Australian Water School

Advancements in Bridge Scour Assessment

April 10, 2024

Federal Highway Administration
RESOURCE CENTER
Office of Innovation Implementation

U.S. Department of Transportation
Federal Highway Administration

NATURAL WATERS

Image Source: Casey Kramer

Overview

- Resources for bridge scour analyses
- Bridge scour components
- Advancements in 2D hydraulic modeling
- Worst case scour concept
- Bridge scour assessment key considerations
- Common pitfalls in computing bridge scour
- Consistent method for computing bridge scour

Image Source: Casey Kramer

Resources for Bridge Scour Analyses

- HEC-18 (2012 5th Edition) – Evaluating Scour at Bridges
- HEC-20 (2012 4th Edition) – Stream Stability at Highway Structures
- HEC-23 Bridge Scour and Stream Instability Countermeasures (2009 3rd Edition) (Volume 1 and Volume 2)
- HDS-7 Hydraulic Design of Safe Bridges (2012)
- Austroads (2019)
- Two-Dimensional Hydraulic Modeling for Highways in the River Environment – Reference Document (2019)
- FHWA Bridge Scour Workshop (2022)
- WSDOT Scour Training (2023)

Bridge Scour Components – <u>Without</u> Potential of Lateral Migration

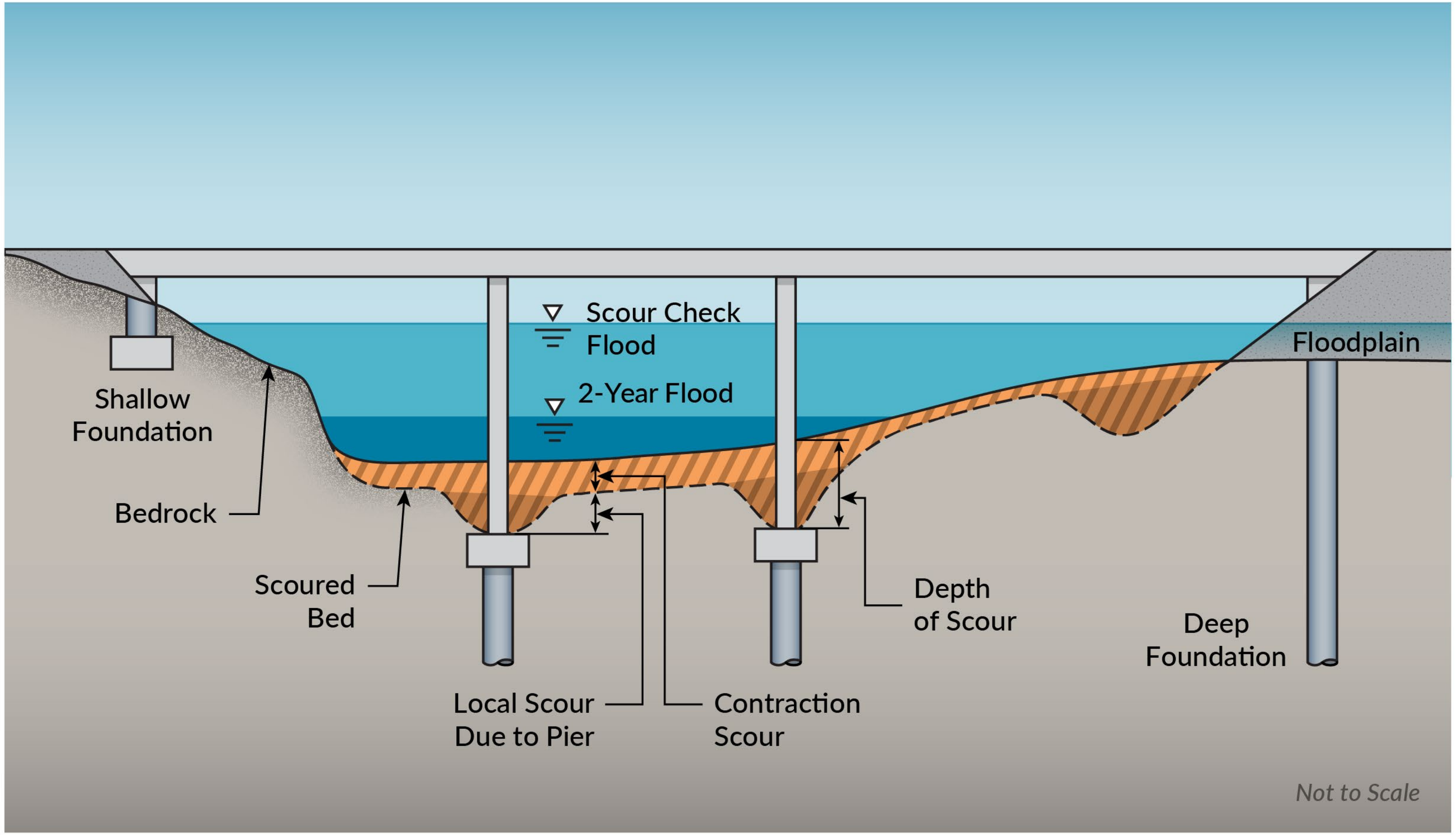


Image Sources: WSDOT

Bridge Scour Components – With Potential of Lateral Migration

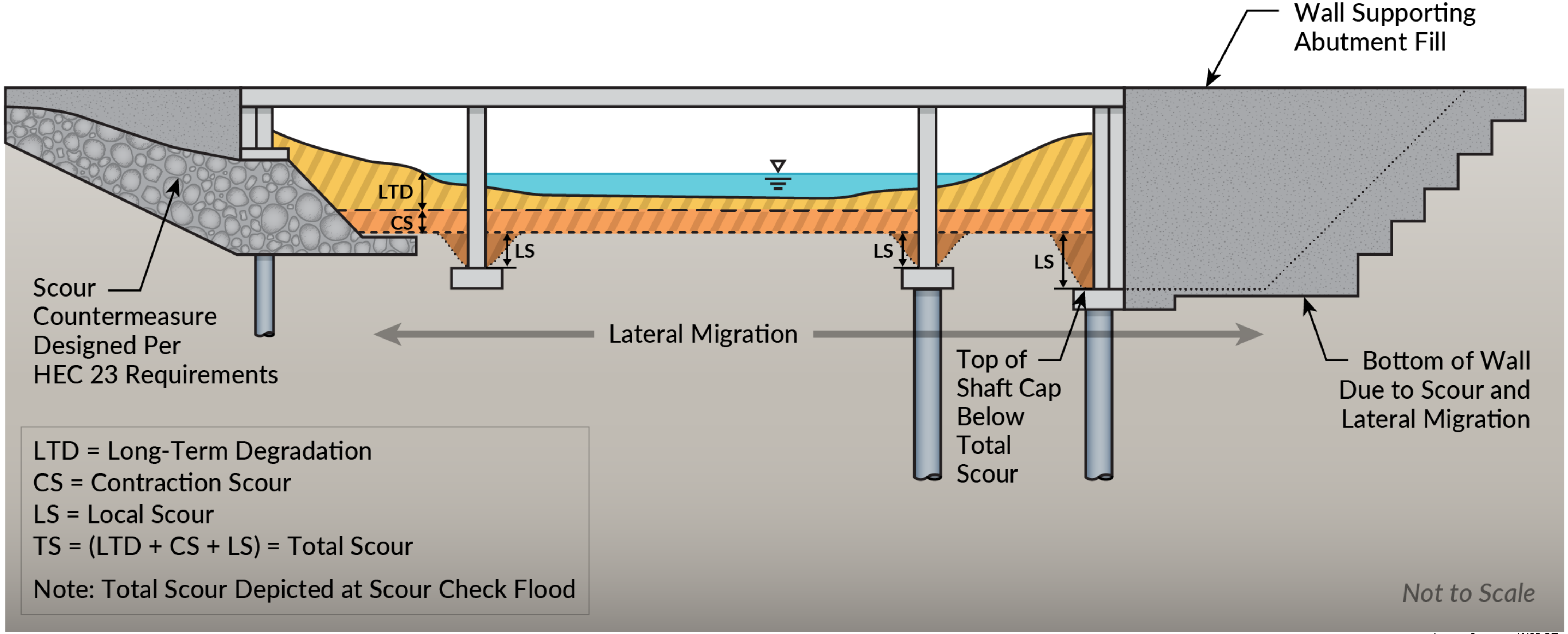


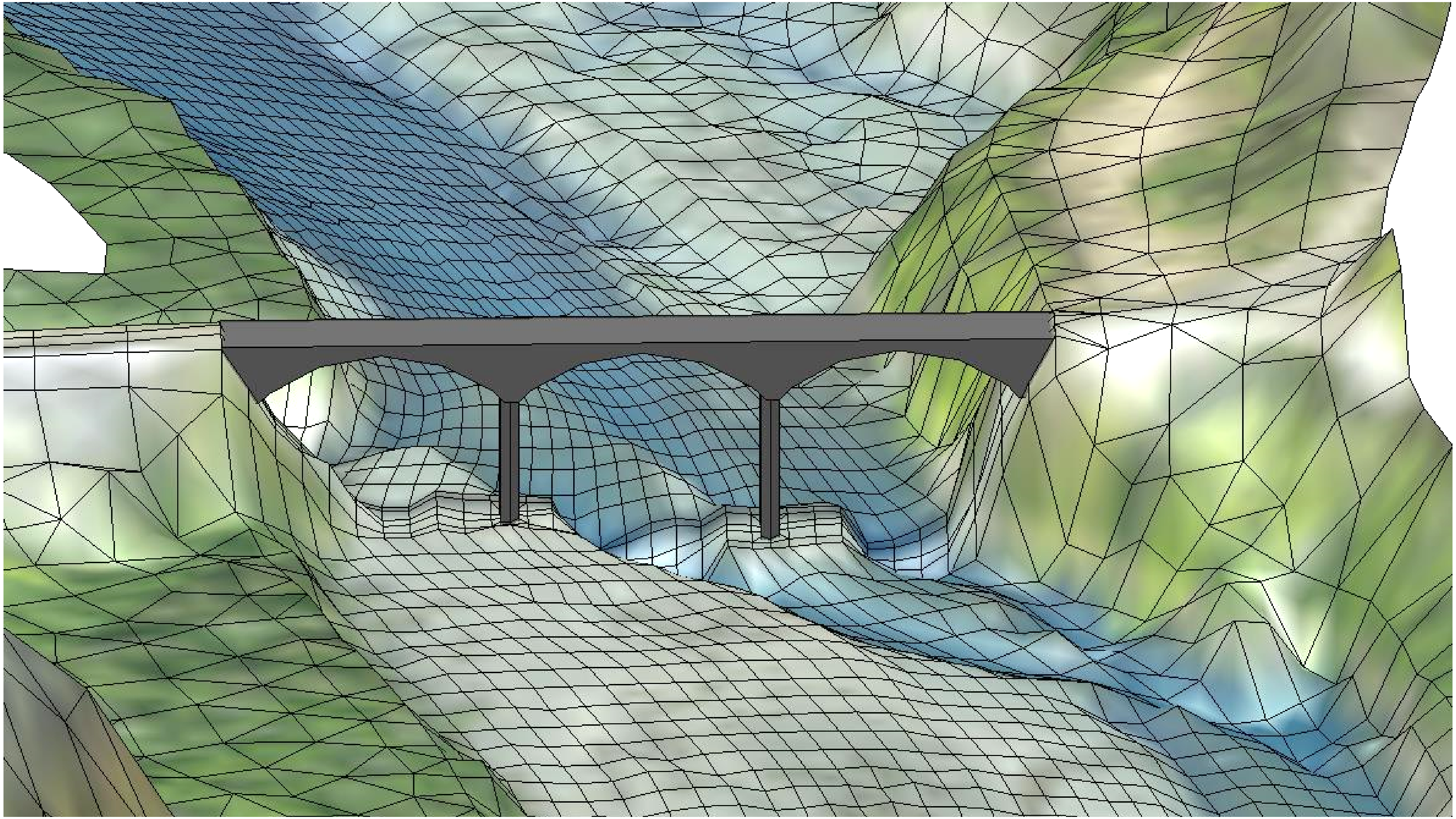
Image Sources: WSDOT

Advancements in 2D Hydraulic Modeling

Hydraulic Variables	1D Modeling	2D Modeling
Flow direction	**Assumed** by user	**Computed**
Flow paths	**Assumed** by user	**Computed**
Land use roughness	**Assumed** constant between cross sections	Roughness values at individual elements used in computations.
Ineffective flow areas	**Assumed** by user	**Computed**
Flow contraction and expansion through bridges	**Assumed** by user	**Computed**
Flow velocity	**Averaged** at each cross section	**Computed** at each element
Flow distribution	**Approximated** based on conveyance	**Computed** based on continuity and momentum
Water Surface Elevation	**Assumed** constant across entire cross section	**Computed** at each element
Flow splits	Based on **Averaged** constant Energy Grade Line	**Computed** based on continuity and momentum

