WSDOT
Scour Workshop

Module 8
Abutment Scour

June 1st, 2023

Scott Hogan

Senior Hydraulic Engineer

FHWA Resource Center

Current Duties

- Training
- Technical Support
- Technology Development and Deployment

Background and Experience

- 10 years at FHWA Resource Center
- 7 years at Central Federal Lands Hydraulics Team Lead
- 14 years consulting engineering

Education

- B.S. Civil Engineering (Colorado State University)
- M.S. Hydraulics (Colorado State University)

Personal Interests

- Hiking
- Camping
- Fishing and Hunting
- Cycling
- DIY Home Improvement

Casey Kramer

Principal River Engineer

Natural Waters, LLC

Current Duties

- Owner of Natural Waters, LLC
- WSDOT HQ staff augmentation team assisting State Hydraulics Engineer

Background and Experience

- Previous WSDOT State Hydraulic Engineer
- Private sector hydraulics and river engineering consultant
- Research River Engineer

Education

- B.S. Civil Engineering (Washington State University)
- M.S. River Engineering (University of Iowa – Iowa Institute of Hydraulic Research)

Personal Interests

- Spending time with family
- Rivers
- Dirt biking, Fishing, Camping, and Coaching/Watching Sports

Abutment Scour Overview

- Define abutment scour and scour conditions at abutments
- Overview of NCHRP 24-20 abutment scour approach and types of abutment scour
- Summary for how to compute abutment scour
- Steps to compute abutment scour using NCHRP 24-20 approach

Image Source: Casey Kramer

Abutment Scour

- Local scour resulting from the flow obstruction caused by an abutment/embankment

- Contracting flow accelerates and forms vortices

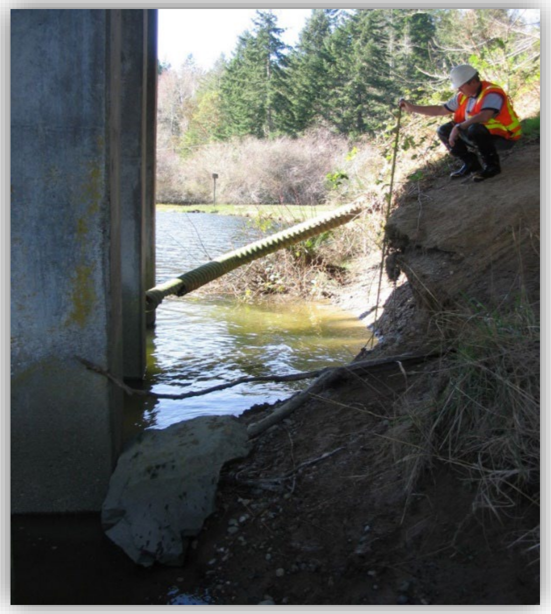


Image Sources: Casey Kramer

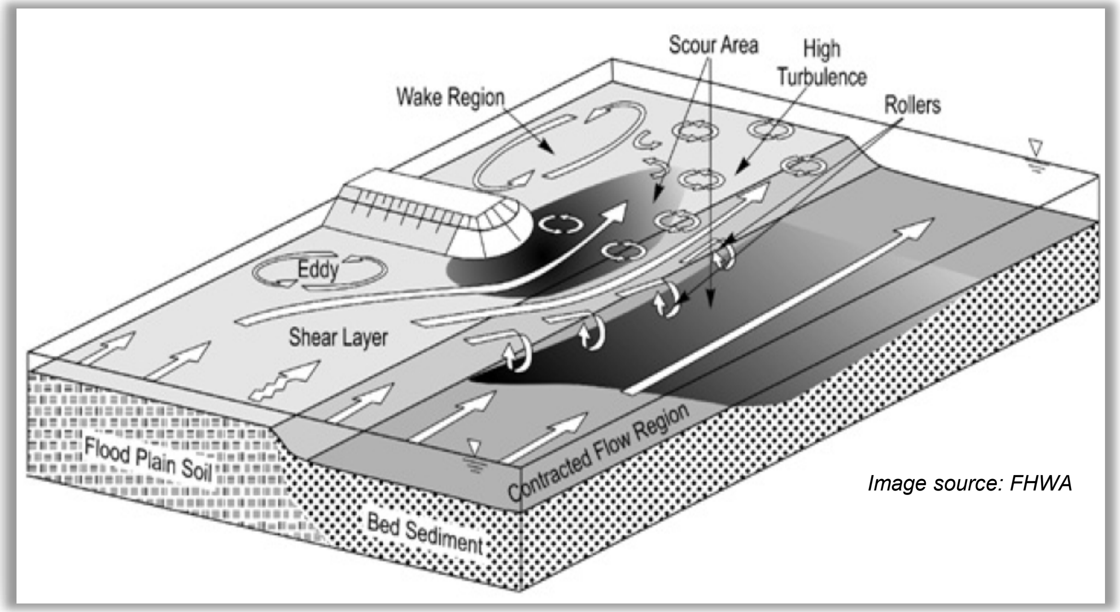


Image source: FHWA

Abutment Scour

- WSDOT requires using the NCHRP 24-20 approach
- When evaluating the abutment scour condition, consider the channel migration potential over the life of the bridge
- Abutment scour is computed by multiplying contraction scour by an empirically derived amplification factor (includes contraction scour)
- Amplification factors were developed for two abutment configurations and two location scenarios
- See FHWA Scour Workshop and NHI courses for more details

