Engineering | Planning | Allied Services

2-D Mobile Bed Hydraulic Modeling

Man-made Impacts on the Floodplain of a Highly Erodible Stream

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IAFSM 2020 Annual Conference

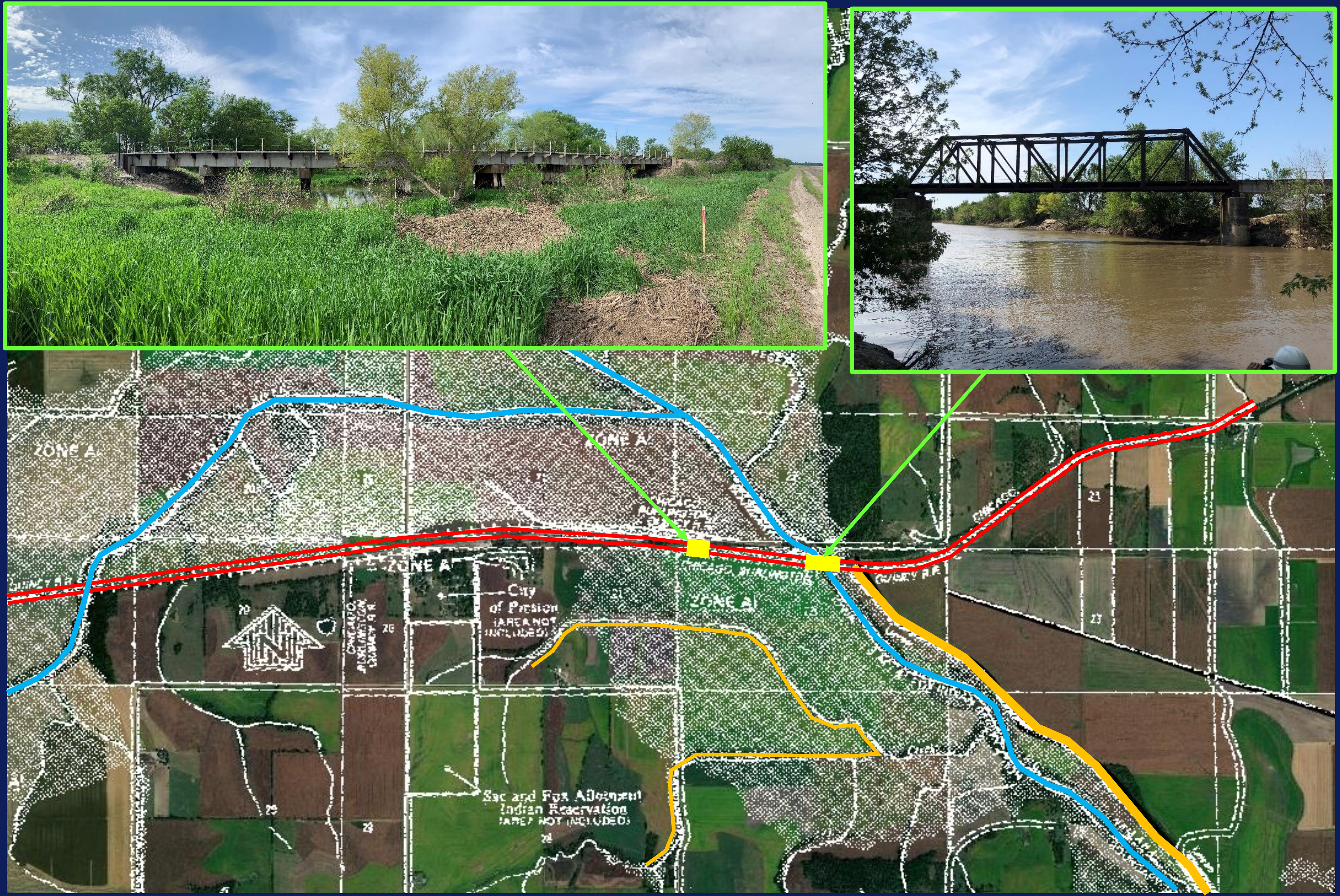
Introduction

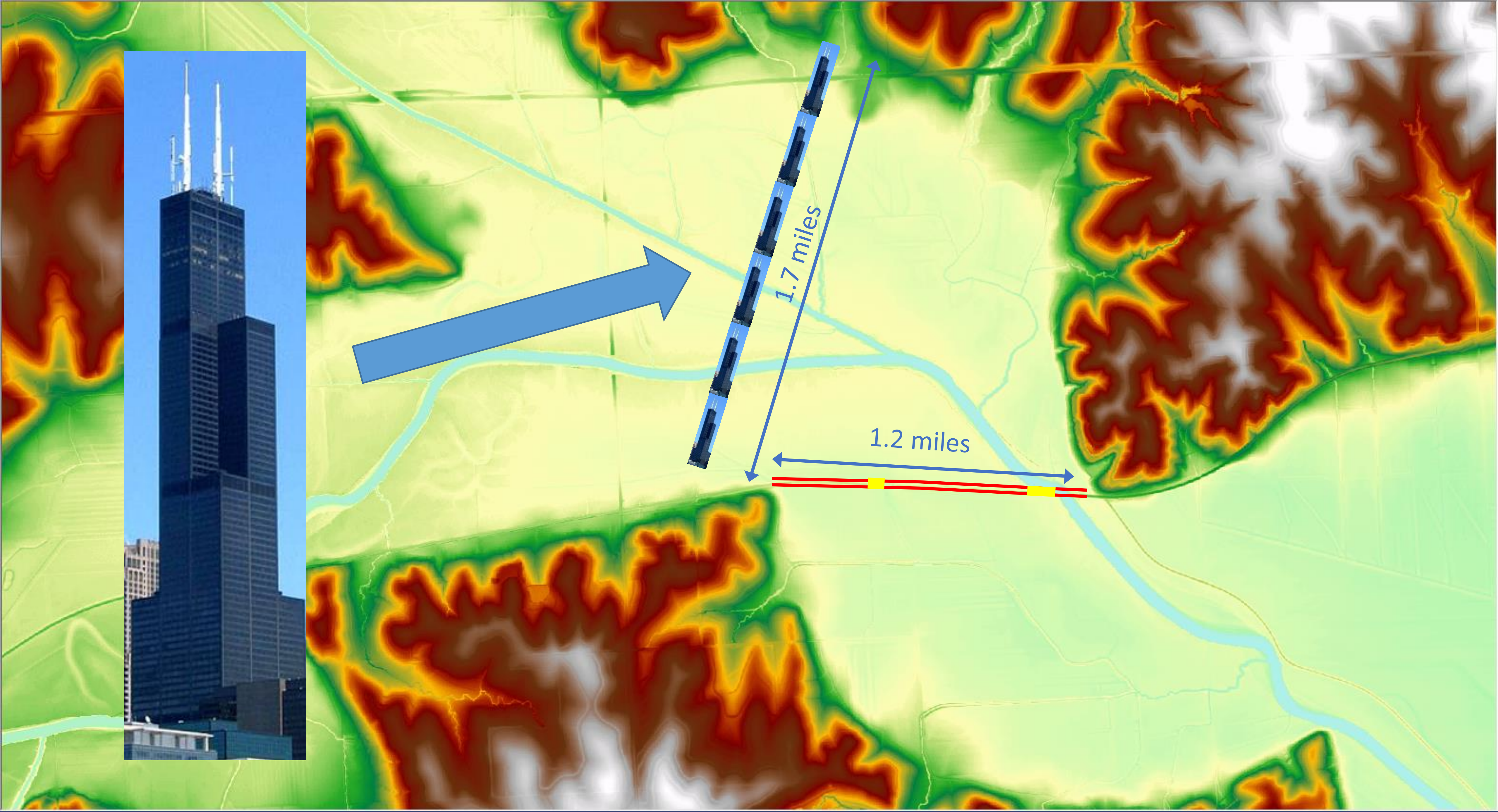
~450-ft Rail Bridge in need of Replacement

- Location: Preston, NE
  - Owned by BNSF
- Built in early 1940's
  - ~200-ft Overflow Relief Bridge Structure

Today's Presentation

- Project Overview
- Estimating Scour Potential in Complex Hydraulic Environments Utilizing 1-D Models
- Can 2-D Models Make this Process Easier?
- Sediment Transport Modeling a useful tool?
- Results Comparison and Discussion of Findings


ZONE A
City of Preston (AREA NOT INCLUDED)
Sac and Fox Allotment Indian Reservation (AREA NOT INCLUDED)