Image Source: FHWA

Advancements in 2D Hydraulic Modeling



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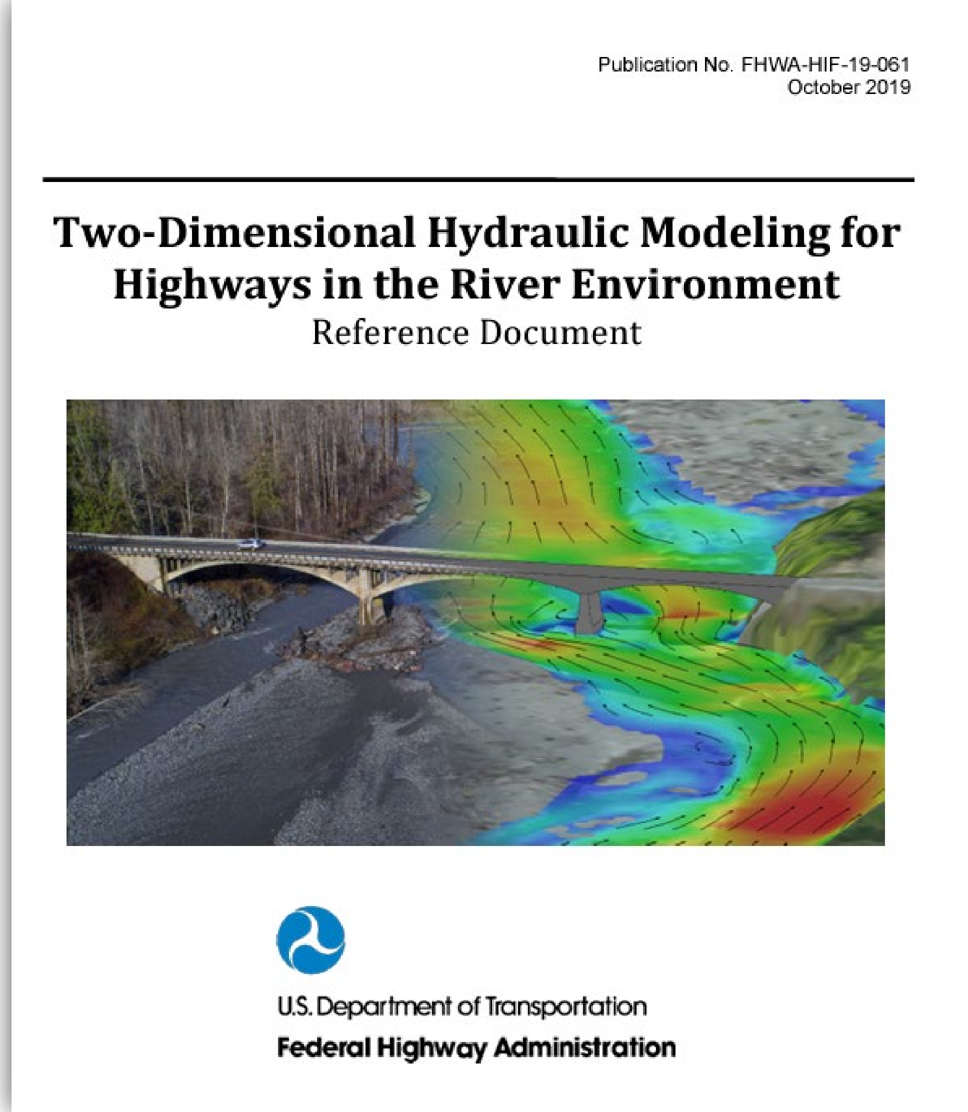
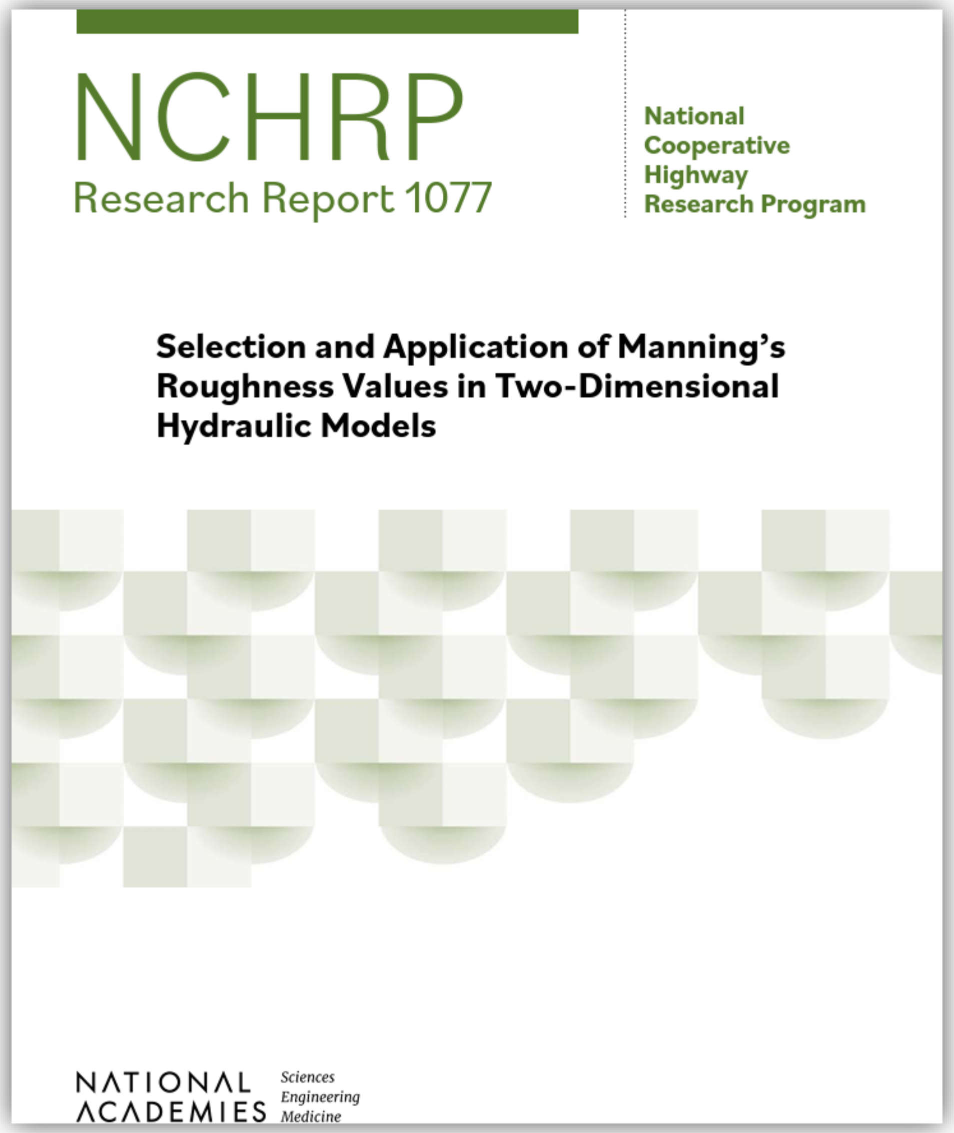
Advancements in 2D Hydraulic Modeling



https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif19061.pdf



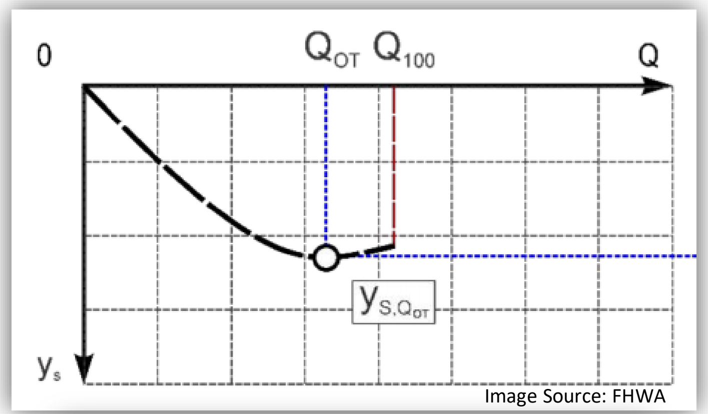
https://www.trb.org/Publications/Blurbs/183186.aspx

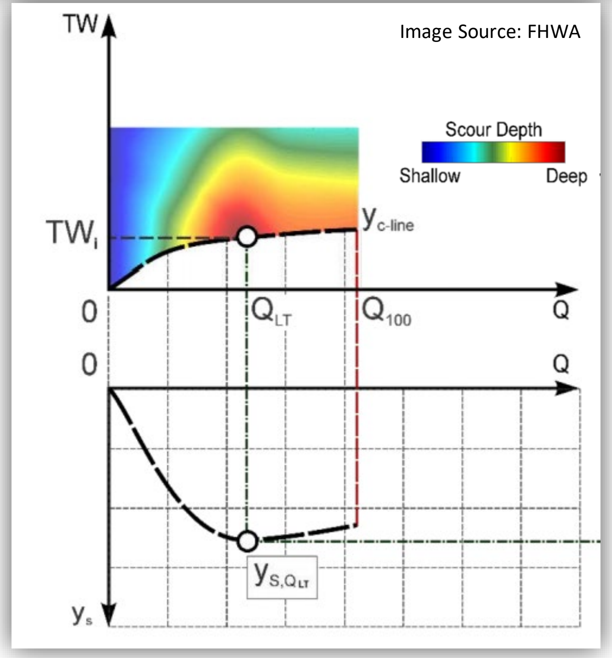
Worst Case Scour Concept

- **Austroads –** "The aim of bridge design should identify the flood event that produces the highest velocities and worst case."