Image Source: Casey Kramer

Image Source: WSDOT

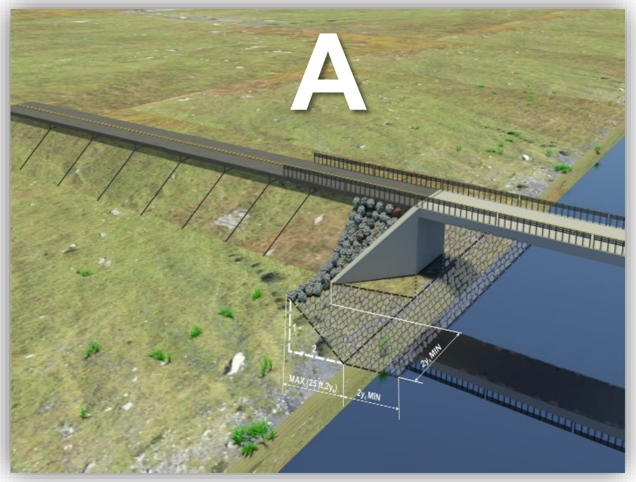
Abutment Scour Conditions

Scour Condition A:

- The abutment is located **near the channel** bank or the channel may migrate into the abutment over the life of the bridge
- Main channel hydraulic parameters are used to compute abutment scour

Scour Condition B:

- The abutment is **set back from the channel** bank far enough that it will not be in contact with the channel over the life of the bridge
- Overbank hydraulic parameters are used to compute abutment scour



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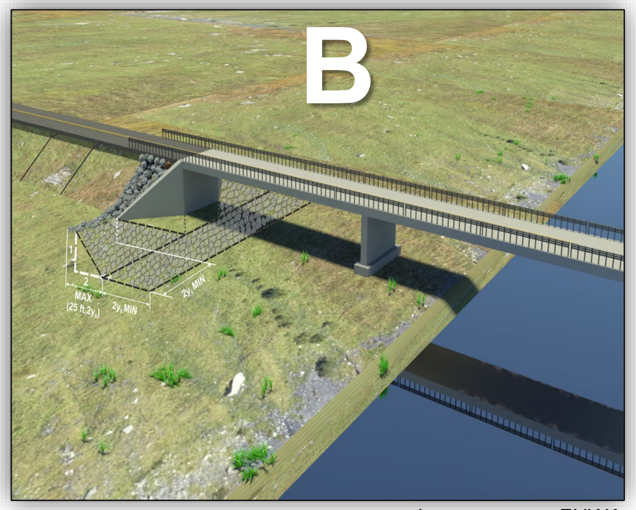

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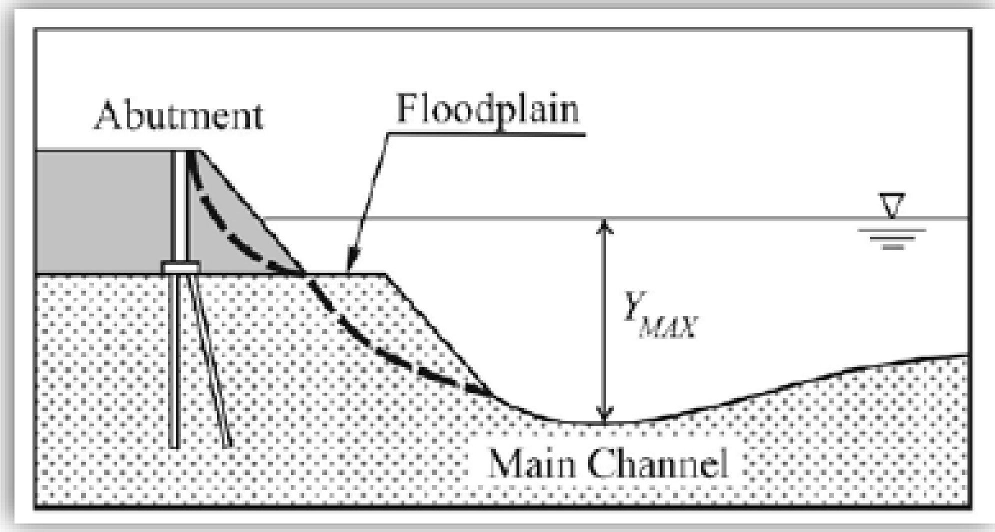
Abutment Types

- Spill-through abutments (sloped)



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- Wingwall abutments (vertical)

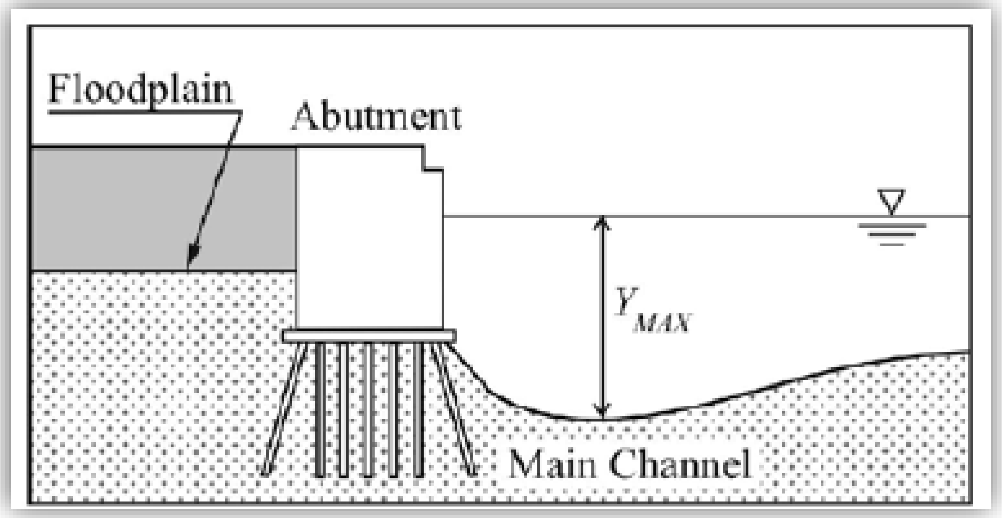


Image source: FHWA

Abutment Scour

Four scour amplification curves in HEC-18 (2012)