1.7 miles
1.2 miles

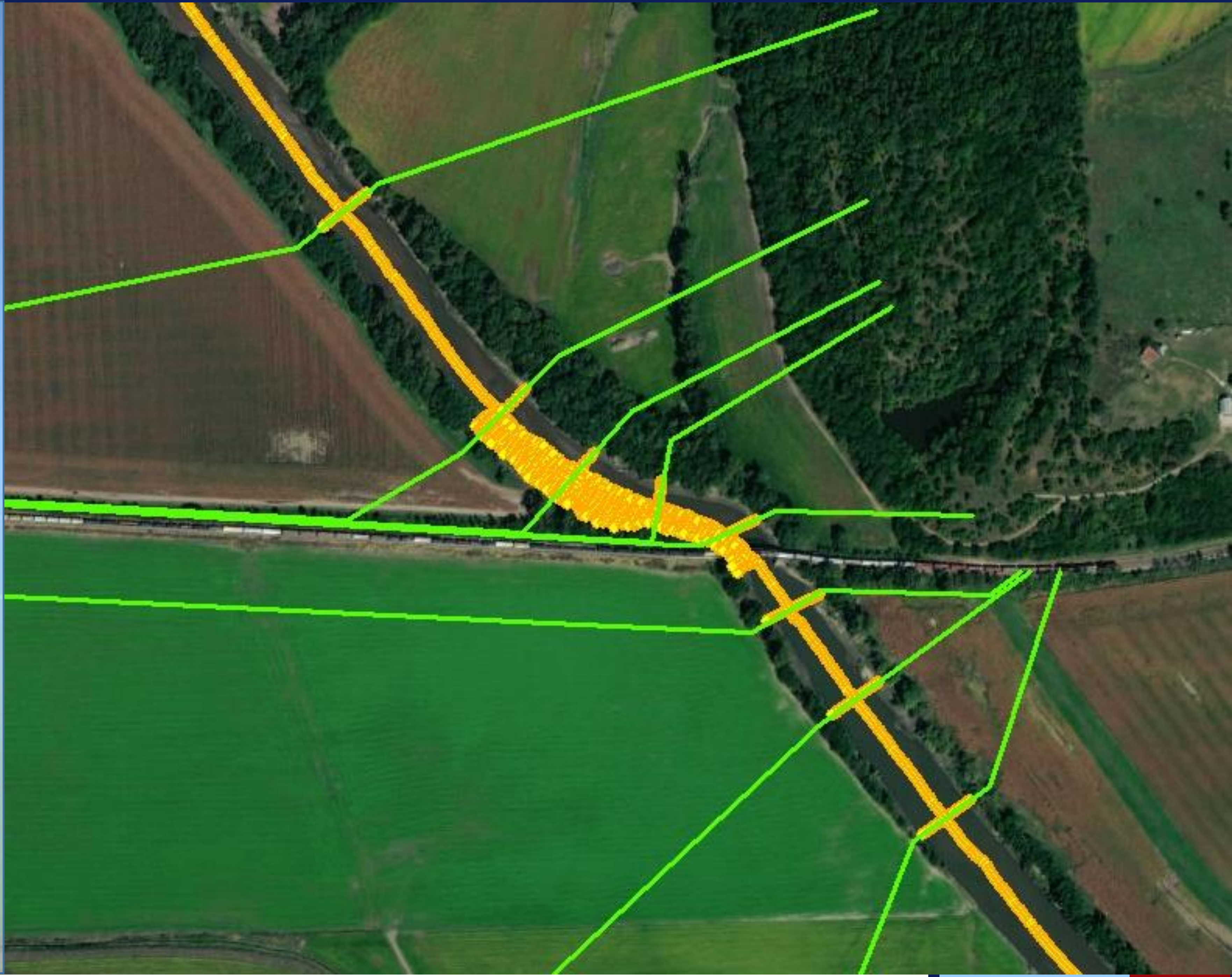
1-D HEC-RAS

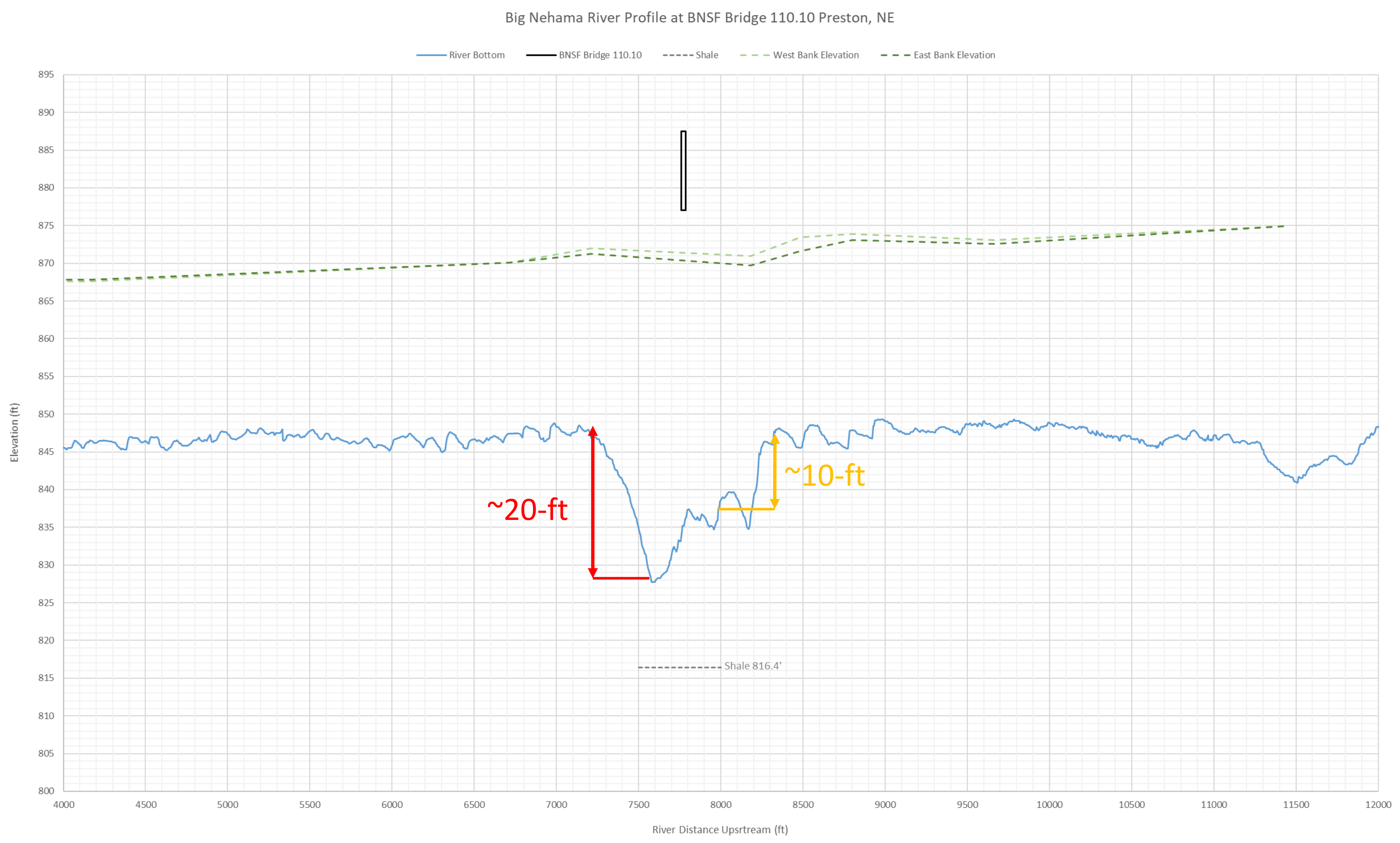
- Cross-Sections
- River
- Flow Paths
- Banks
- Bridge (Multiple Opening)
- Ineffective Areas

Goals

- Quantify Floodplain Impacts (Permit)
- Estimate Scour Potential (Design)

