographs			
8	Source of stillwater height appropriate			
9	Development of hydrograph in accordance with SCDOT 2009 HDM			
10	Duration of time series extends past recession of storm surge			
11	Timing of storm surge plus tide represents worst case condition			
12				
13				
14				
9				
10				
11				

*Comment Status: 1 = Comment Submitted; 2 = Unresolved; 3 = Resolved; 4 = N/A; 5 = Closed

7.3 Quality Assurance

The Quality Assurance process involves checking to ensure that Quality Management procedures are being followed completely and consistently. Prior to submitting studies to the SCDOT, quality assurance checks will be performed as follows:

As shown in **Figure 24,** the non-lead consultants will follow the following process for the Quality Control/Quality Assurance process required for each bridge scour analysis assessment:

1. Each completed bridge scour analysis assessment will be placed in the specified (Scour Assessment QA Submittals) ProjectWise (PW) folder by each of the non-lead consultants.
2. The lead consultant will move each completed bridge scour analysis assessment to the specified bridge project folder in PW.
3. An individual Bluebeam Session will be created for each bridge and a link to the Bluebeam session will be sent to each reviewer.
4. Each completed bridge scour analysis assessment will be reviewed by the lead consultant; if there are no comments, the lead consultant will send the BlueBeam Session to the SCDOT HDSO. If there are comments, the bridge scour analysis assessment will be sent back to the Non-Lead Consultant for revisions/responses to comments. This cycle will be repeated until all comments are resolved.
5. The SCDOT HDSO will either accept or reject the completed bridge scour analysis assessment. If accepted, the completed bridge scour analysis assessment will be placed in the specified PW bridge file. If rejected, the completed bridge scour analysis assessment will cycle back through until it is accepted by the SCDOT HDSO.

As shown in **Figure 25**, the lead consultant will adhere to the following process for the Quality Control/Quality Assurance process required for each bridge scour analysis assessment:

1. Each completed bridge scour analysis assessment will be placed in the specified ProjectWise (PW) folder by the lead consultant.
2. The lead consultant will move each completed bridge scour analysis assessment to the specified bridge project folder in PW.
3. An individual Bluebeam Session will be created for each bridge and a link to the Bluebeam session will be sent to the reviewer.
4. Each completed bridge scour analysis assessment will be reviewed by a non-lead consultant; if there are no comments, the BlueBeam Session is sent to the SCDOT HDSO. If there are comments, the bridge scour analysis assessment will be sent back to the Lead Consultant for revisions/responses to comments. This cycle will be repeated until all comments are resolved.
5. The SCDOT HDSO will either accept or reject the completed bridge scour analysis assessment. If accepted, the completed bridge scour analysis assessment will be placed in

the specified PW bridge file. If rejected, the completed bridge scour analysis assessment will cycle back through until it is accepted by the SCDOT HDSO.

Quality Assurance will be coordinated through Bluebeam Revu Studio sessions. Bluebeam Studio Sessions provide a platform for designers, reviewers, HDSO to provide comments, comment responses, revisions, and approvals on PDF documents. This application provides a streamlined process in order to consolidate tracking the status of comments, responses, and revisions made in subsequent file submittals. At the completion of the review and approval process, Bluebeam Revu produces a log of the comments and responses that can be stored in the Bridge File along with the approved document. Quality Assurance reviews will primarily be based on the Scour Study in PDF format, so all information used to develop the analysis should be well documented in the report. All supporting documentation will be available to the Quality Assurance reviewer, if it is deemed necessary to resolve a discrepancy.

Items to be completed during the Quality Assurance review are:

- Confirm required Quality Control spreadsheets are complete, including checker's initials/signature
- Confirm review comments spreadsheets are complete and up to date
- Confirm submittal package follows required guidelines and format for documentation

If the Quality Assurance process, as detailed in the flow chart shown on the previous page, reveals an issue with the Quality Control documents, the Lead Consultant will provide comments within 10 days of receipt of the submittal. The Non-Lead Consultant shall provide responses within 10 days of receipt of comments.