(Note the clarifications in Figure Captions)

- Scour Condition A, spill-through abutments (Figure 8.9)
- Scour Condition A, vertical abutments/wingwalls (Figure 8.10)
- Scour Condition B, spill-through abutments (Figure 8.11)
- Scour Condition B, vertical abutments/wingwalls (Figure 8.12)

- When q_2/q_1 is low, contraction scour is small and flow separation and turbulence dominate the scour process

- When q_2/q_1 is large, contraction scour dominates the process and the amplification factor is small

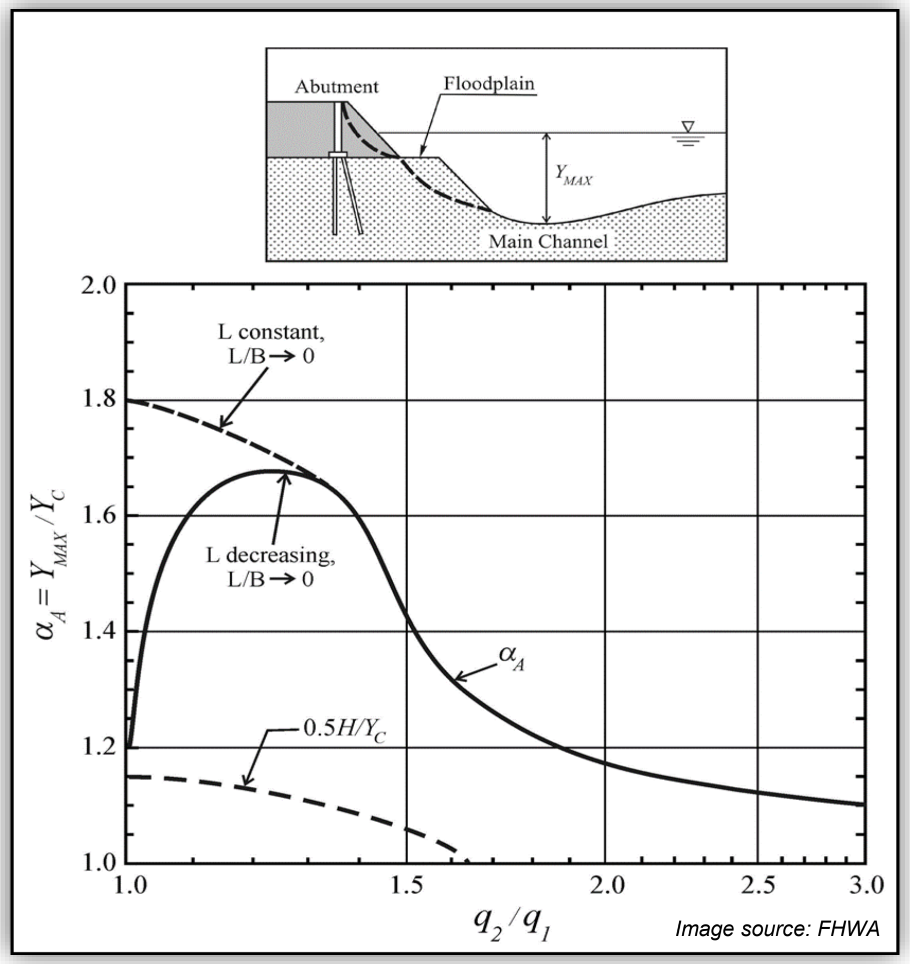


Figure 8.9. Scour amplification factor for spill-through abutments and *live-bed conditions (Scour Condition A)*

How to Compute Abutment Scour

- Compute contraction scour for all flows up to the scour design flood and scour check flood

- If pressure flow exists (existing bridges), abutment scour cannot be computed using current HEC-18 methods. An abutment scour countermeasure is required

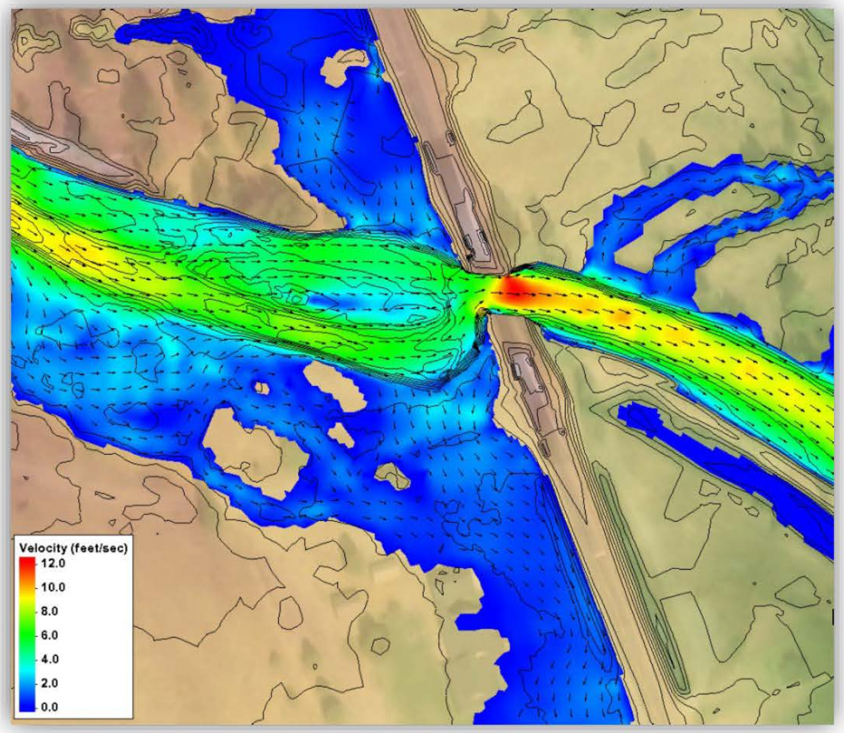


Image Source: Casey Kramer

How to Compute Abutment Scour

- Determine Scour Condition (A or B)
  - For Scour Condition A, use main channel average hydraulic parameters to compute abutment scour
  - For Scour Condition B, use overbank average hydraulic parameters to compute abutment scour (Most overbank scenarios will be a clear-water condition when vegetation is present)
- Compute unit discharges (q_1 and q_2) using hydraulic parameters from contraction scour
- Evaluate the amplification factor ($\alpha_{A/B}$) from HEC-18 Figures 8.9 through 8.12