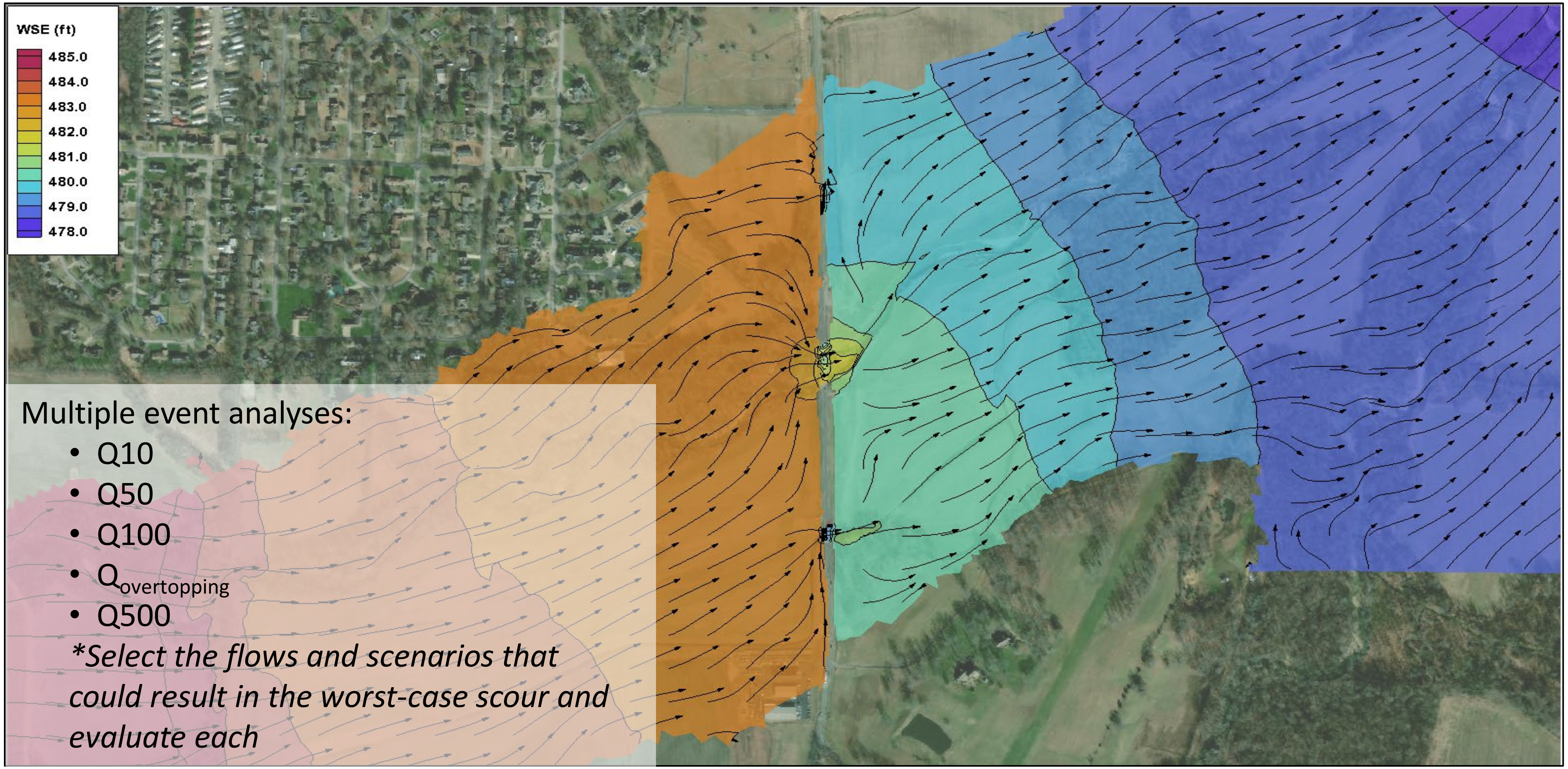
- **FHWA -** Worst Case Scour Depth – "The conditions (e.g., discharge, velocity, depth, tailwater, geometry, orientation, type of foundation, etc.) that would produce the maximum scour depth at a particular foundation element."

- **AASHTO**
  - Scour Design Flood – "A discharge of an annual probability of exceedance selected to estimate scour for the design and evaluation of the bridge foundation for strength, service, and Extreme Event I and II limit state events."
  - Scour Check Flood – "A discharge of an annual probability of exceedance selected to estimate scour for an evaluation of the bridge foundation for Extreme Event II limit state"





Worst Case Scour Concept



Multiple event analyses:

- Q10
- Q50
- Q100
- $Q_{overtopping}$
- Q500

**Select the flows and scenarios that could result in the worst-case scour and evaluate each*

Image Source: FHWA

Bridge Scour Assessment Key Considerations

- 2D hydraulic model
  - Sufficiently refined mesh and results
  - Possible worst case flood events
- Bed material gradation and sample locations
- Long term degradation and stream stability assessment
- Extraction of hydraulic variables (location, type, and adjustments for skew)
- Determination of live-bed vs. clear water scour

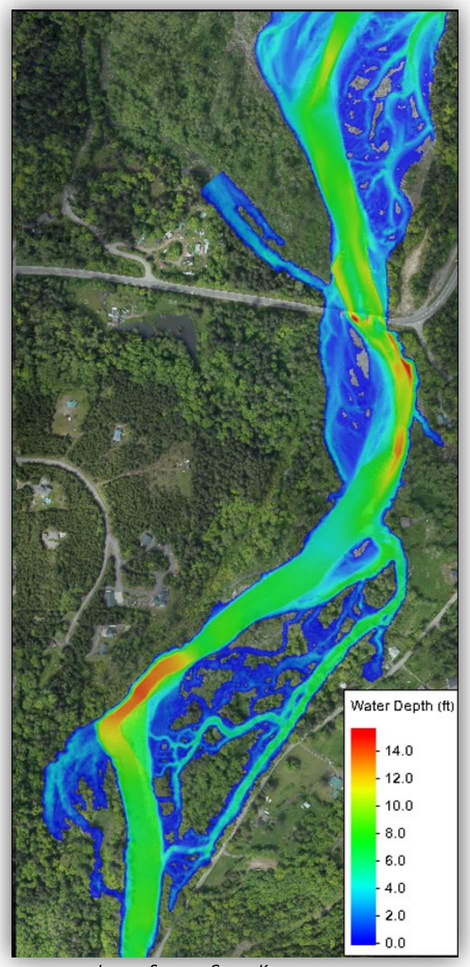


Image Source: Casey Kramer

Approach and Contracted Sections

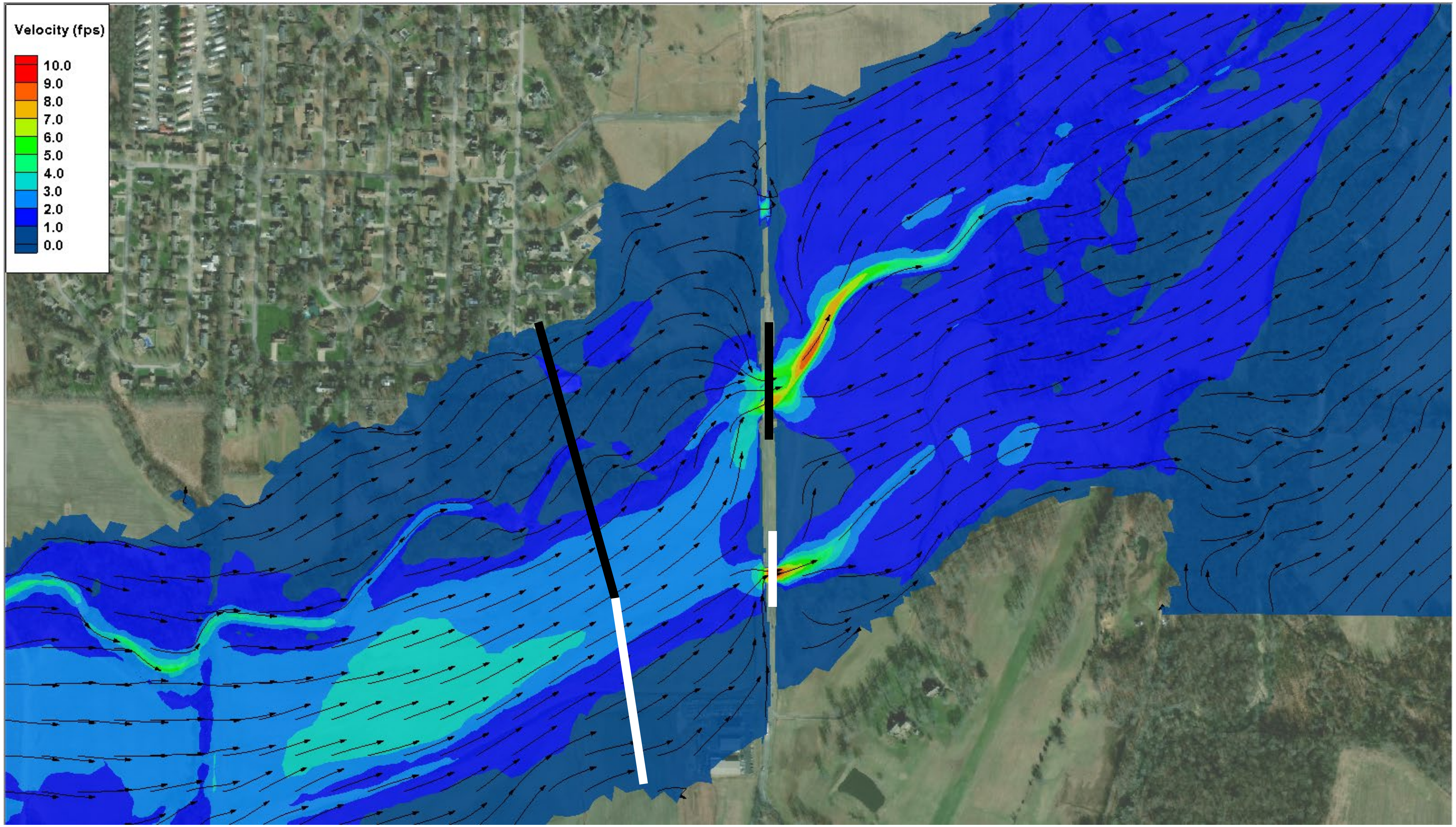


Image Source: FHWA

Bridge Scour Assessment Key Considerations

- Pier scour
  - Pier dimensions, orientation and angle of attack
  - Pier configuration and complex pier geometry
  - Location where depth and velocity values were extracted
  - Location of piers and potential for channel to migrate
- Abutment scour
  - Location of abutments relative to main channel
  - Channel migration potential
  - Application of NCHRP Method, Scour Condition A or B
  - Application of abutment scour depth to determine the scour elevation
- Total scour results review (Interdisciplinary review)