Figure 24: Quality Control/Quality Assurance Process for the Non-Lead Consultants

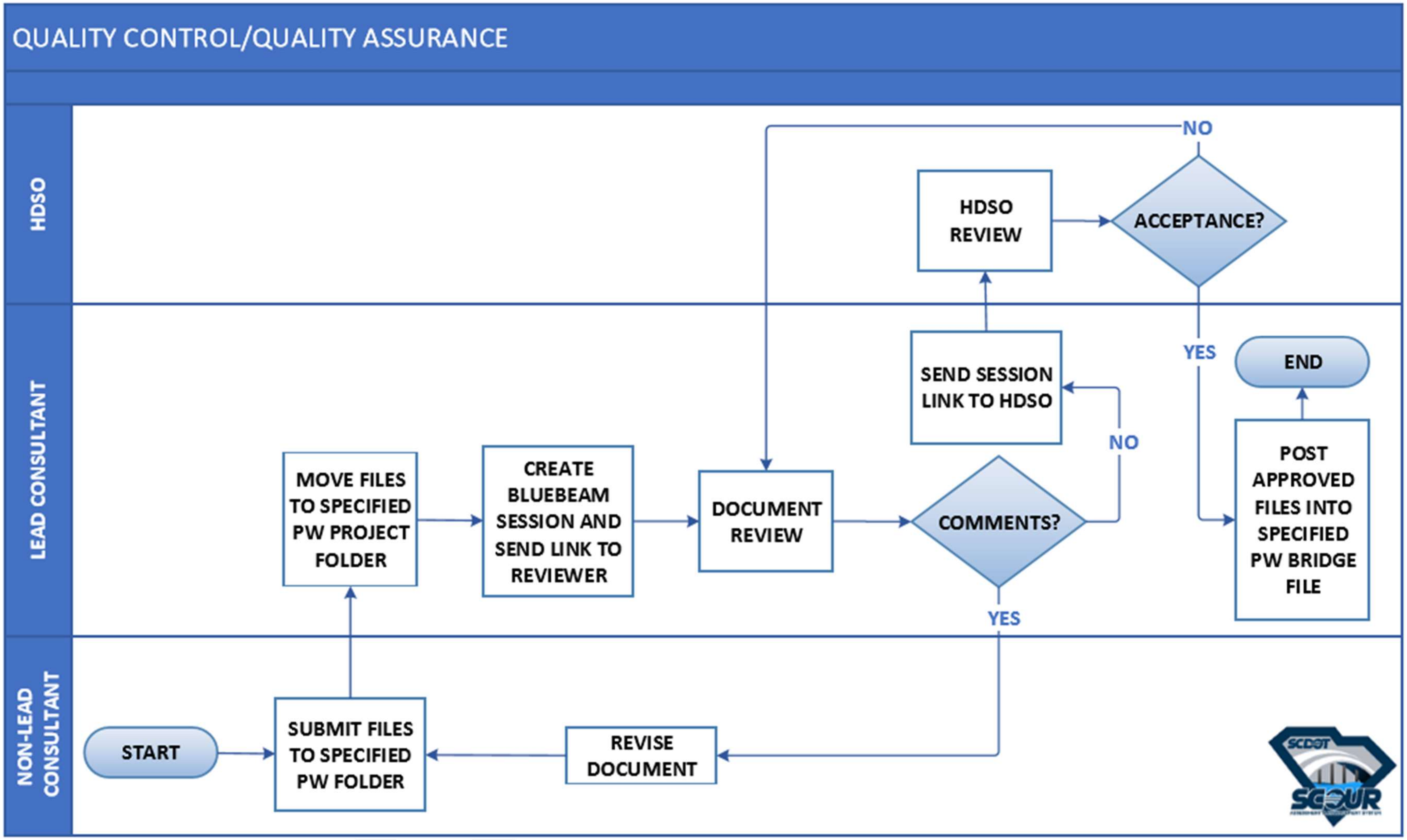
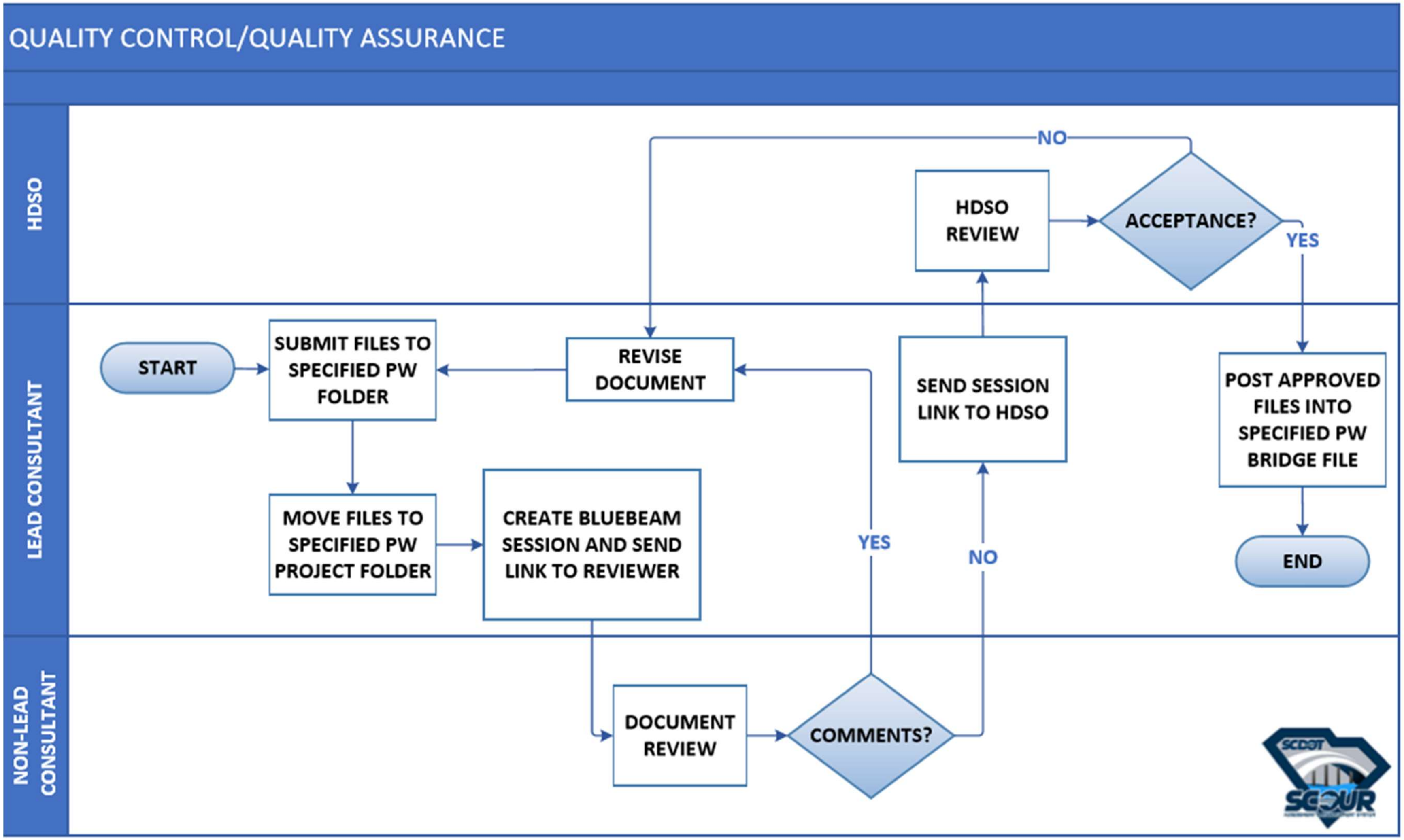