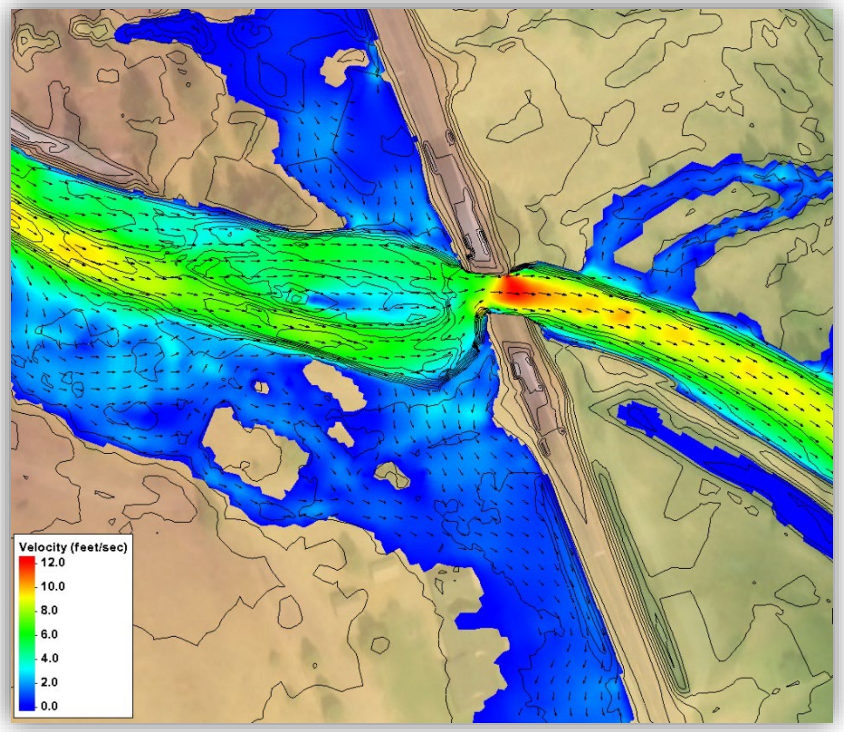
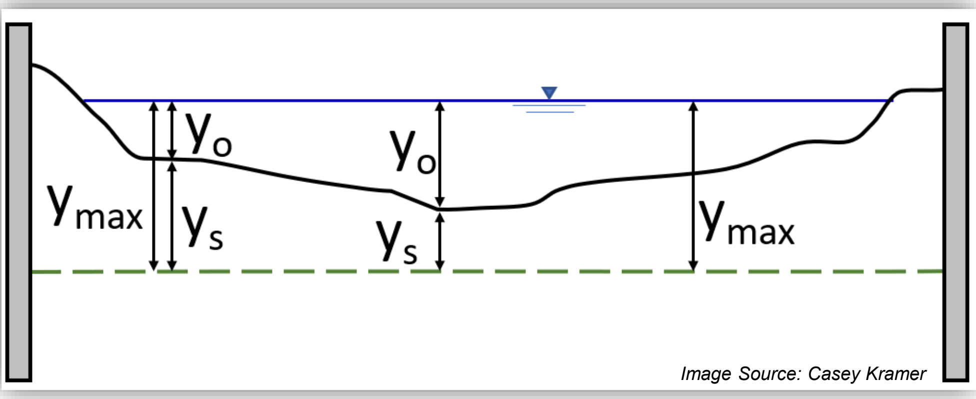


Image Source: Casey Kramer

How to Compute Abutment Scour

- NCHRP 24-20 estimates a maximum flow depth resulting from abutment scour (y_{max})
  - The reference location is used to determine the depth of abutment scour, y_s (measured below streambed) at that location (e.g., y_s is based on the selected location)
  - y_s should always be reported with a refence location (e.g., depth below thalweg for PHD) or the scour elevation at y_{max} should be documented

For representation of NCHRP 24-20 terms ONLY



$$y_s = y_{max} - y_o$$

HEC-18 (2012) Eqn. 8.4

Abutment Scour

- The following provides an example for computing abutment scour for a PHD

- Key assumptions:
  - The structure type, size and location has not been determined

  - Abutment scour is determined at the selected contracted section location. Per the WSDOT H_HD template other total scour tables may be necessary to perform scour analysis at appropriate locations

  - Channel profile and geometry is typical through crossing, therefore flow depths are assumed to be uniform. Applying depths of scour at locations other than the location of the selected contraction scour arc needs to be assessed carefully

Abutment Scour

- The hydraulics engineer of record determines appropriate total scour elevations that are commensurate with the site and acceptable level of risk in coordination with WSDOT

- Ultimate goal is to determine scour elevations at each infrastructure component being designed. Coordination MUST happen with the project, geotechnical, and bridge and structures offices to determine appropriate scour elevations to be used for design as the design progresses