Image Sources: Casey Kramer

Velocity and Depth at Piers

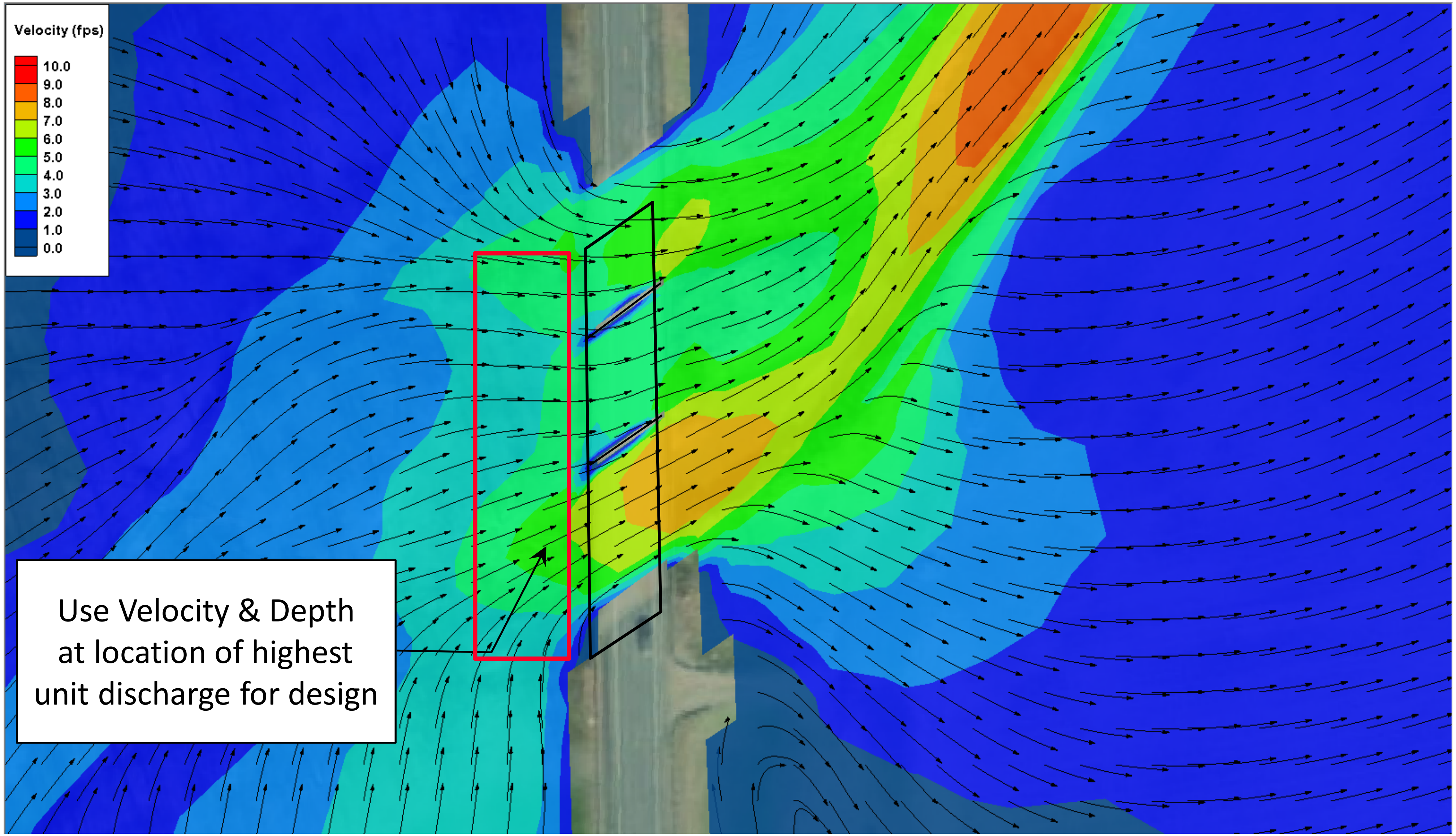


Image Source: FHWA

Common pitfalls in computing bridge scour

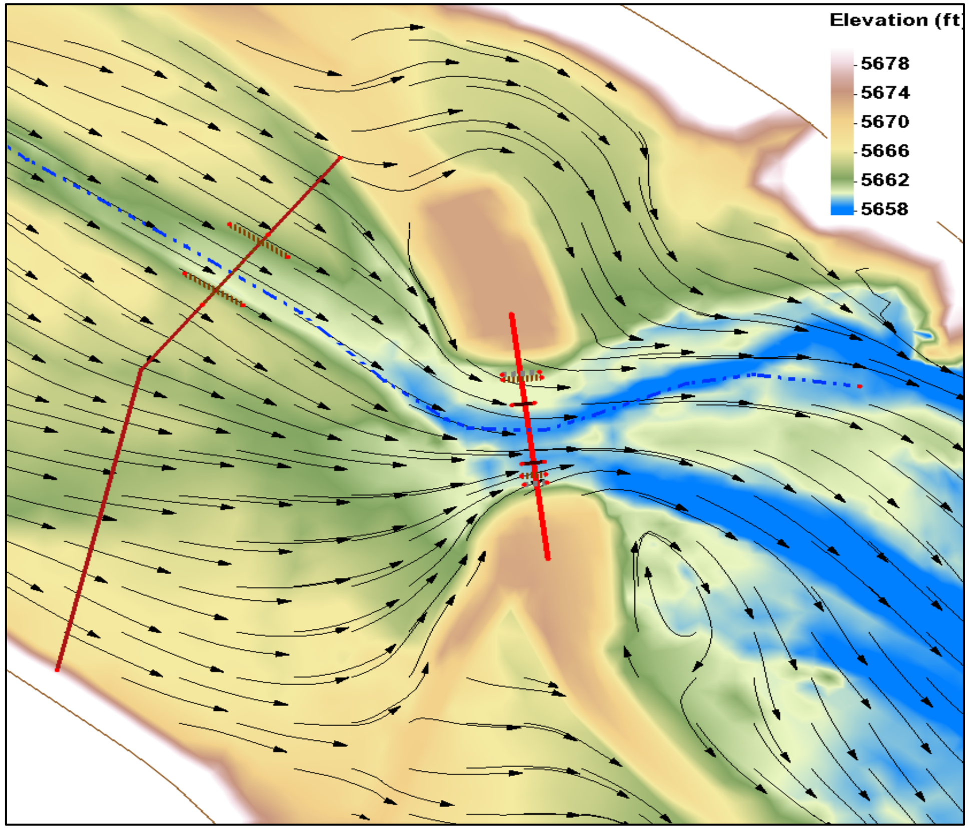
- Assuming hydraulic modeling results are good (without review)
- Missing the worse case scour condition
- Incorrectly locating the approach section for contraction scour
- Incorrectly defining the width of flow transporting sediment
- Misinterpreting a live-bed vs. clear water scour condition