Figure 25: Quality Control/Quality Assurance Process for the Lead Consultant



7.3.1 BridgeWatch

BridgeWatch is a proprietary, web-based bridge scour monitoring system that can be implemented statewide. This system can integrate USGS stream gauges, NEXRAD rainfall data, as well as other sources of hydrologic warning data such as in situ scour monitoring equipment, ALERT2 data, and more. The SCDOT Scour Project will integrate the data developed into the BridgeWatch system to monitor storms exceeding a pre-determined threshold for discharge, rainfall, or other measurable metric. This will allow SCDOT to prioritize scour critical bridges and implement POA in a timely manner, when necessary.

[This section is a placeholder for how the scour project will interface with BridgeWatch]

Table 10: QC and QA Responsibilities

ACTION ITEM	LEAD CONSULTANT	NON-LEAD CONSULTANTS
Perform quality control review of all computations prepared by your Firm in accordance with the guidelines and checklists in Section 7.2, in addition to any procedures required by Consulting Firm's internal QA/QC processes.	X	X
Submit files to Projectwise folder for QA check per Section 7.3.	X	X
Move submitted files to the project folder and create a Bluebeam session for reviewer per Section 7.3.	X	
If the Quality Assurance process reveals an issue with the Quality Control documents as detailed in Section 7.3, provide comments within 10 working days of receipt of the submittal.	X	
Provide responses to any QA comments received within 10 working days of receipt of comments.		X
Once all QA comments are resolved (per Section 7.3), provide Bluebeam session link to HDSO.	X	
Once a scour study is accepted by the HDSO, post approved files in the Bridge File on Projectwise.	X	

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Section 8. Item 113 Coding

8.1 Purpose

All scour studies will include Item 113 evaluation for bridges – see **Table 11**. All bridges will be evaluated for scour by a hydraulic engineer. Geotechnical and structural bridge engineers may be consulted as deemed necessary. Bridges will be coded for scour vulnerability using the following criteria:

- Single Span Bridges:
  - Single span bridges with riprap in good condition: Item 113=8

Figure 26: Single Span Bridge

- Pile Foundations:
  - 10 feet or greater penetration below calculated scour: Item 113=8
  - Between 5 feet and 10 feet penetration below calculated scour: Item 113=5
  - Less than 5 feet of penetration below calculated scour: Item 113=3

- Bridges with Unknown Foundations:
  - Foundation Type of Bridge is Unknown: Item 113=U
  - Since the foundation type is unknown, it is impossible to evaluate the bridge for its scour vulnerability using conventional analysis methods. Therefore, each of these bridges must have an individual POA developed for it.

- When a bridge is founded on timber piles in the Piedmont and Blue Ridge regions of the State, the timber foundations are scour critical when the depth to rock is less than 5 feet. Because this is known to be a common condition in this region, a scour study is not required to assign the scour code (Item 113 = 3) under these conditions; but a POA is required.

Table 11: NBI Item 113 Scour Codes

Code	Description
N	Not over waterway
U	Unknown Foundation.
T	Tidal. Not evaluated. Low Risk.
9	Foundations above Floodwater.
8	Foundations Stable. Scour above top of footings.
7	Countermeasures Installed.
6	Scour study not performed.
5	Foundations Stable. Scour within the limits of footings or piles.
4	Foundations Stable. Action required to protect exposed foundations.
3	Scour Critical. Scour within footings or piles. Foundations Unstable.
2	Scour Critical. Scour observed. Foundations Unstable.
1	Scour Critical. Failure eminent. Bridge Closed.
0	Scour Critical. Bridge failed. Bridge Closed.
99	Mis-coded

<u>Code</u> <u>Description</u>

N Bridge not over waterway.

U Bridge with "unknown" foundation that has not been evaluated for scour. Until risk can bedetermined, a plan of action should be developed and implemented to reduce the risk to users from a bridge failure during and immediately after a flood event (see HEC 23).

T Bridge over "tidal" waters that has not been evaluated for scour but considered low risk. Bridge will be monitored with regular inspection cycle and with appropriate underwater inspections until an evaluation is performed ("Unknown" foundations in "tidal" waters should be coded U.) **Code 'T' is no longer used.**

9 Bridge foundations (including piles) on dry land well above flood water elevations.

8 Bridge foundations determined to be stable for the assessed or calculated scour condition. Scour is determined to be above top of footing (Example A) by assessment (i.e., bridge foundations are on rock formations that have been determined to resist scour within the service life of the bridge), by calculation or by installation of properly designed countermeasures (see HEC 23).

7 Countermeasures have been installed to mitigate an existing problem with scour and to reduce the risk of bridge failure during a flood event. Instructions contained in a plan of action have been implemented to reduce the risk to users from a bridge failure during or immediately after a flood event.

6 Scour calculation/evaluation has not been made. (Use only to describe case where bridge has not yet been evaluated for scour potential.)

5 Bridge foundations determined to be stable for assessed or calculated scour condition. Scour is determined to be within the limits of footing or piles (Example B) by assessment (i.e., bridge foundations are on rock formations that have been determined to resist scour within the service life of the bridge), by calculations or by installation of properly designed countermeasures (see HEC 23).