- The intent of the next slides is to show an example for how abutment scour should be calculated but does not go into detail of all scenarios and analyses required to develop total scour. Completion of NHI Course 135046 and the FHWA scour workshop is required for more details on computing total scour

Abutment Scour

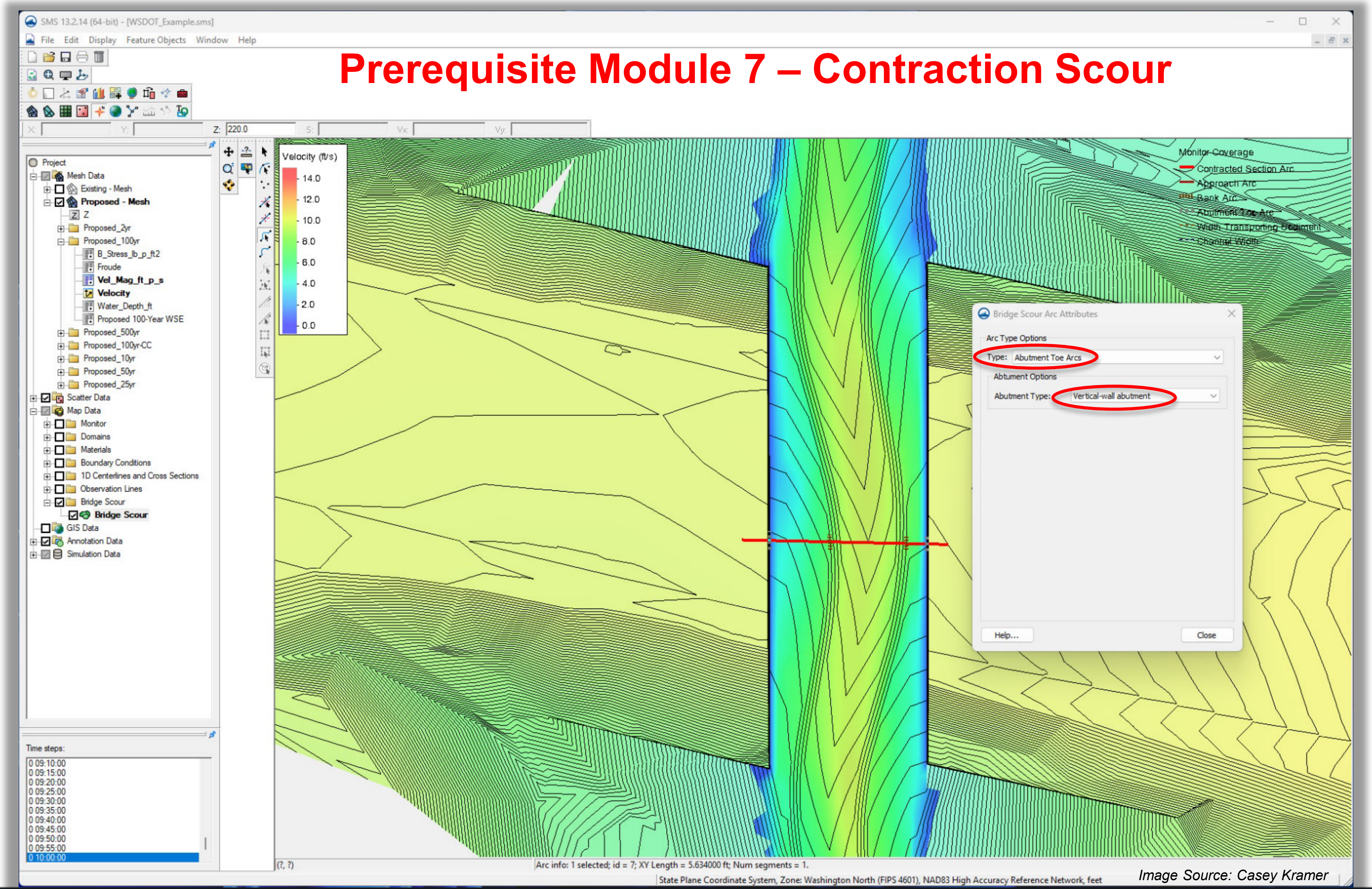
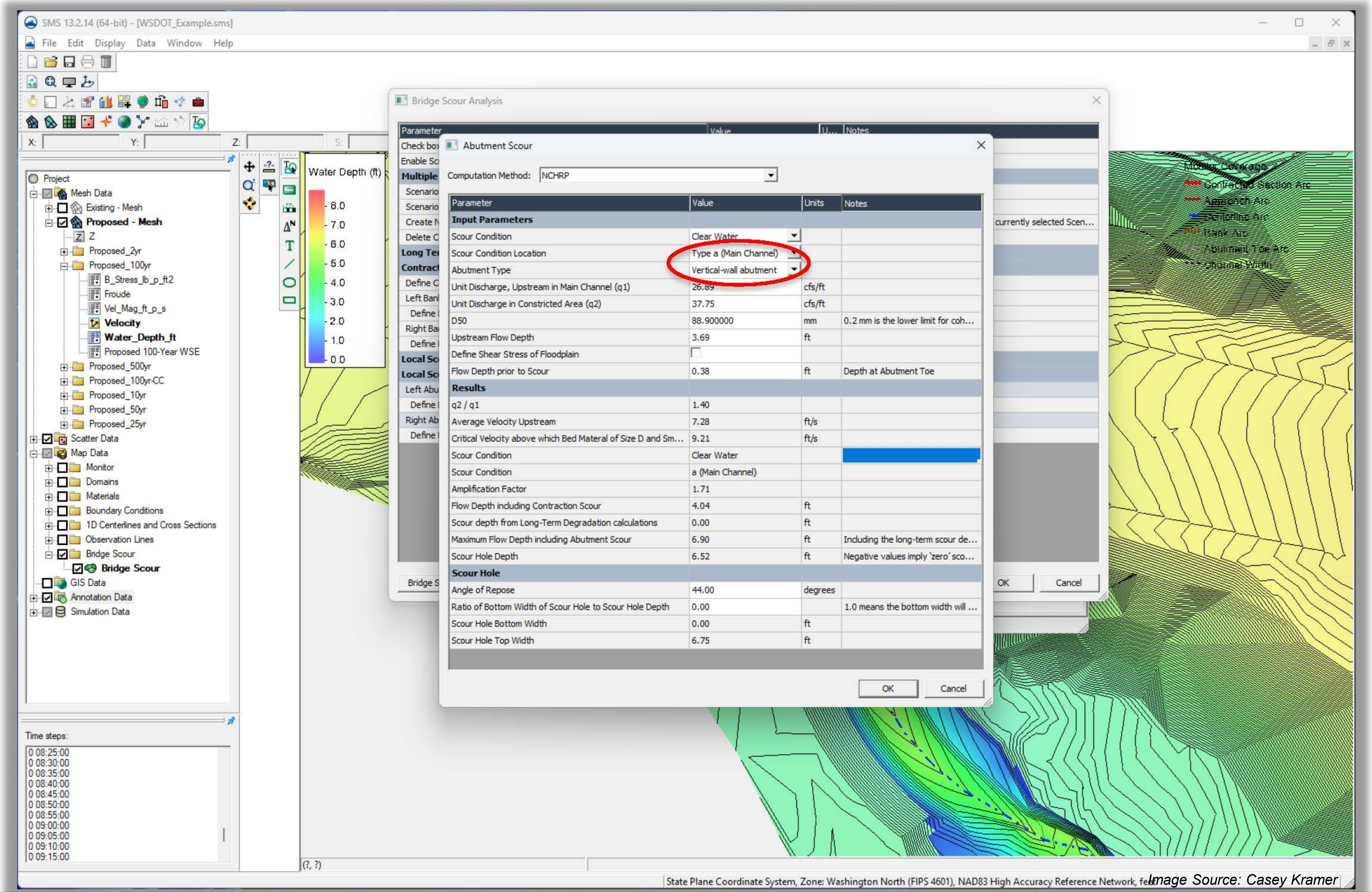