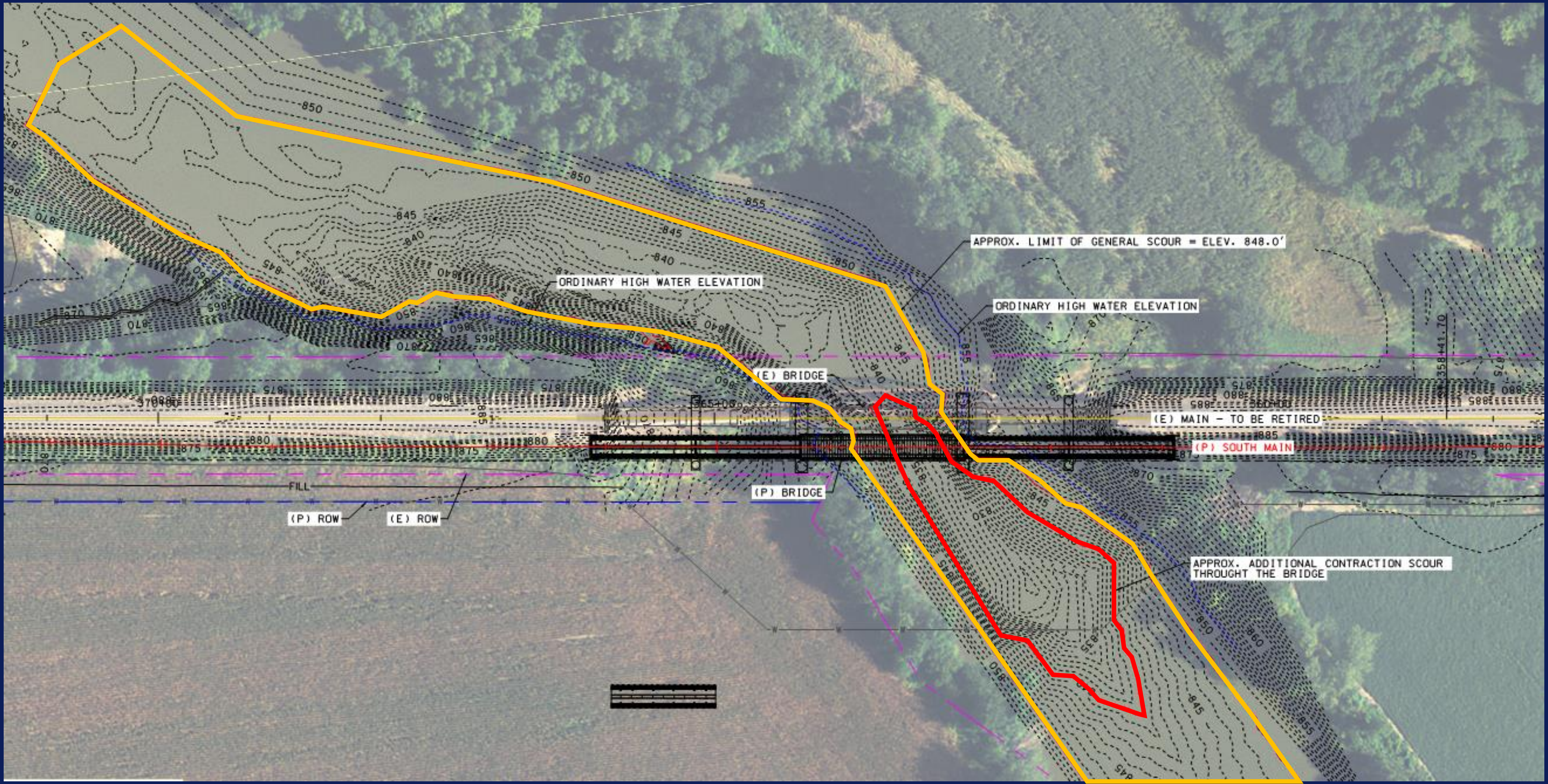
Bathymetric Survey



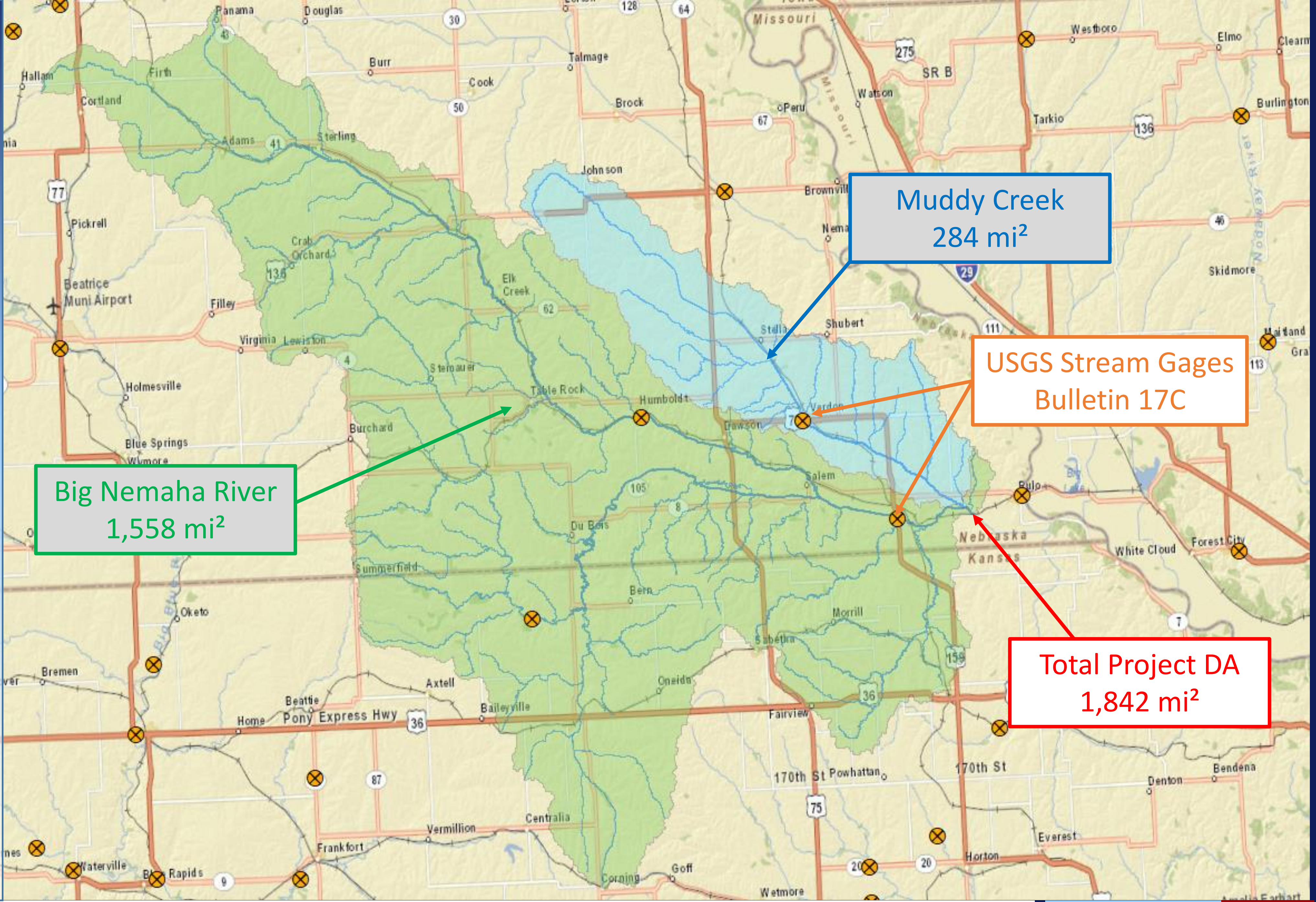


Big Nehama River Profile at BNSF Bridge 110.10 Preston, NE
River Bottom
BNSF Bridge 110.10
Shale
West Bank Elevation
East Bank Elevation
Elevation (ft)
895
890
885
880
875
870
865
860
855
850
845
840
835
830
825
820
815
810
805
800
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
11500
12000
River Distance Upsrtream (ft)
~20-ft
~10-ft
Shale 816.4'

Existing Scour



Hydrology


Muddy Creek
284 mi²
USGS Stream Gages
Bulletin 17C
Big Nemaha River
1,558 mi²
Total Project DA
1,842 mi²

Hydrology

Big Nemaha River

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1974	Oct. 11, 1973	31.40	71,600
1993	Jul. 06, 1993	29.77	59,000
1965	Jun. 29, 1965	28.90	47,700
1960	Mar. 28, 1960	27.75	46,900
1982	Aug. 13, 1982	27.60	46,000
2007	May 07, 2007	30.46	44,900
1979	Mar. 03, 1979	26.10	44,800
2013	May 30, 2013	28.91	44,800
1978	May 07, 1978	25.85	44,000

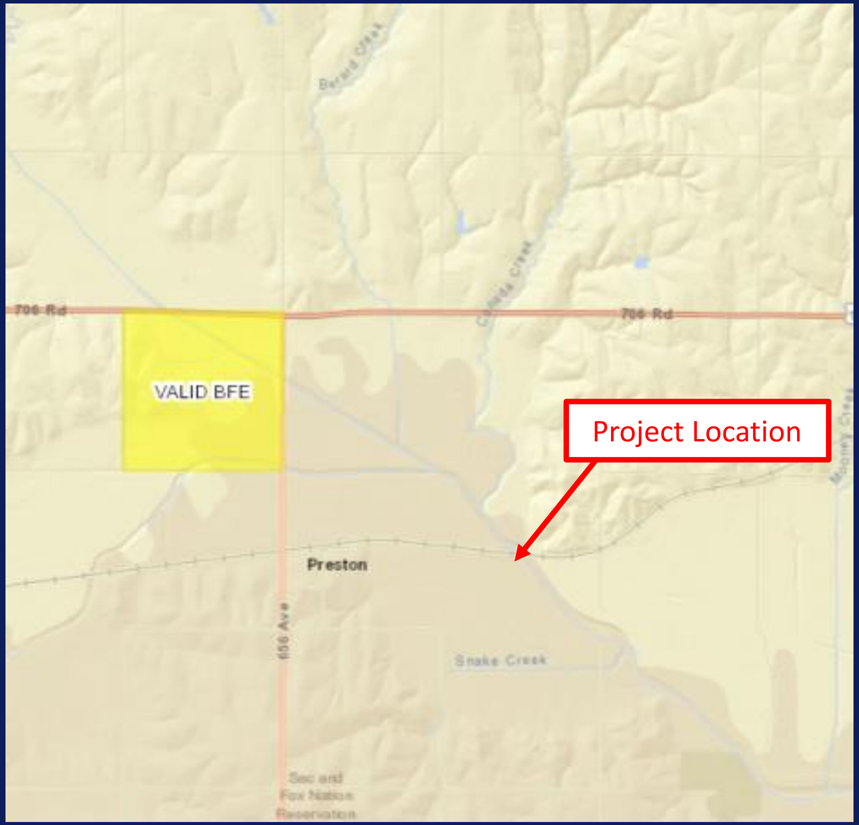
Muddy Creek

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1973	Aug. 12, 1973	32.71	35,000
1958	Jul. 10, 1958	31.50	31,900
1960	Mar. 27, 1960	23.90	20,000
1961	Sep. 30, 1961	24.58	17,800
1954	Jun. 17, 1954	22.97	17,100
1964	Jun. 17, 1964	22.20	13,800
1969	May 07, 1969	21.75	13,000
1957	Jun. 17, 1957	18.35	10,200
1962	May 28, 1962	19.60	10,100