Common pitfalls in computing bridge scour

- Mis-applying tributary inflow immediately upstream of bridge
- Using maximum hydraulic values for contraction scour rather than averaged values
- Not considering lateral migration potential
- Using insufficient or inaccurate gradation information
- Incorrectly interpreting scour depths to elevations

Consistent Method for Computing Bridge Scour

- SMS Bridge Scour Tool
- FHWA Hydraulic Toolbox



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FHWA Hydraulic Toolbox Version 5.3.0

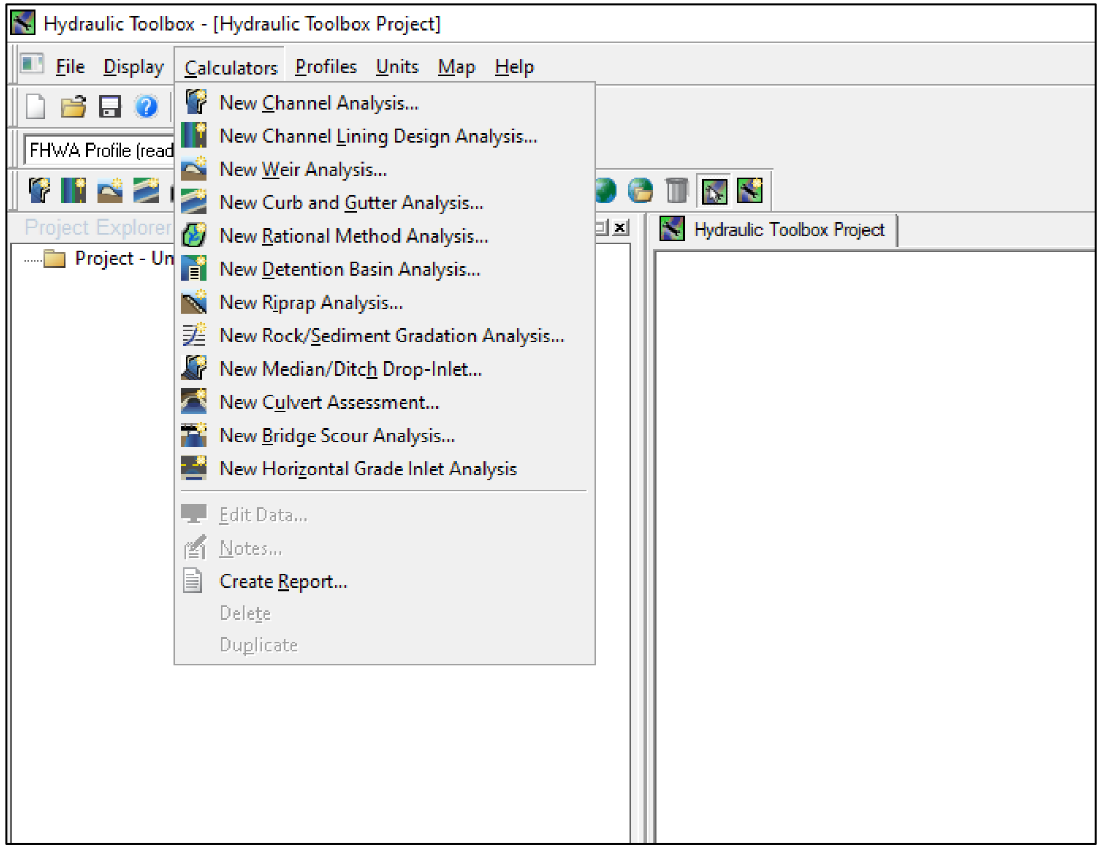


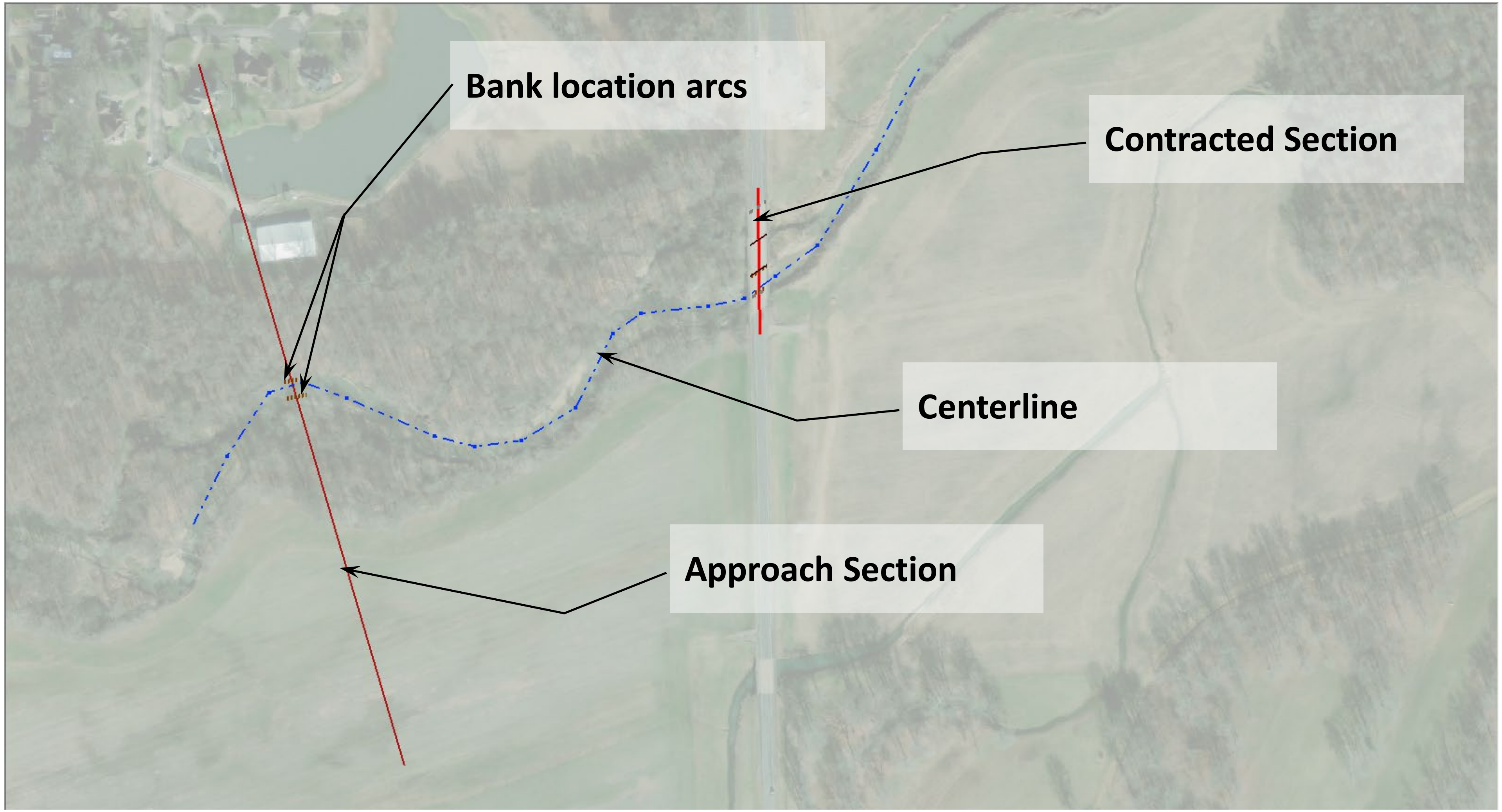
Image Source: FHWA

Bridge Scour Tool in SMS

Overview of steps:

- Create a Bridge Scour coverage in SMS
- Define the bridge scour arcs
- Define Bridge Scour coverage properties
- Compute and export hydraulic parameters to the Hydraulic Toolbox