4 Bridge foundations determined to be stable for assessed or calculated scour conditions; field review indicates action is required to protect exposed foundations (see HEC 23).

3 Bridge is scour critical; bridge foundations determined to be unstable for assessed or calculated scour conditions:

- Scour within limits of footing or piles. (Example B)
- Scour below spread-footing base or pile tips. (Example C)

2 Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations, which are determined to be unstable by:

- a comparison of calculated scour and observed scour during the bridge inspection, or
- an engineering evaluation of the observed scour condition reported by the bridge inspector in Item 60.

1 Bridge is scour critical; field review indicates that failure of piers/abutments is imminent. Bridge is closed to traffic. Failure is imminent based on:

- a comparison of calculated and observed scour during the bridge inspection, or
- an engineering evaluation of the observed scour condition reported by the bridge inspector in Item 60.

0 Bridge is scour critical. Bridge has failed and is closed to traffic.

99 Miscoded data

[Placeholder for 113 recoding process] On the coversheet below, Item 113 is listed from the latest inspection date. At the end of the assessment process, it may be revealed that the current rating for 113 needs to be updated. Under this circumstance, the following steps should be taken:

1. Contact HDSO
2. Submit a … <rating revision form>
3. Coordinate with HDSO through final approval process>

Each Asset ID will have a Scour Summary Coversheet on file. The purpose of the coversheet is to provide HDSO and other Hydraulic Engineers a snapshot of the scour status of the bridge based on the key information found in the Scour Assessment Report. The coversheet also acts as a quick reference for SCDOT Bridge maintenance staff to use during routine inspections and provide a means to communicate vital inspection information back to HDSO. See Figure 26 for the Cover Sheet.

Figure 27: SCDOT Scour Summary Cover Sheet

SCDOT SCOUR SUMMARY COVER SHEET

Version 1.1
Rev 4/20/21

To Clear Out contents of cells with dropdown menus, select the cell, and then press DELETE

Page 1

SECTION 1 - GENERAL BRIDGE DATA

(8) Asset ID	SC Bridge ID	(27) Year Built	Inspection Cycle (months)	POA On File	(113) Scour Code
(6) Feature Intersected	Route Type	(7) Facility Carried	Underwater Insp. Cycle (months)		
(2) District	(3) County	(22) Bridge Owner	(11) Milepoint	(13) LRS	
(16) Latitude	(17) Longitude	Bridge or Culvert	(45) # of Main Unit Spans	(46) # of Approach Spans	
(49) Length (ft)	(34) Skew Angle (deg)	(52) Deck Width (ft)	Foundation Type (Channel)	Foundation Type (Overbank)	
(43A) Structure Kind	(43B) Structure Type	Abutment Type	(61) Channel Protection	(71) Waterway Adequacy	

SECTION 2 - BRIDGE OBSERVED CONDITION (From Site Visit for Scour Study/POA)

Abutment Protection Condition	Channel Bank Erosion	Embankment Erosion	Aggradation/Degradation
Channel Migration	Flow Damage to Bridge Elements	Debris Present	Sediment Deposits Present
Observed Channel Protection	Countermeasures Present	Countermeasure Condition	Maintenance Repair

SECTION 3 - HYDRAULIC DATA

	Riverine		Tidal	
Drainage Area (sq mi)	Q (Design) (cfs)	Q (1% AEP) (cfs)	1% AEP Stillwater Elevation	1% AEP Velocity (fps)
	Velocity (Design) (fps)	1% AEP Velocity (fps)	0.2% Stillwater Elevation	0.2% AEP Velocity (fps)
FEMA Zone	Design HW Elevation	1% AEP HW Elevation	MHHW Elevation	MLLW Elevation
	Highest HWM Elevation	Overtopping Q (cfs)	Max Wave Height for 1% AEP	Max Wave Crest El. for 1% AEP

SECTION 4 - SCOUR DATA (FROM DESIGN STUDY)

Physiographic Region	Hydraulic Model Used	Geometric Contraction Ratio (m)	Longterm Scour	Pier Scour
Riverine / Tidal	Scour Study on File	Soil Type	Abutment Scour	Critical Scour Tapedown (Channel)
Scour Method Used		Benchmark for Scour Depth	Contraction Scour	Critical Scour Tapedown (Overbanks)