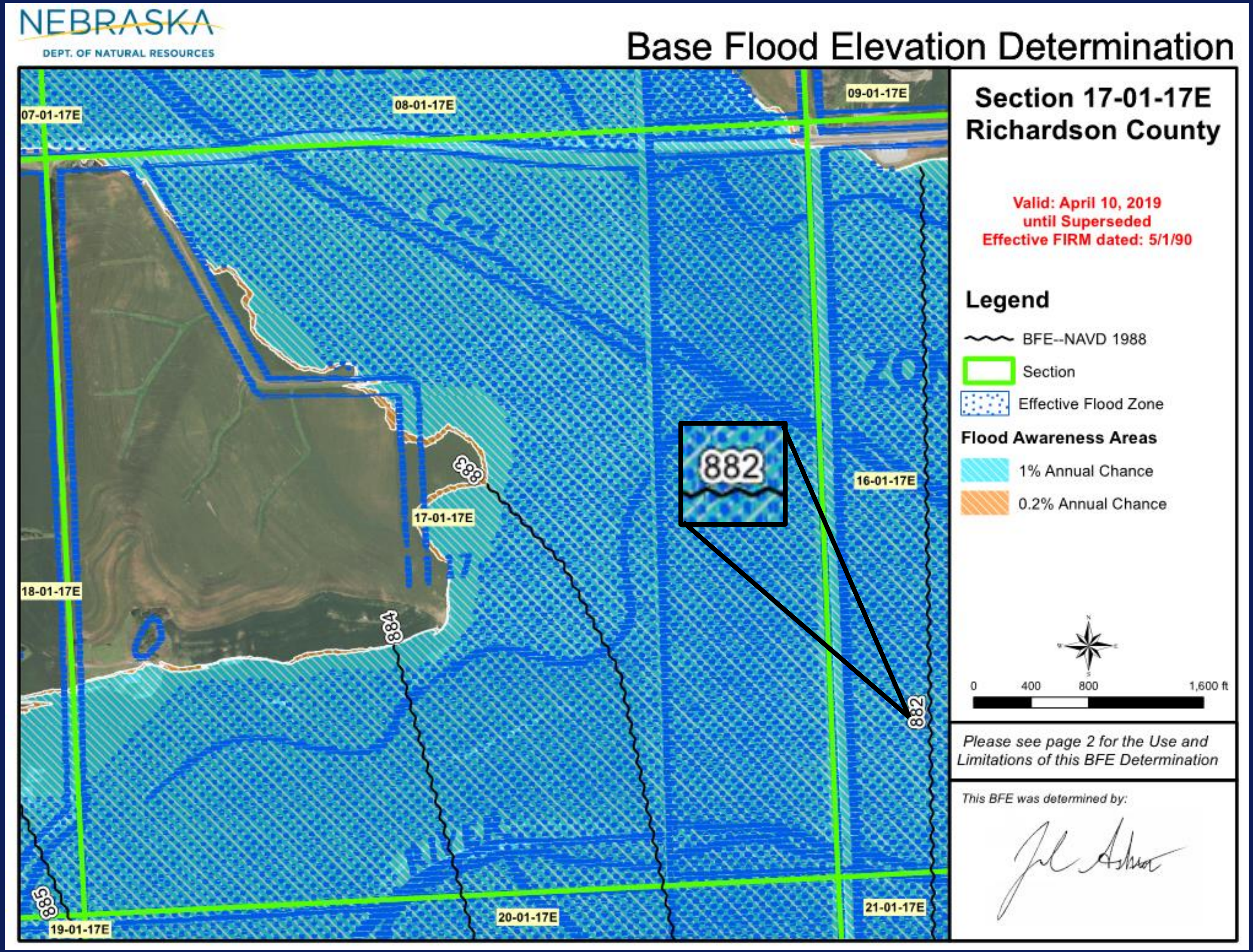
Bulletin 17C and
Adjusted for Total Area

Adjusted Project Location	
% Chance Exceedance	**Flow (cfs)**
0.2	170,275
0.5	147,191
1	130,287
2	113,823
5	92,622
10	76,858
20	61,057
50	38,815
80	24,270
90	18,863
95	15,265
99	10,174

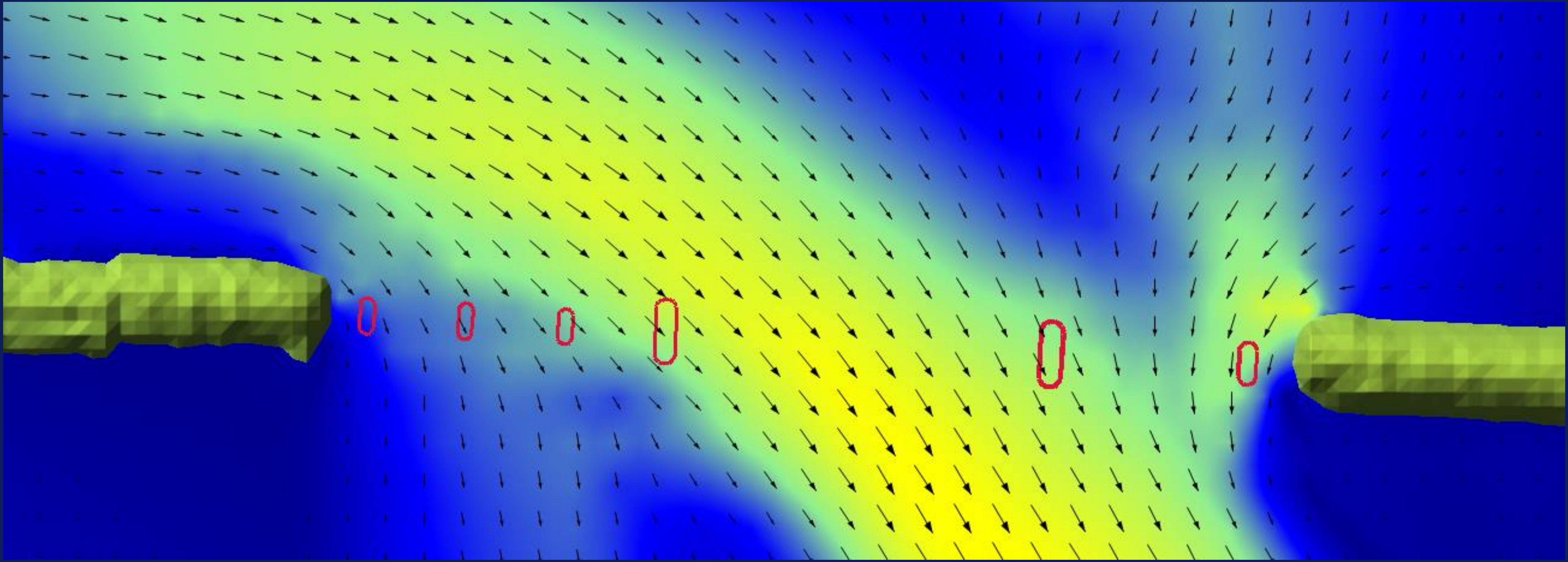
Calibration



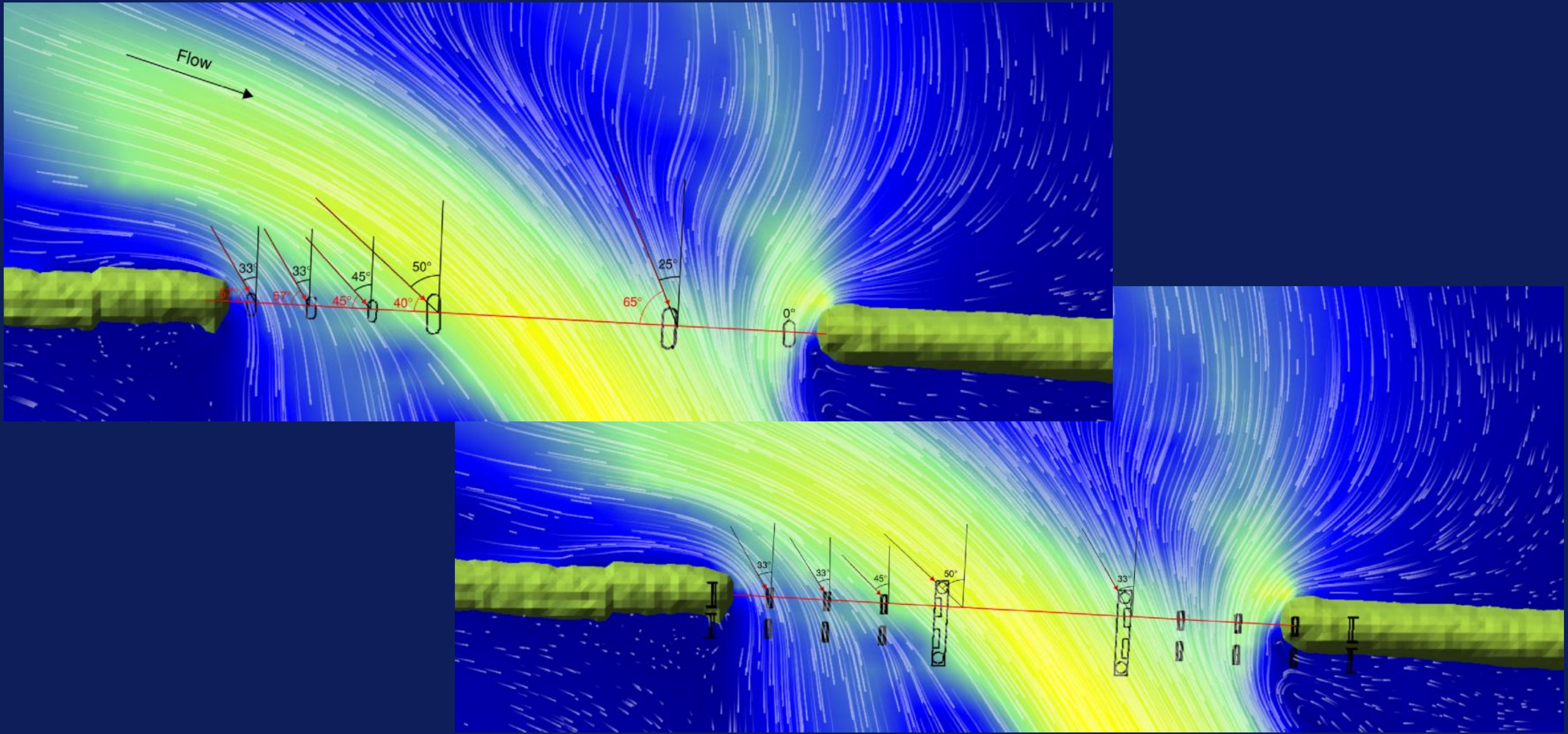
- Regression Equations
- Recent Storm Event
- BFE Determination