Image Source: Casey Kramer

Abutment Scour



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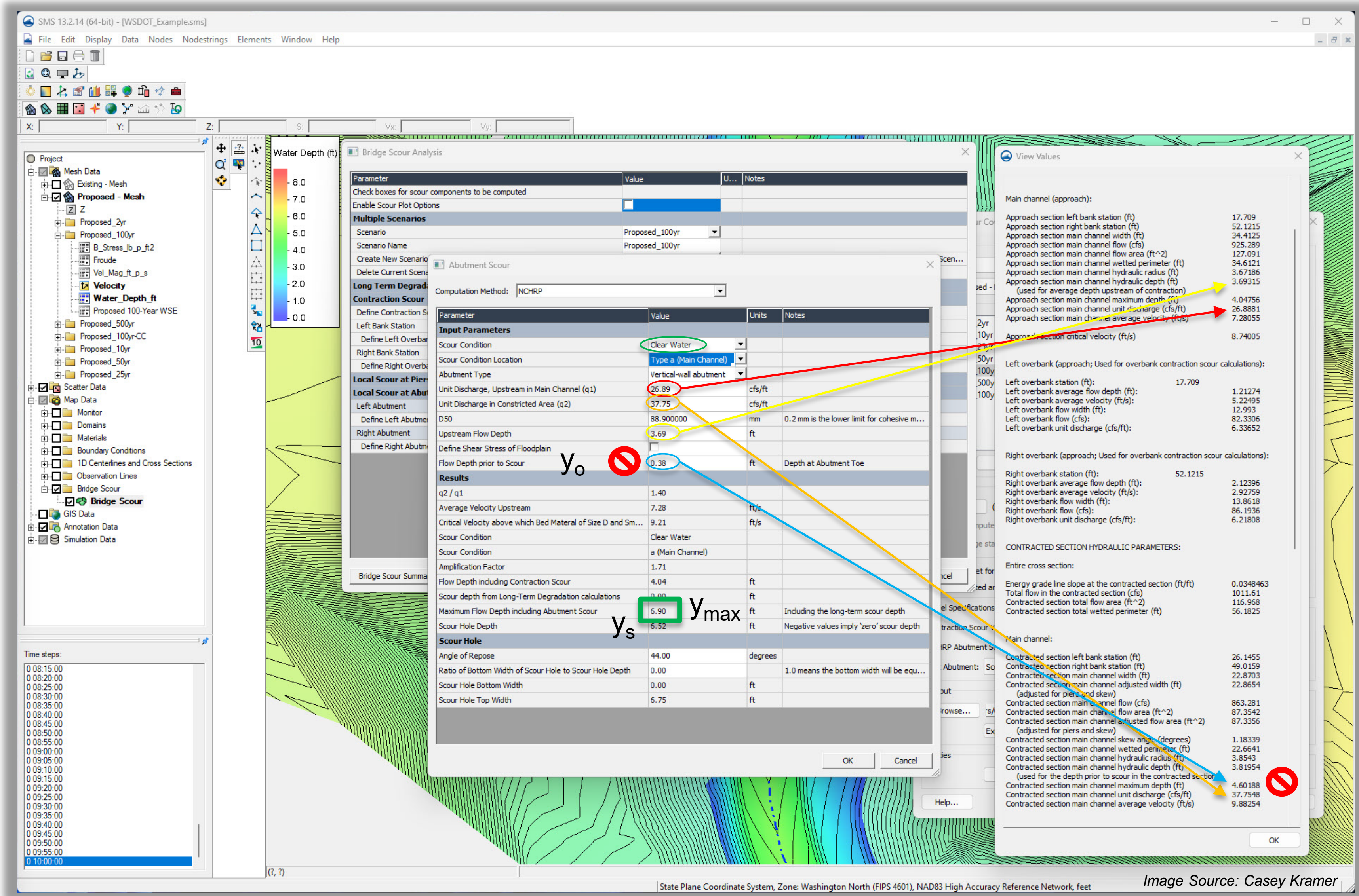
Abutment Scour