SECTION 5 - ASSUMPTIONS AND TRIGGERS (Completed by Hydraulic Engineer)

Assumptions N/A Structure Comment Waterway Comment Streambed Comment	Comments
Coding Change Triggers N/A Change in Bridge Opening Change in Waterway Change in Streambed Change in Waterway Use (i.e.Mining) Exposed Footings New Bridge	Comments
Triggers for New Study N/A Change in Bridge Opening Change in Waterway Change in Streambed Change in Waterway Use (i.e.Mining) New Bridge	Comments
Triggers for Updated POA N/A Change in Countermeasure Change in Monitoring System Change in Detour Route Change in ADT/Road Class New Bridge New Scour Study	Comments
Other Observations	Comments

SECTION 6 - SIGNATURES

Hydraulic Engineer		Quality Control Engineer		HDSO Engineer	
Name:		Name:		Name:	
Company/Title:		Company/Title:		Company/Title:	
Date:		Date:		Date:	

ITEM 113 RECODING FORM

BRIDGE DATA			
Asset ID		**Structure Number**	
County		**Facility Carried**	
Waterbody		Skew Angle	
Bridge Length		Bridge Width	
Year Built		Span Arrangement	
Longitude		Pier Size (ft)	
Latitude		Pier Shape	
Abutment Type		Roadway Alignment	
Previous coding	*##*	**Recommended Coding**	*##*

REASON FOR RECODING

SCOUR STUDY ON FILE?	*Yes/No*	**NEW STUDY?**			*Yes/No*		
POA ON FILE?	*Yes/No*	**POA STATUS**					
		New	*Yes/No*	**Modified**	*Yes/No*	**Retired**	*Yes/No*

Please include Edits to Summary Coversheet with submittal of this form

Certification: *This assessment was performed in accordance with SCDOT Scour Analysis for Existing Structures, Jan 2021.*

Prepared By:	Initials:	Date:
Checked By:	Initials:	Date:
Approved By:	Initials:	Date:

1

Table 12: Item 113 Coding Responsibilities

Action Item	Lead Consultant	Non-Lead Consultants
Assigned bridges will be coded and evaluated for scour vulnerability using the criteria in Section 8.1.	X	X
Complete SCDOT Scour Summary Cover Sheet for each bridge.	X	X

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Section 9. Plan of Action

9.1 Purpose

All bridges coded as *scour critical* , an nondesigned/non-properly constuctioned scour countermeasure (code 7), or as *unknown foundation* will be required to have a Plan of Action (POA) developed. The POA will provide guidance for owners, inspectors, and engineers that has the capability of being implemented for scour critical bridges before, during, and after flood events to protect the traveling public. The POA may include the use of bridge countermeasures or bridge monitoring. A calculated flood elevation from the scour investigation will trigger bridge monitoring or bridge closure. Every bridge will be reevaluated before reopening after every major flood event.

Plans of Action will be prepared by the engineer using the appropriate category as shown in **Table 13**. This table and guidance document are in draft status.

Table 13: POA Categories

Bridge Category	Relative Fragility	Relative Consequence	POA Variance
Category A: Vital	Low to High	High	Full POA
Category B: Extreme	High	Low to Moderate	Quick Closure POA
Category C: Severe	Moderate	Low to Moderate	Monitoring POA
Category D: Moderate	Low	Low to Moderate	Abbreviated POA

Guidance on the selection of the appropriate POA category and details of the POA contents are found in the Guidance Manual ***Plans Of Action For Scour Critical Bridges***, prepared by Ayres Associates (2021) for SCDOT.

Guidance on selection of the appropriate bridge monitoring methodologies are found in the Guidance Manual ***Monitoring Guidance for Scour Critical Bridges***, prepared by AECOM (2021) for SCDOT.

ADD BRIDGEWATCH DISCUSSION HERE

9.2 Plan of Action (POA) Examples

9.2.1 POA for Scour Critical Bridges

An example of an existing POA for a bridge located in Abbeville County deemed to be scour critical (scour rating code=3) is provided on the following page. This form has been replaced with the specific Categorical POA Form (the Category A POA Form is shown in **Figure 28**).