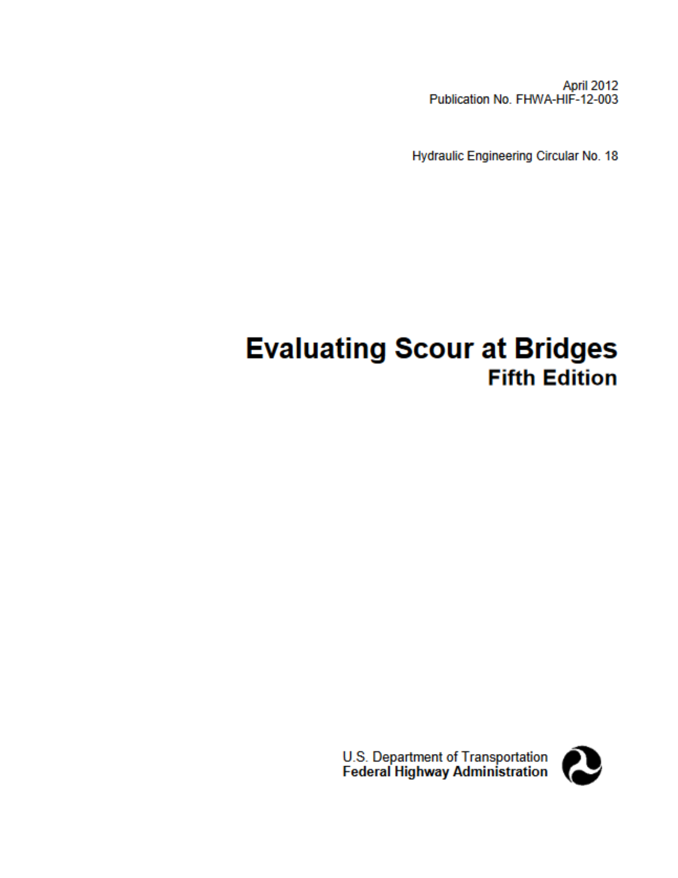
Flow Angle of Attack



Flow Angle of Attack



HEC-18 Bridge Scour

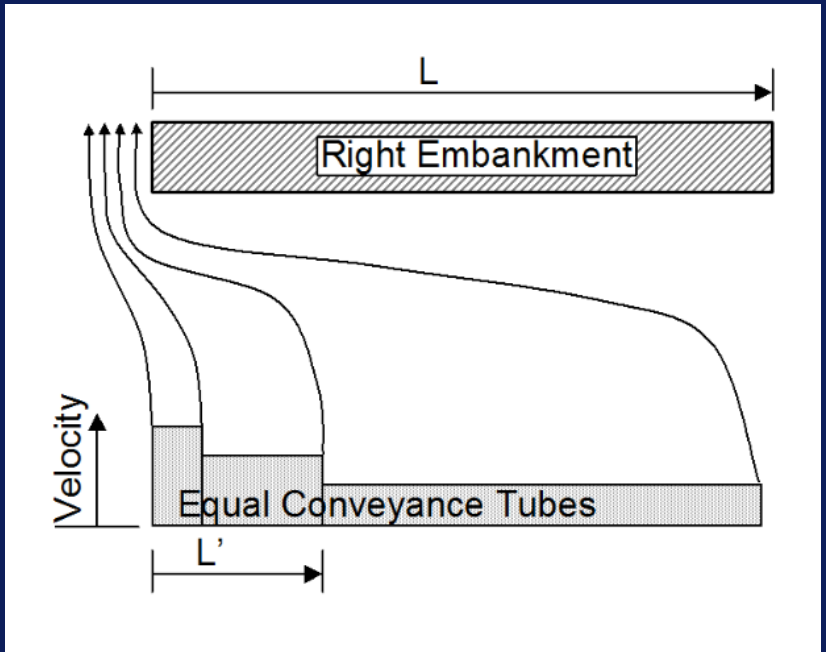

April 2012
Publication No. FHWA-HIF-12-003

Hydraulic Engineering Circular No. 18

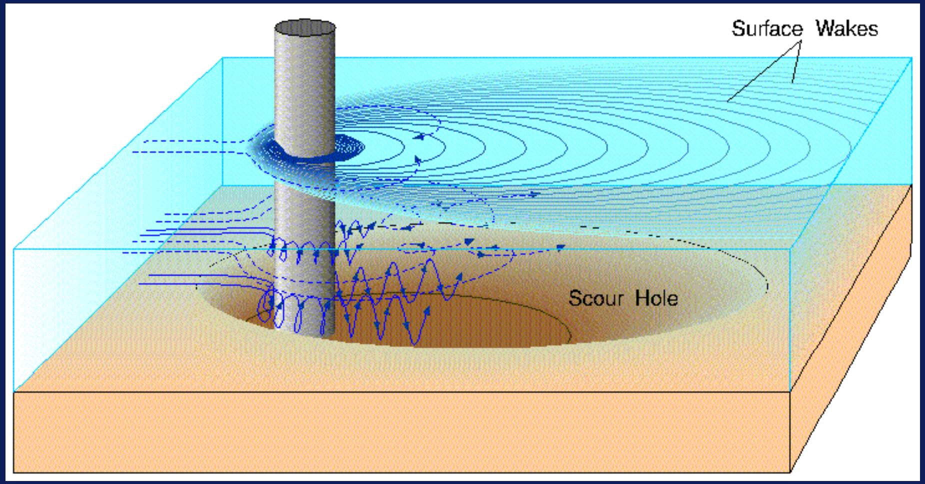
Evaluating Scour at Bridges
Fifth Edition