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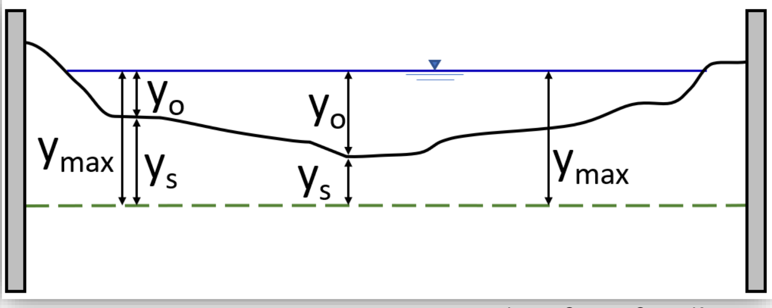

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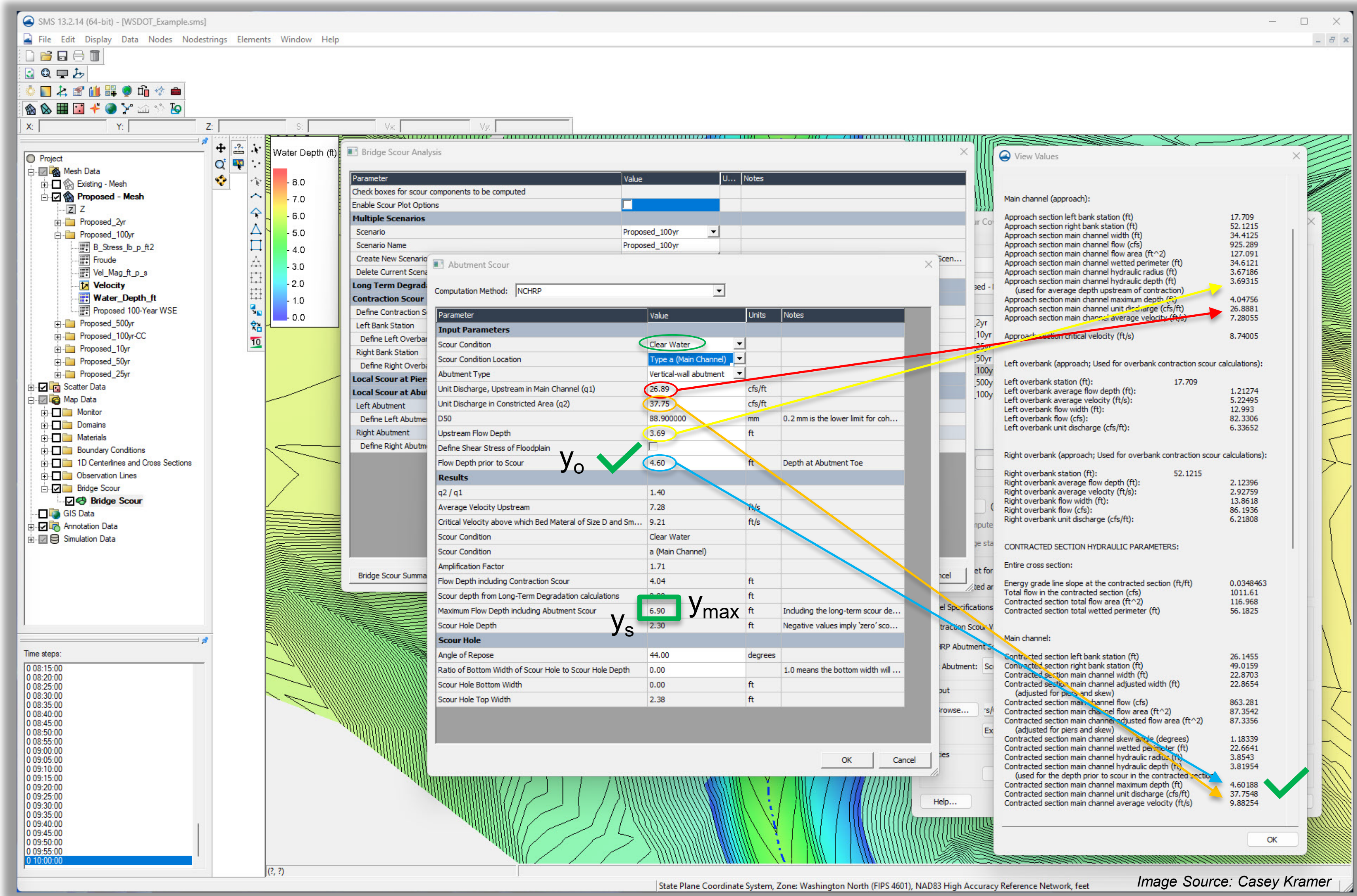
Abutment Scour



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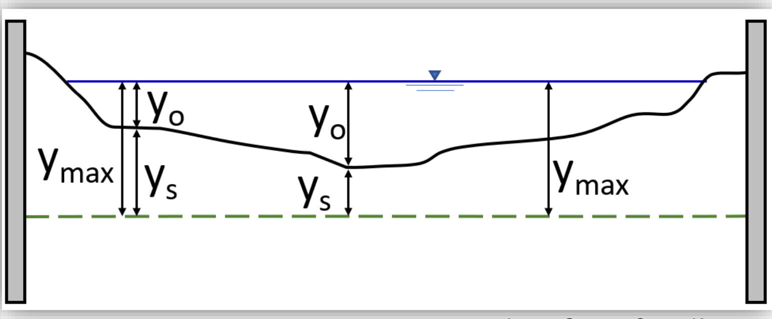