Figure 28: POA for Scour Critical Bridges Form

SCDOT South Carolina Department of Transportation

Plan of Action (POA) for Scour Critcal Bridges

County		Route No	Stream Crossing	Location
2	1	SC 28	CALHOUN CREEK	2.9 MI N W ABBEVILLE

Bridge ID	Latitude			Longitude			Sufficiency Rating	ADT	Truck ADT	Year ADT	Detour
0140002800200	34	12	28	82	24	53	99.4	2700	6	2011	3

Scour Rating	Foundation Type	Foundation Soil Type
3		

Bridge Programed For Replacement	Length of Structure Improvement	Bridge Cost	Roadway Cost

Total Project Cost:

Inspection and Monitoring:

Inspection Frequency: 24

Inspection Type:

Inspection Criteria: High water event when water surface exceeds bank full flow.

Criteria For Closure: Bridge should be monitored during high water event. Bridge should only be closed if debris accumulates on piles or settlement occurs at bent locations.

Criteria For Reopening: Bridge to be inspected after high water event. Countermeasures to be evaluated if needed.

Countermeasures:

Countermeasures Recommended:

Cost: Status:

Countermeasures Approved: Signature:

Date Completed: Signature:

Responsibility For POA:

Author of POA: Date of POA: #Name?

POA Updated By: Date POA Updated:

Items Updated:

POA Update Frequency: Date of Next Update:

9.3 Plan of Action (POA) Form

As discussed in Section 9.1, Guidance on the selection of the appropriate POA category and details of the POA contents are found in the Guidance Manual ***Plans Of Action For Scour Critical Bridges***, prepared by Ayres Associates (2021) for SCDOT.

9.3.1 Category A POA Form

Each of the four POA Categories has a designated POA form with detailed instructions for the engineer to populate the form completely and correctly. Each of the four forms are found in the Guidance Manual ***Plans Of Action For Scour Critical Bridges***, prepared by Ayres Associates (2021) for SCDOT. The POA form for Category A: Vital Scour Critical Bridges is provided for information in Figure 29. Please reference the Guidance Manual ***Plans Of Action For Scour Critical Bridges***, prepared by Ayres Associates (2021) for SCDOT.

Figure 29: POA for Category A Vital Scour Critical Bridges Form

CATEGORY A PLAN OF ACTION FOR VITAL SCOUR CRITICAL BRIDGES

South Carolina Department of Transportation

Version 1.0

SECTION 1 - GENERAL INFORMATION

Asset ID Number:	Bridge Structure Number:	County:	Stream Crossing:	Facility Carried:
District:	Latitude:	Longitude	Mile Marker:	
Owner:	Year Built:	Year Rebuilt:	Bridge Replacement Plans (If Scheduled):	Anticipated Opening Date:
Structure Type:	Size and Description:	Bridge ADT:	Year/ADT:	% Trucks
Foundations (Known/Unknown):	Does bridge provide service to emergency facilities and/or evacuation route?:	Subsurface Soil Information		
Type: Depth:	POA Triggers for Inspections:			

SECTION 2 - RESPONSIBILITY FOR POA DEVELOPMENT AND CONTACT INFORMATION

POA Prepared by (name, title, agency/organization):

Scour Evaluation Team Members (name, title, agency/organization, telephone, pager, email):

POA Update Triggers:

Scour Study Update Triggers:

SECTION 3 - SCOUR VULNERABILITY

Current Item 113 Rating: ___ 3 / ___ 2 / ___ 1 / ___ Other Describe:	Source of Scour Critical Rating: ___ Observed / ___ Assessment / ___ Calculated / ___ Other:
Scour Evaluation Summary:	Scour History (Location, extent, depth of previous scour):
Current Measured Scour Depth and Tapedown Measurement: / Anticipated Scour Depth:	

SECTION 4 - RECOMMENDED ACTION(S) (SEE SECTIONS 6 AND 7)

	Recommended	Implemented
POA Triggered Inspection:		
Action Selection and Decision matrix:		
Increased Inspection Frequency:		
Fixed Monitoring Device(s):		
Flood Monitoring Program:		
Hydraulic/Structural Countermeasures:		

SECTION 5 - NBIS CODING INFORMATION

	Current	Previous
Inspection Date		
Item 113: Scour Critical		
Item 60: Substructure		
Item 61: Channel & Channel Protection		
Item 71: Waterway Adequacy		
Item 9381 Underwater Appraisal Raiting		

Comments: (drift, scour holes, etc. - depict in sketches in Section 10):

SECTION 6 - MONITORING PROGRAM

Diagram of Bridge (Include Design Scour, Foundation Information, and Inspection Tapedowns in Attatchment C)

POA/Flood Inspection

Items to Watch:

Triggers for POA Inspection:

Triggers for Flood Inspection:

Regular Inspection Program

Items to Watch:

Increased Inspection Frequency (mo.)