U.S. Department of Transportation
Federal Highway Administration

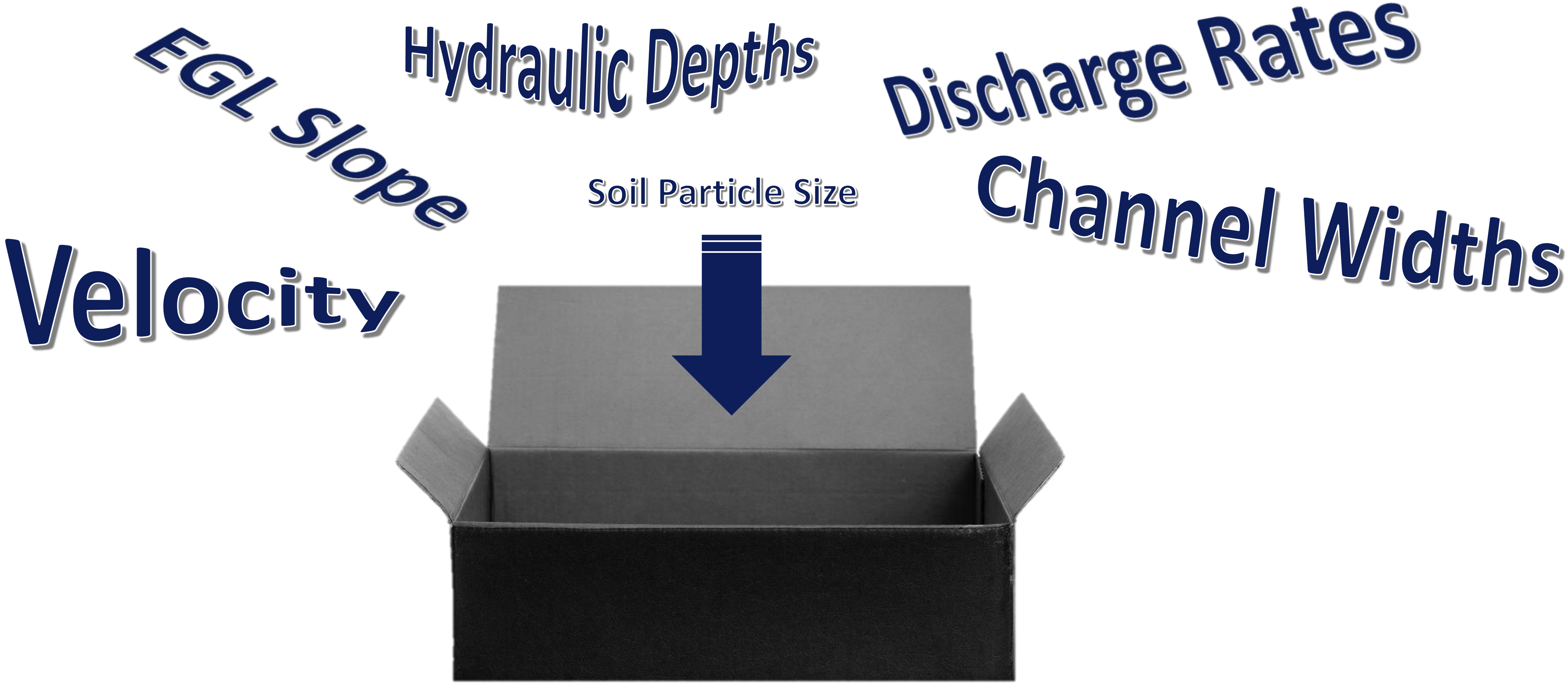
Contraction Scour



Pier (Local) Scour

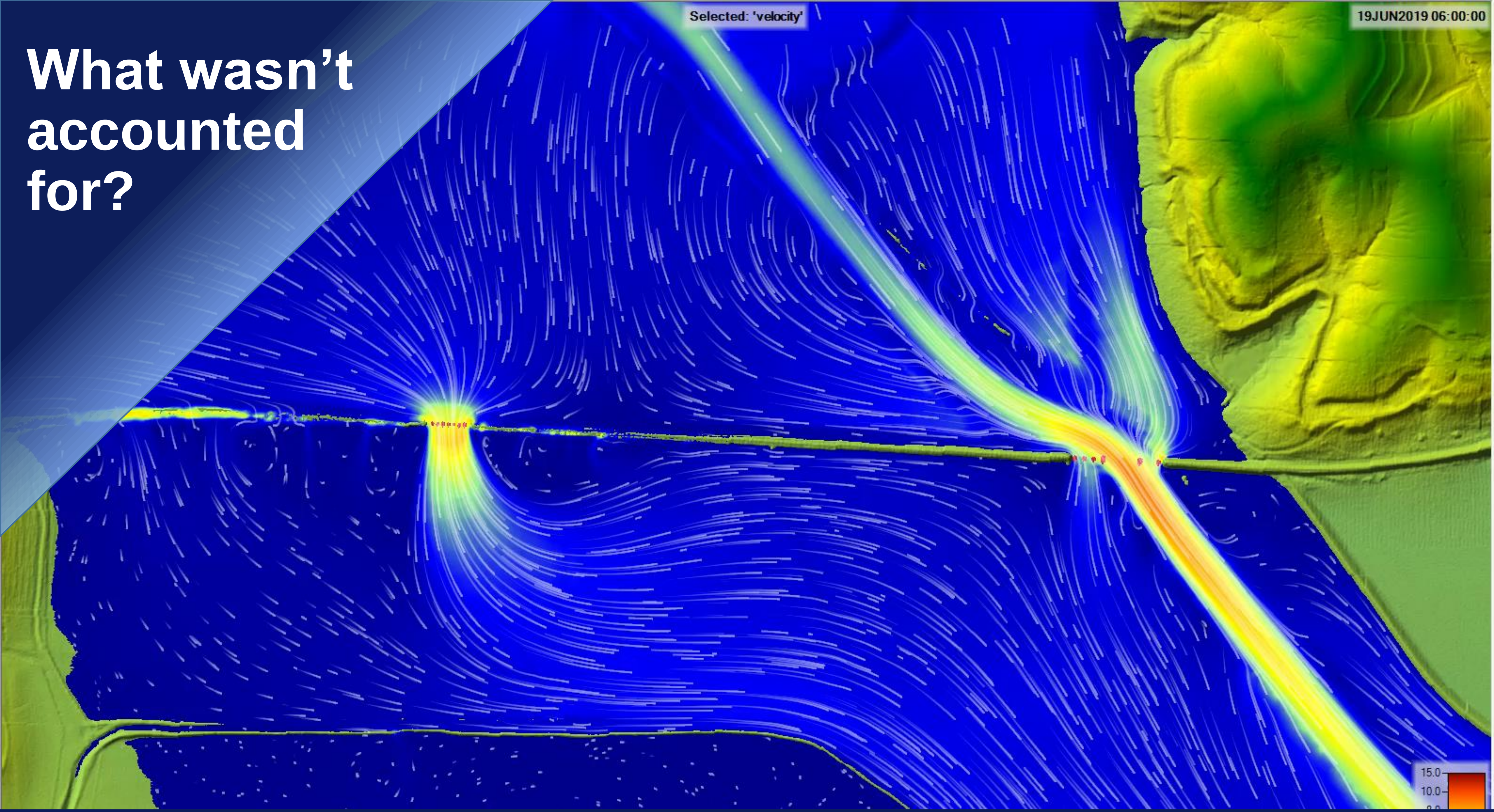


Scour Analysis



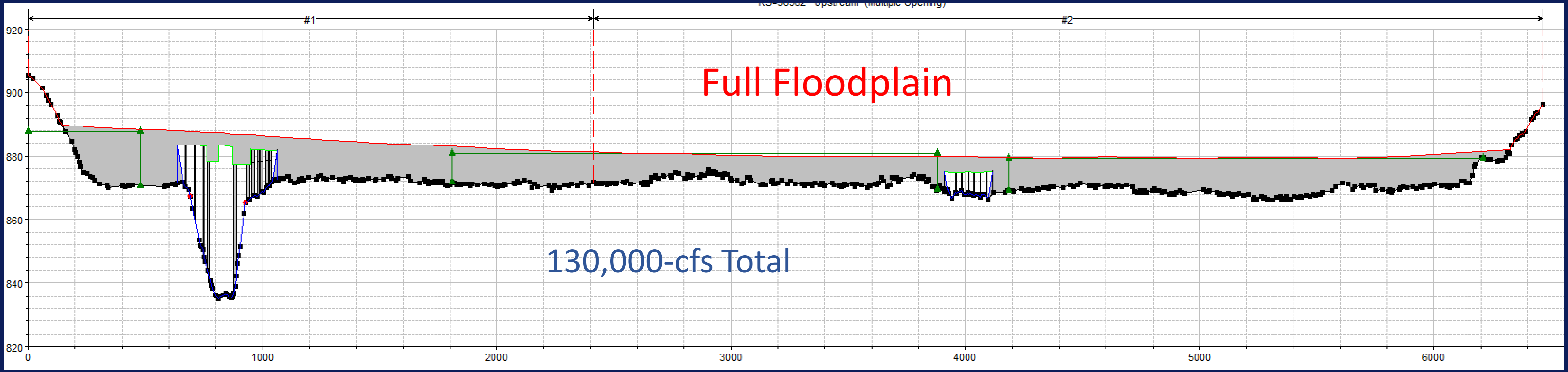
Scour Results

What wasn’t accounted for?

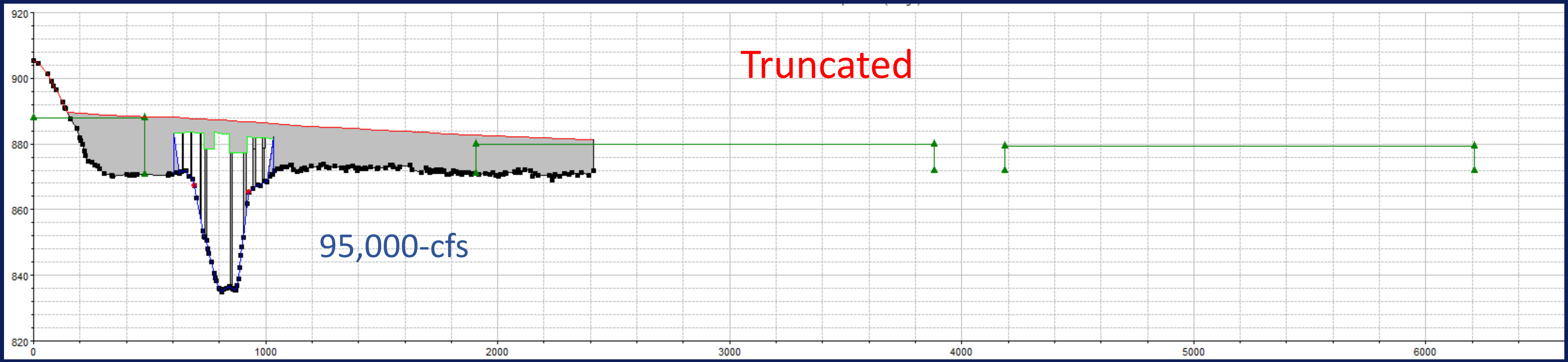


Truncated

1-D Model

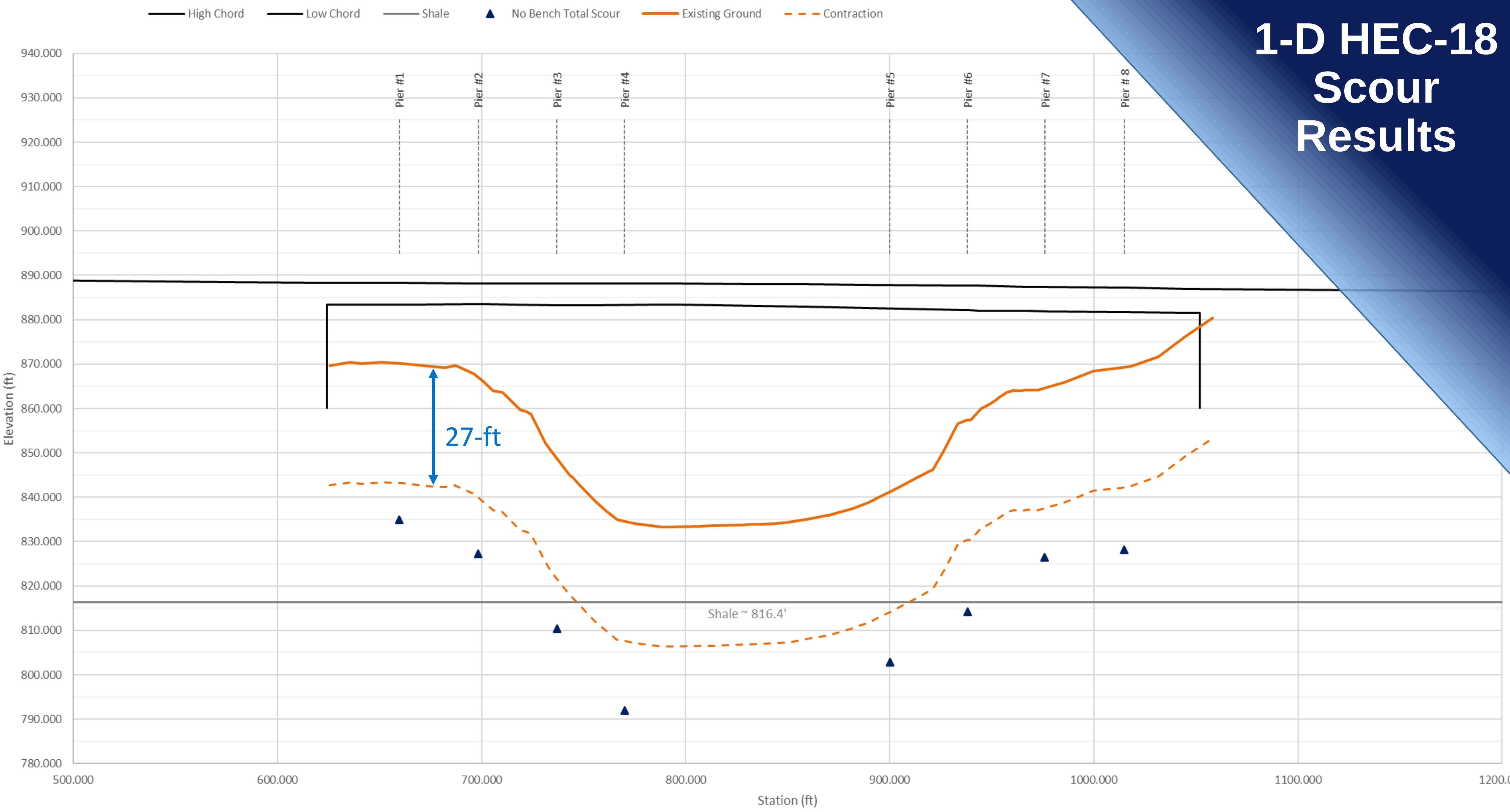


#1
#2
Full Floodplain
130,000-cfs Total
920
900
880
860
840
820
0
1000
2000
3000
4000
5000
6000

