Advancements in Bridge Scour Evaluation with 2D Hydraulic and Sediment Transport Modeling

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Extended Abstract

As hydraulic modeling technology advances, FWHA strives to continue to improve the accuracy and efficiency of bridge scour evaluations through research, and improved methodology and application. The more accurate hydraulic results from two-dimensional (2D) hydraulic models, coupled with new tools implemented in the Surface Water Modeling System (SMS) that automatically extract the needed hydraulic parameters from multiple 2D flow simulations, offer a substantial improvement in the state of the practice in bridge scour evaluation. The recent developments in the SMS Bridge Scour Tools and FHWA Hydraulic Toolbox Bridge Scour Calculators utilize the 2D modeling results and generate summary tables and plots for the estimated total scour, providing a highly efficient and effective means of performing bridge scour analyses. Although the tools are not limited to a specific 2D model, the SRH-2D flow sediment transport model (Lai 2008; 2010; 2020), along with the SMS/SRH-2D user interface, have been adopted and widely used. This presentation includes examples to show that the tools are valuable to help verify contraction scour estimates and provide better insight for more complex hydraulic conditions, in addition to estimating the local scour due to bridge piers.

For many years, States and practitioners have computed bridge scour estimates primarily using one-dimensional (1D) hydraulic modeling results and for one or two design flood events, commonly the one percent chance of exceedance flow (100-year event) and/or the 0.2 percent chance of exceedance flow (500-year event). While this approach generally represents the state of practice to date, it does not adequately capture the worst-case scour for all scenarios. Site specific conditions, including downstream controls, roadway embankment overtopping, complex channel geometries, skewed approach flow, and other factors may cause the maximum total scour to occur at flows less than the specified peak floods. Consequently, it is prudent to evaluate a range of flow conditions to ensure that the worst-case scour condition is represented. This is consistent with FHWA's HEC-18 guidance (FHWA 2012), which states, "… special conditions (angle of attack, submerged-flow, decrease in velocity or discharge resulting from high flows overtopping approaches or going through relief bridges, ice jams, etc.) may cause a more severe condition for scour with a flow smaller than the overtopping or design flood." The need for practitioners to utilize 2D hydraulic modeling for better representation of site conditions and perform multiple hydraulic simulations and bridge scour analyses efficiently is evident.

1D hydraulic modeling results have been used to support bridge scour analyses for roughly 40 years, and although the methodology relies on copious hydraulic assumptions, until recent years 1D modeling has been the most effective tool available for these analyses. With the transition to 2D hydraulic modeling, advocated by FHWA, flow paths and flow directions can now be directly computed and visualized, rather than assumed, and more accurate representations of water surface elevation and flow/velocity distribution can be achieved using the 2D models. Additional parameters, such as the Critical Velocity Index (FHWA 2019) can also be computed with 2D model results to gain a better understanding of the sediment transport characteristics through a project reach. Although much of the current HEC-18 (FHWA 2012) bridge scour equations are still based on empirical equations and averaged hydraulic parameters, the superior representation of the flow characteristics with 2D hydraulic modeling offers an opportunity for improved accuracy, leading to improved bridge scour estimates.

Since current HEC-18 scour analyses rely on averaged hydraulic parameters, FHWA initiated the development of the Bridge Scour Tool in the SMS/SRH-2D user interface to support more efficient, consistent, and accurate total scour analyses. The user is prompted to define locations of the contracted section, approach section, bank stations, piers, and abutment toe locations. Additional attributes can be added for piers and abutments to define their type and geometry. The averaged hydraulic parameters required to compute scour in the main channel and overbanks are then automatically extracted from 2D model results and adjusted for skew and effective pier width, which are exported to a FHWA Hydraulic Toolbox file for scour analyses. The parameter values are also available to be copied to customized scour spreadsheets or similar tools. Channel and bridge geometry can also be extracted from the 2D model terrain and 3D bridge feature to compute the bridge pressure scour and generate a comprehensive total scour plot in the Hydraulic Toolbox.

The Hydraulic Toolbox has included bridge scour component calculators since 2012 and has recently been updated to support multiple concurrent flow conditions and scour computations. The values in the scour calculators are automatically populated with the values extracted from the 2D hydraulic simulation results, but it is still prudent for users to review all input and verify the values are complete and reasonable for contraction scour, pier scour, and abutment scour. The long-term degradation component of scour requires a separate site-specific channel stability assessment following the procedures outlined in HEC-20 (2012), with the degradation estimate being included in the total scour estimate. The auto-generated Bridge Scour Summary Table shows the computed scour elevation for each scour component as well as the total scour estimate. Bridge scour plots can be generated for each individual event or combined onto a single summary plot. The FHWA Hydraulic Toolbox is free to the public and the SMS Bridge Scour Tool is also available in a free community version of the SMS package. Regular training is also carried out for engineers to use these tools.

2D sediment transport modeling within SMS/SRH-2D can also be used to estimate long term degradation and contraction scour, but it cannot currently be used to evaluate local scour at piers or abutments. It is a valuable tool for verifying contraction scour estimates, as well as evaluating scour for complex hydraulic site conditions where the HEC-18 contraction scour equations may not be applicable (i.e., channel confluence at the bridge). A greater level of project site data is needed to better characterize sediment inflow and channel bed and substrate composition through the reach, but 2D sediment transport modeling can provide a more accurate representation of the scour conditions as well as more insight to the site conditions and resiliency of the project design. Sediment transport analyses will continue to play a greater role in bridge scour analyses as computational power increases and as ongoing research replaces current empirical methods with more direct shear and bed resistance approaches.

This presentation highlights advancements in the state of the practice for bridge hydraulic and scour analysis and emphasizes the best practices. Examples of extracting hydraulic parameters from 2D models for bridge scour analysis are demonstrated and compared with results of 2D sediment transport modeling. FHWA's goals for future development in bridge scour analyses are briefly noted.

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