Item(s) to watch:

Flood Monitoring Device(s)

Instrument Type:

Installation Locations:

Sample Interval:

Frequency of download/review

Increased Underwater Inspection Frequency (mo.)

Item(s) to watch:

Scour alert elevation for each pier/abutment:

Scour critical elevation for each pier/abutment:

Flood monitoring program?

Inspection Type

Flood Monitoring Required?

Flood monitoring event defined by (document all that apply):

Discharge:

Stage:

Elev. measured from:

Rainfall: ___ (in / mm) per ___ (hour)

Flood forecasting information:

Flood warning system:

Post-flood monitoring required:

Frequency of post-flood monitoring:

Criteria for termination of flood monitoring:

Criteria for termination of post-flood monitoring:

Action(s) required if scour alert elevation detected (include notification and closure procedures for each pier/abutment):

Counter Measure Inspections (Items to Watch)

Agency and department responsible for monitoring:

Contact person (include name, title, telephone, pager, e-mail):

SECTION 7 - BRIDGE CLOSURE PLAN

Scour monitoring criteria for consideration of bridge closure:

___ Water surface elevation reaches ______ at______

___ Overtopping road or structure

___ Scour measurement results / Monitoring device (See Section 6)

___ Observed structure movement / Settlement

___ Discharge: ___ cfs/cms

___ Flood forecast:

___ Other (Describe):

Emergency repair plans (include source(s), contact(s), cost, installation directions):

Agency and department responsible for closure:

Contact persons (name, title, agency/organization, telephone, pager, email):

Agency and person responsible for re-opening the bridge after inspection:

Criteria for re-opening the bridge:

SECTION 8 - DETOUR ROUTE (Determined by District Maintenance Engineer)

Detour Route Number	Route From	Route To	Detour Length	Detour Signs
Bridge Number (Asset ID)	Waterway	Load Limitations	Item 113	Barriers

Additional Considerations/Issues:

Process for Selecting an Alternate Detour Route (BridgeWatch):

SECTION 9 - COUNTERMEASURE RECOMMENDATIONS

Maintaining Existing Countermeasures

List of Existing Countermeasures:	Repair options	Basis for Repair
1		
2		
3		

4		
5		

Monitoring and Closure

Applicability:	Trigger for New Countermeasures:

New Countermeasures

Preffered Countermeasures	Basic Data for Countermeasures	Project Process	Cost Data
1			
2			
3			
4			
5			

Design and Constriction Plans	As-Built Plans	Inspection Plans	Maintenance Plans	Agency and department responsible for countermeasure program:
Yes/No?	Yes/No?	Yes/No?	Yes/No?	
File No.	File No.	File No.	File No.	

Contact person (include name, title, telephone, pager, e-mail):

SECTION 10 - ATTACHMENTS

	Attachment A: Boring logs and/or other subsurface information		Attachment E: Map showing detour routes
	Attachment B: Cross sections from current and previous inspection reports		Attachment F: Photos
	Attachment C: Bridge elevation showing streambed, foundation depth, observed and/or calculated scour depths		Attachment G: Other information
	Attachment D: Plan view showing location of scour holes, debris, etc		

SECTION 11 - REMARKS

Inspector comments for historical flood information for determining triggers:

SECTION 12 - SIGNATURES

Hydraulic Engineer		Quality Control Engineer		HDSO Engineer	
Name:		Name:		Name:	
Company/Title:		Company/Title:		Company/Title:	
Date:		Date:		Date:	

Table 14: Plan of Action Responsibilities

Action Item	Lead Consultant	Non-Lead Consultants
All bridges coded as *scour critical* or as *unknown foundation* will have a Plan of Action (POA) developed.	X	X
For each bridge requiring a POA, the appropriate POA Form (A, B, C, or D) will be completed.	X	X