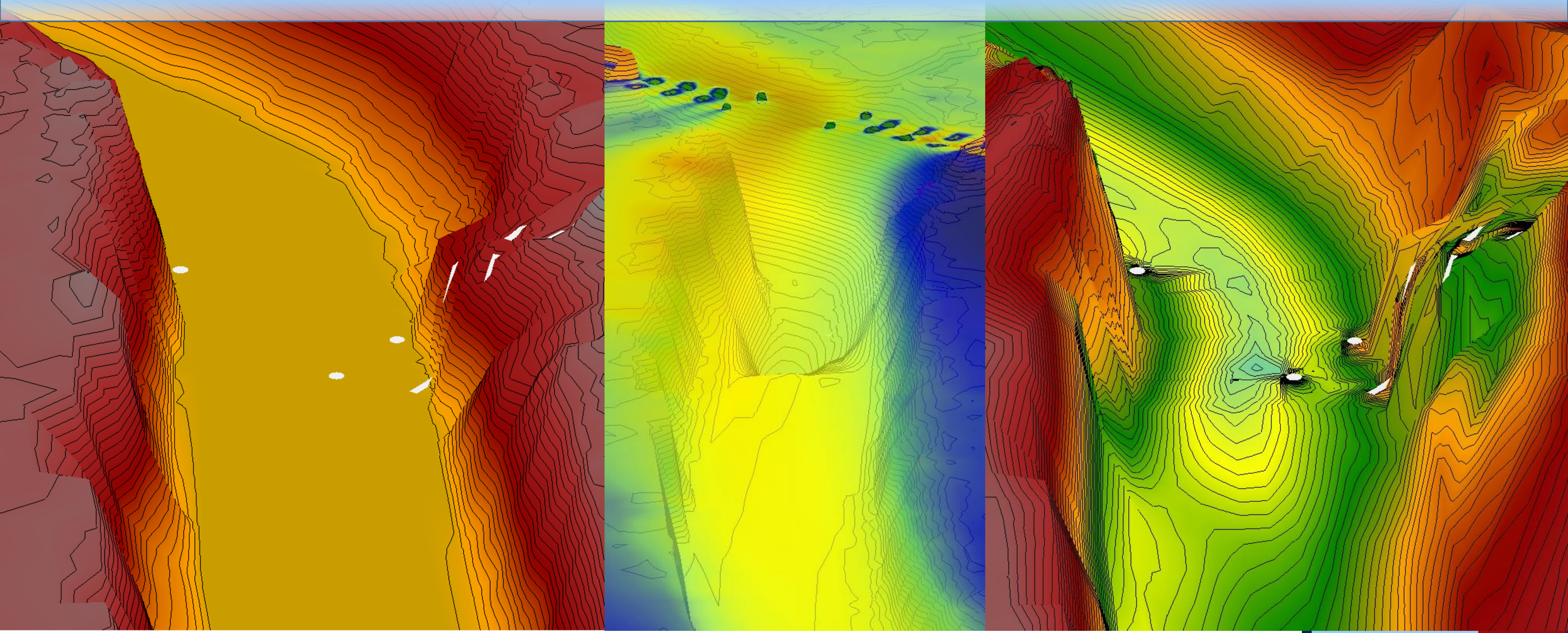


Truncated
95,000-cfs
920
900
880
860
840
820
0
1000
2000
3000
4000
5000
6000

1-D HEC-18 Scour Results

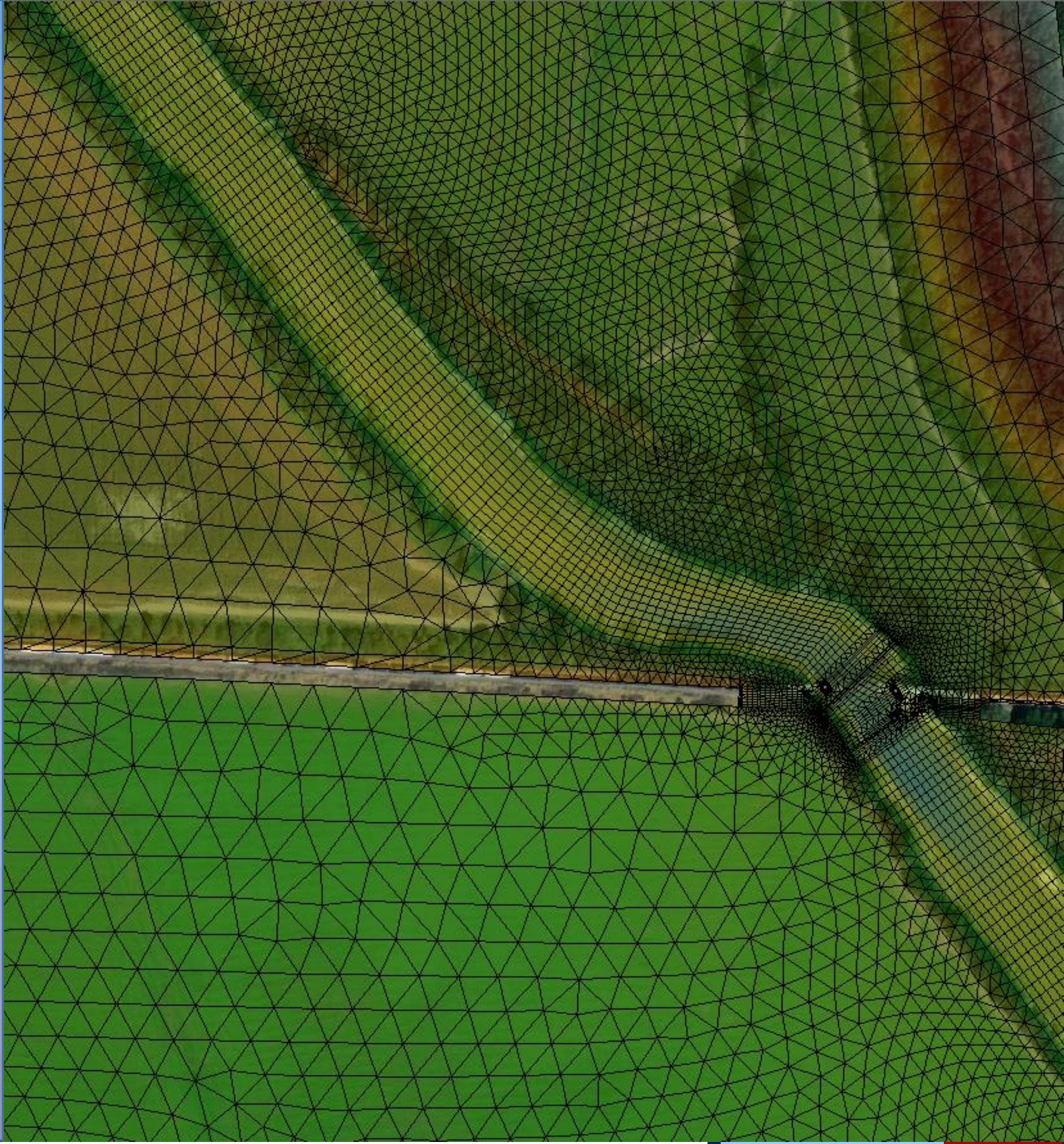


SRH-2D (Sedimentation and River Hydraulics)