Image Source: Casey Kramer

Abutment Scour

To Demonstrate Requirement of All Flows Up To Scour Design Flood and Scour Check Flood ***ONLY***

Bridge Scour Summary Table

Parameter	Proposed_2yr	Proposed_10yr	Proposed_25yr	Proposed_50yr	Proposed_100yr	Proposed_500yr	Proposed_100yr-CC	Units	Notes
Scenario	☐	☐	☐	☐	☐	☐	☐		
Contraction Scour									
Selected Contraction Computation Method	Clear-Water...	Clear-Water ...	Clear-Water ...	Clear-Water ...	Clear-Water a...	Clear-Water an...	Clear-Water and Li...		Clear-Water and Live-Bed Scour
Applied Contraction Scour Depth	0.00	0.00	0.00	0.00	0.00	**0.16**	0.10	ft	
Clear Water Contraction Scour Depth	**-0.37**	**-0.30**	**-0.24**	**-0.17**	**-0.09**	**0.16**	**0.10**	ft	Item bolded is the governing contraction scour for scenario
Live Bed Contraction Scour Depth	0.61	0.77	0.73	0.71	0.70	0.71	0.71	ft	Item bolded is the governing contraction scour for scenario
Local Scour at Abutments									
Left Abutment									
Abutment Scour Depth	-0.07	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	2.53	4.07	5.05	6.04	6.90	8.85	8.44	ft	Including the long-term scour depth
Total Scour at Abutment	0.00	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	
Right Abutment									
Abutment Scour Depth	-0.07	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	2.53	4.07	5.05	6.04	6.90	8.85	8.44	ft	Including the long-term scour depth
Total Scour at Abutment	0.00	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	

Depths of Scour are Determined at PHD as Structure Type, Size and Location has not Been Determined

Total Scour Elevation at Each Infrastructure Component is Determined by Interdisciplinary Team as Design Progresses

Abutment Scour

Clear-water

Bridge Scour Summary Table

Parameter	Proposed_2yr	Proposed_10yr	Proposed_25yr	Proposed_50yr	Proposed_100yr	Proposed_500yr	Proposed_100yr-CC	Units	Notes
Scenario	☐	☐	☐	☐	☐	☐	☐		
Contraction Scour									
Selected Contraction Computation Method	Clear-Water...	Clear-Water ...	Clear-Water ...	Clear-Water ...	Clear-Water a...	Clear-Water an...	Clear-Water and Li...		Clear-Water and Live-Bed Scour
Applied Contraction Scour Depth	0.00	0.00	0.00	0.00	0.00	**0.16**	0.10	ft	
Clear Water Contraction Scour Depth	**-0.37**	**-0.30**	**-0.24**	**-0.17**	**-0.09**	**0.16**	**0.10**	ft	Item bolded is the governing contraction scour for scenario
Live Bed Contraction Scour Depth	0.61	0.77	0.73	0.71	0.70	0.71	0.71	ft	Item bolded is the governing contraction scour for scenario
Local Scour at Abutments									
Left Abutment									
Abutment Scour Depth	-0.07	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	2.53	4.07	5.05	6.04	6.90	8.85	8.44	ft	Including the long-term scour depth
Total Scour at Abutment	0.00	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	
Right Abutment									
Abutment Scour Depth	-0.07	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	2.53	4.07	5.05	6.04	6.90	8.85	8.44	ft	Including the long-term scour depth
Total Scour at Abutment	0.00	0.67	1.25	1.79	2.30	**3.55**	3.24	ft	

Live-bed

Bridge Scour Summary Table

Parameter	Proposed_...	Proposed_10yr	Proposed_25yr	Proposed_50yr	Proposed_100yr	Proposed_500yr	Proposed_100yr-CC	Units	Notes
Scenario	☐	☐	☐	☐	☐	☑	☐		
Contraction Scour									
Selected Contraction Computation Method	Clear-Wate...	Clear-Water ...	Clear-Water ...	Clear-Water ...	Clear-Water a...	Clear-Water a...	Clear-Water and ...		Clear-Water and Live-Bed Scour
Applied Contraction Scour Depth	0.00	0.00	0.00	0.00	0.00	**0.16**	0.10	ft	
Clear Water Contraction Scour Depth	**-0.37**	**-0.30**	**-0.24**	**-0.17**	**-0.09**	**0.16**	**0.10**	ft	Item bolded is the governing contraction scour for scenario
Live Bed Contraction Scour Depth	0.61	0.77	0.73	0.71	0.70	0.71	0.71	ft	Item bolded is the governing contraction scour for scenario
Local Scour at Abutments									
Left Abutment									
Abutment Scour Depth	1.11	2.53	3.06	3.47	3.84	**4.66**	4.45	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	3.71	5.93	6.86	7.72	8.44	9.96	9.65	ft	Including the long-term scour depth
Total Scour at Abutment	1.11	2.53	3.06	3.47	3.84	**4.66**	4.45	ft	
Right Abutment									
Abutment Scour Depth	1.11	2.53	3.06	3.47	3.84	**4.66**	4.45	ft	NCHRP Method: Scour Condition A (includes LTD)
Max Flow Depth including Abutment Scour	3.71	5.93	6.86	7.72	8.44	9.96	9.65	ft	Including the long-term scour depth
Total Scour at Abutment	1.11	2.53	3.06	3.47	3.84	**4.66**	4.45	ft	