Bridge Scour Arcs



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Bridge Scour Arcs

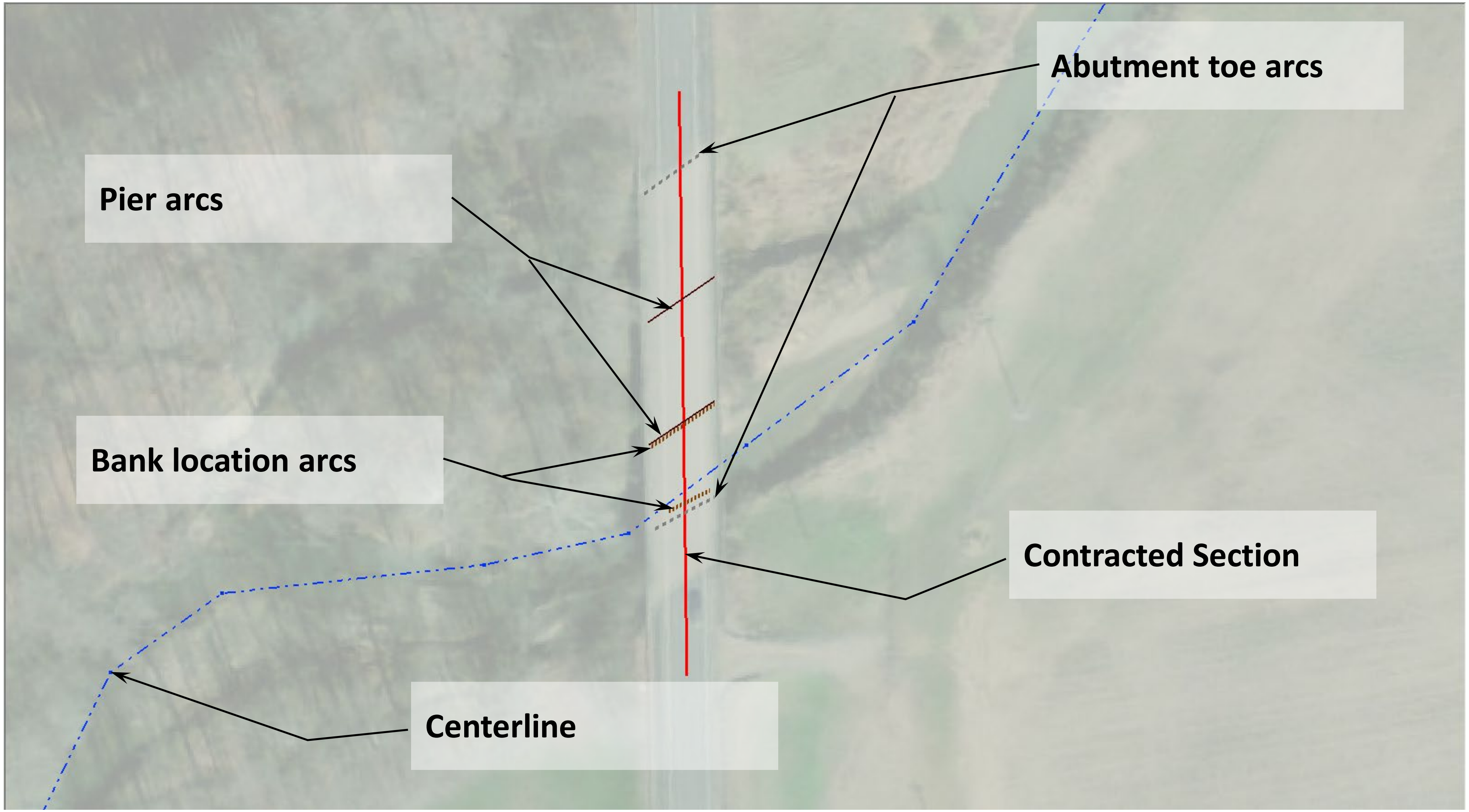


Image Source: FHWA

Bridge Scour Coverage Properties

- Approach arc attributes
  - Channel bed gradation
- Contraction arc attributes
  - Channel bed gradation
- Pier arc attributes
  - Pier shape and size
  - Bed condition
  - Elevation reference
- Abutment arc attributes
  - Abutment type

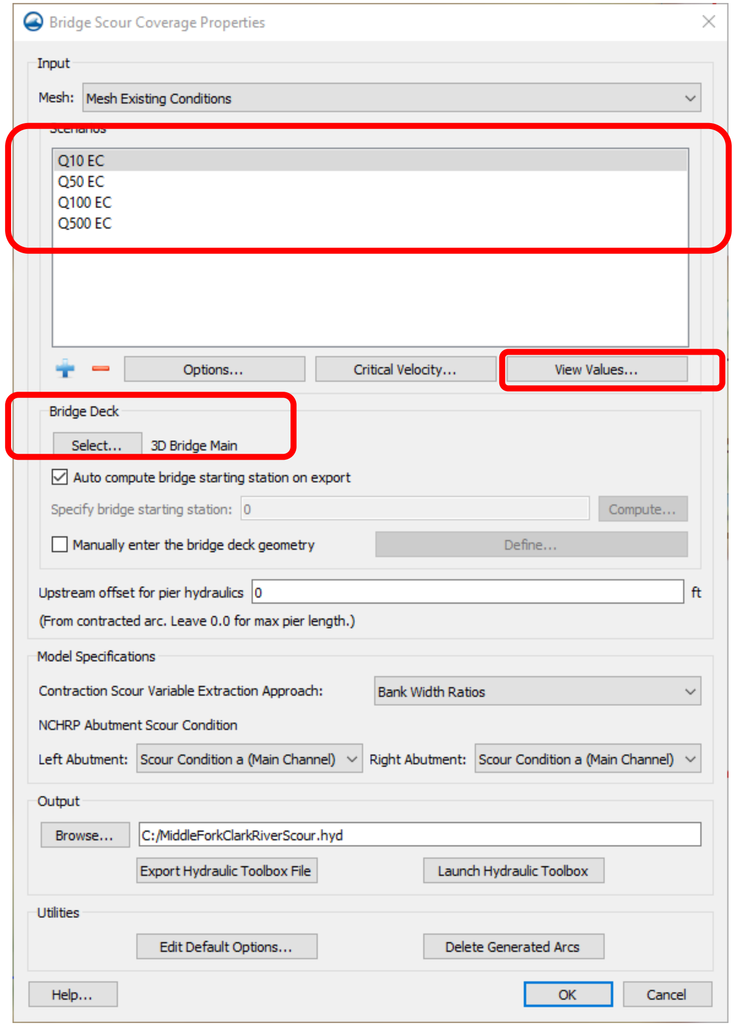


Image Source: FHWA

Hydraulic Toolbox Export

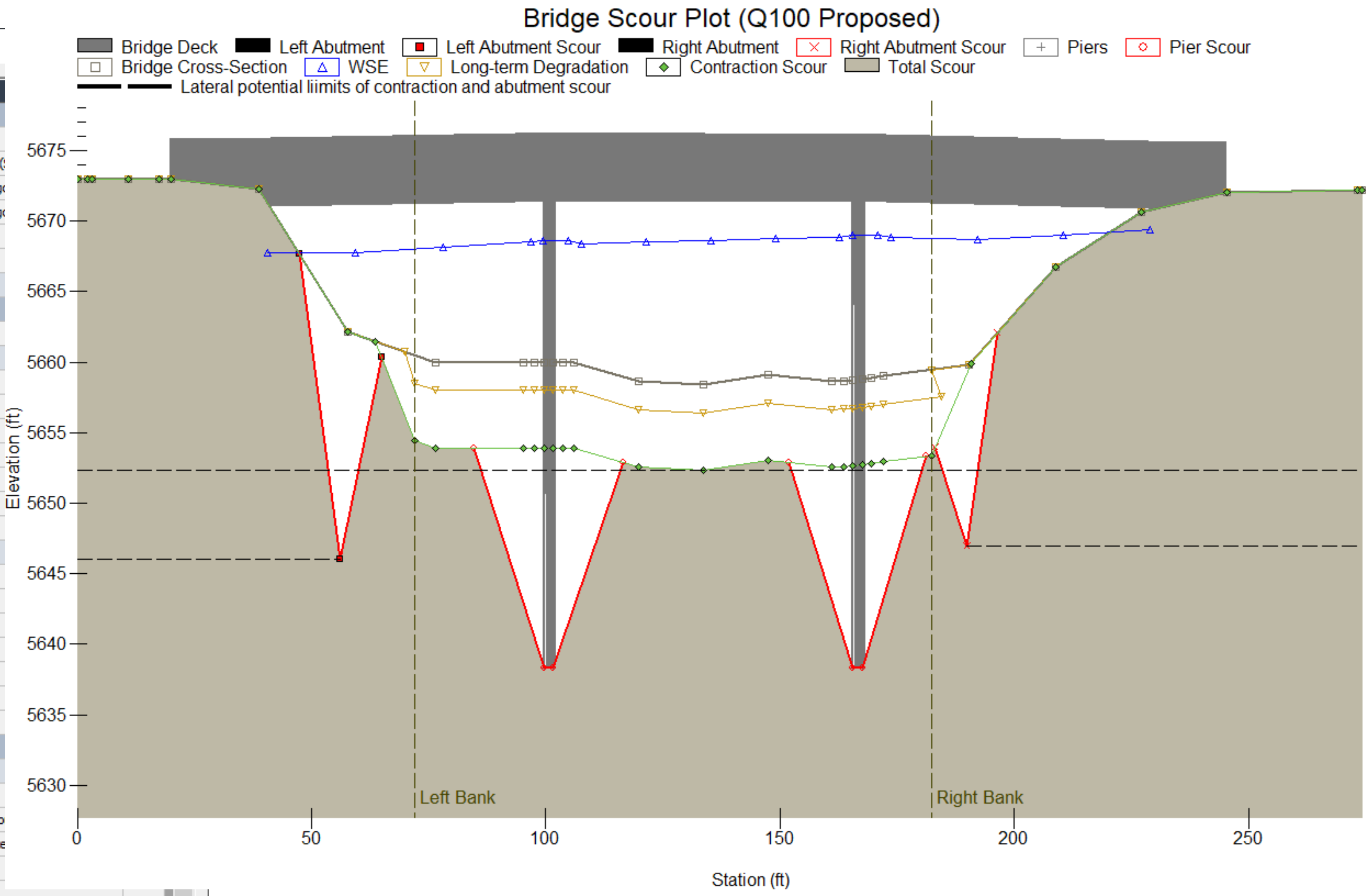
- Average hydraulic parameters exported (main channel & overbank)
- Velocity and depth at maximum unit discharge location are extracted for pier scour (local values can still be used)
- Pressure flow hydraulic parameters exported
- Bridge (contracted) section and pier geometry are adjusted for skew
- Bridge deck and pier geometry are exported
- Review all values
- Verify design angle of attack
- Long Term Degradation values are not included and need to be added manually (use HEC-20 or other available resources)

Hydraulic Toolbox
Scour Summary Table

Bridge Scour Summary Table

Parameter	Q50 Propo…	Q100 Prop…	Q500 Prop…	Units	Notes
Contraction Scour	☐	☑	☐		
Selected Contraction Computation Method	Clear-Wate…	Clear-Wate…	Clear-Wate…		
Applied Contraction Scour Depth	3.18	**4.11**	4.11	ft	Q50 Proposed 190 (
Clear Water Contraction Scour Depth	5.57	7.44	7.44	ft	Item bolded is the g
Live Bed Contraction Scour Depth	**3.18**	**4.11**	**4.11**	ft	Item bolded is the g
Streambed Thalweg Elevation	5658.39	5658.39	5658.39	ft	
Applied Contraction Scour Elevation with LTD	5655.21	**5654.28**	5654.28	ft	
Approach Cross-Section					
Local Scour at Piers					
Plot Pier Scour	☐	☑	☐		
Piers					
Pier Name	Pier 1	Pier 1	Pier 1		
Pier Computation Method	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	6.97	**7.95**	7.95	ft	
Max Flow Depth including Pier Scour	19.12	22.66	22.66	ft	
Total Scour at Pier	6.97	**7.95**	7.95	ft	
Streambed Thalweg Elevation	5658.39	5658.39	5658.39	ft	
Total Scour Elevation at Pier	5648.24	**5646.32**	5646.32	ft	
Piers					
Pier Name	Pier 2	Pier 2	Pier 2		
Pier Computation Method	HEC-18	HEC-18	HEC-18		
Pier Scour Depth	14.82	**15.49**	15.49	ft	
Max Flow Depth including Pier Scour	26.65	29.83	29.83	ft	
Total Scour at Pier	14.82	**15.49**	15.49	ft	
Streambed Thalweg Elevation	5658.39	5658.39	5658.39	ft	
Total Scour Elevation at Pier	5640.39	**5638.78**	5638.78	ft	
Local Scour at Abutments					
Left Abutment					
Plot Left Abutment Scour	☐	☑	☐		
Abutment Scour Depth	11.49	**13.37**	13.37	ft	NCHRP Method: Sco
Max Flow Depth including Abutment Scour	16.45	20.02	20.02	ft	Including the long-te
Total Scour at Abutment	11.49	**13.37**	13.37	ft	
Local Streambed Elevation at Abutment	5661.13	5661.13	5661.13	ft	
Total Scour Elevation at Abutment	5650.05	**5647.86**	5647.86	ft	
Right Abutment					☑
Plot Right Abutment Scour	☐	☑	☐		☐
Abutment Scour Depth	9.92	**12.08**	12.08	ft	NCHRP Method: Scour Condition A (in…
Max Flow Depth including Abutment Scour	16.45	20.02	20.02	ft	Including the long-term scour depth

Plot Cross Section | ☑ Color-Filled Plots | Bar Plot Scour Depth | OK | Cancel



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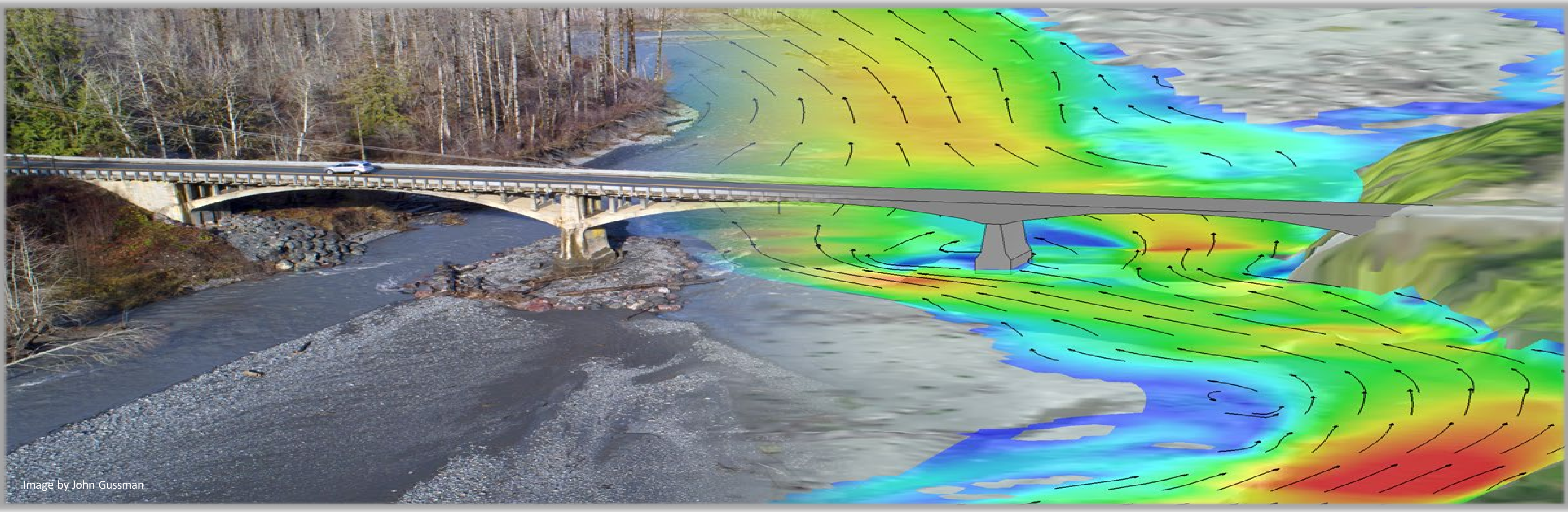

THANK YOU!

Scott Hogan
FHWA Resource Center
Scott.hogan@dot.gov

Casey Kramer
Natural Waters, LLC
ckramer@naturalwaters.design