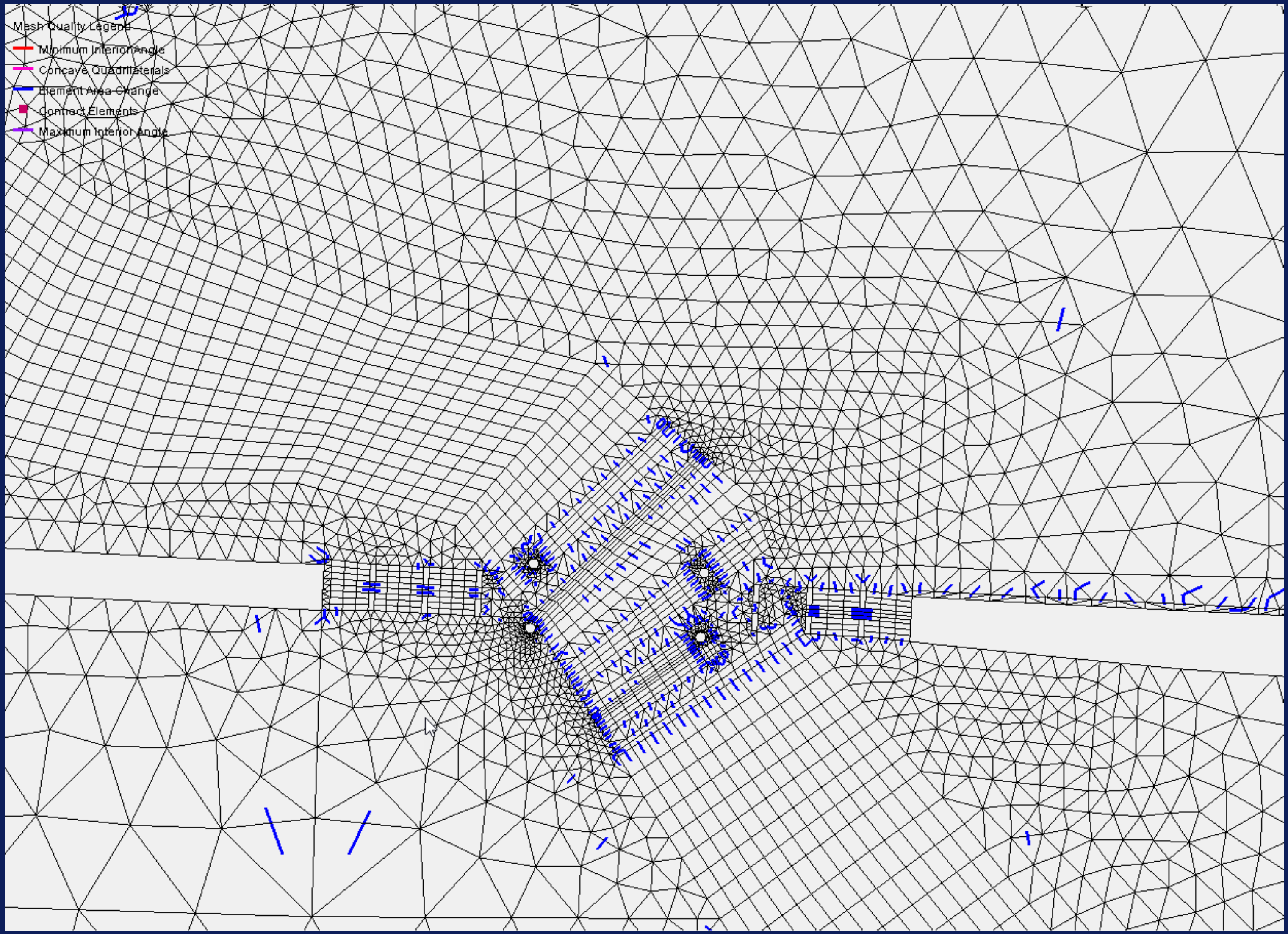
2D Steady State

- Steady Flow – No Transport
- Restart Required
- Ensure model accuracy
  - Keep Sediment Transport in Mind
  - Low Resolution Mesh
- 2D Parts
  - Mesh Density and Quality
  - Polygons/Mesh Orientation
  - Topo Surface
  - Materials
  - Boundary Conditions

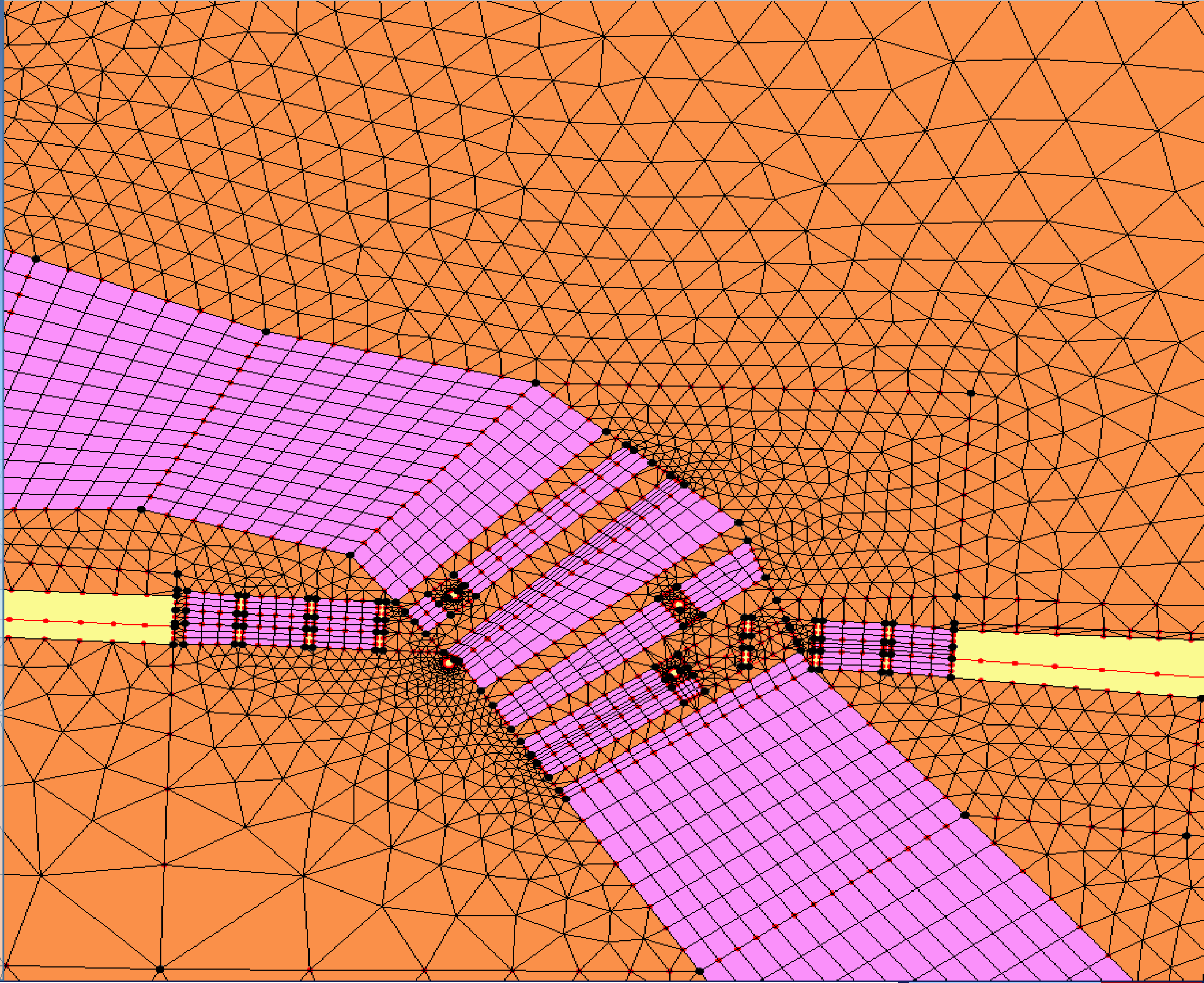


Mesh Density and Quality

- Computationally Complex
  - Steady
    - 150,000 elements (computer power)
  - Sediment
    - 40,000 but 30 is better
- 5-ft to 100-ft
- Maintain Quality
- Hole in mesh
  - No Slip

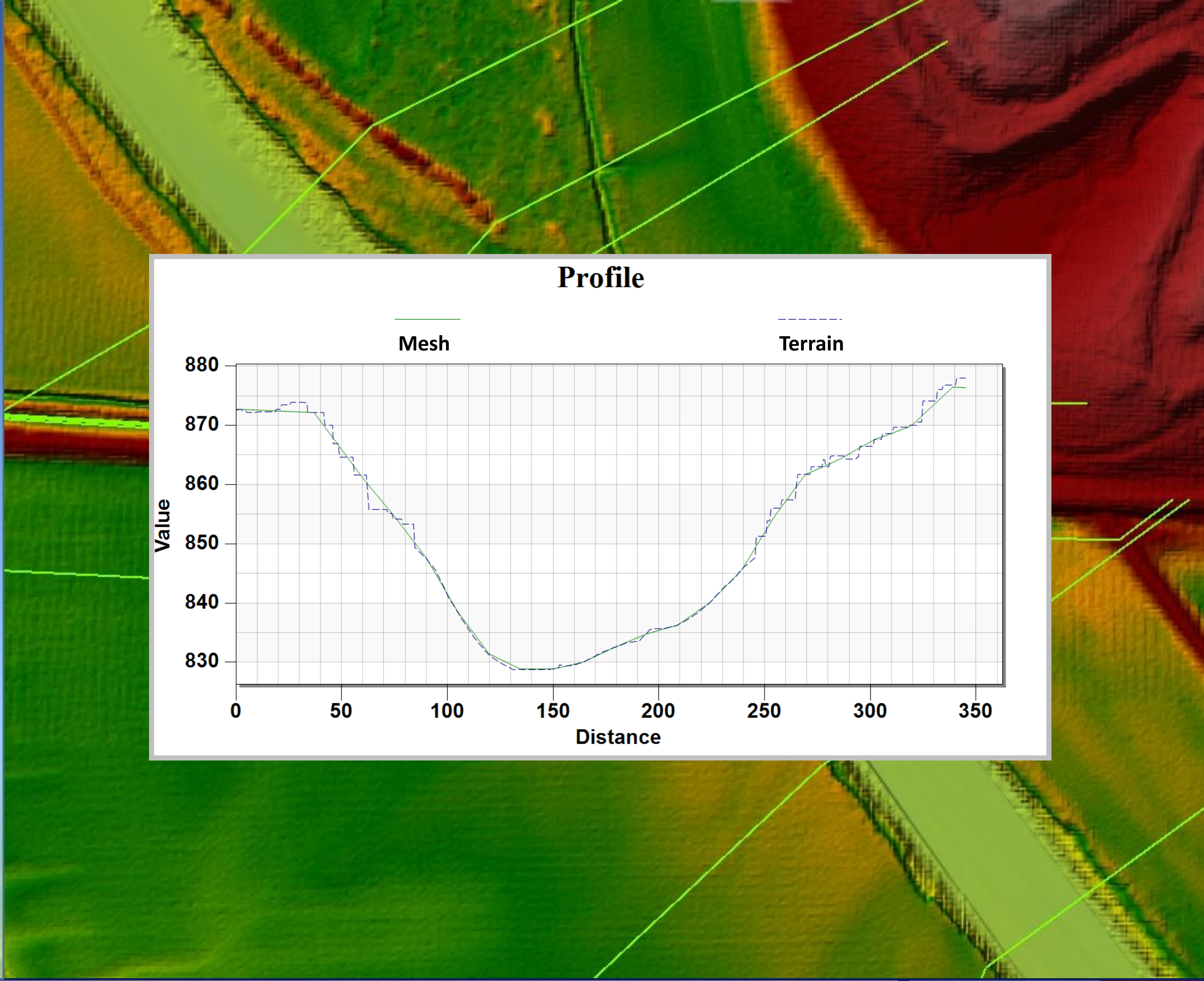


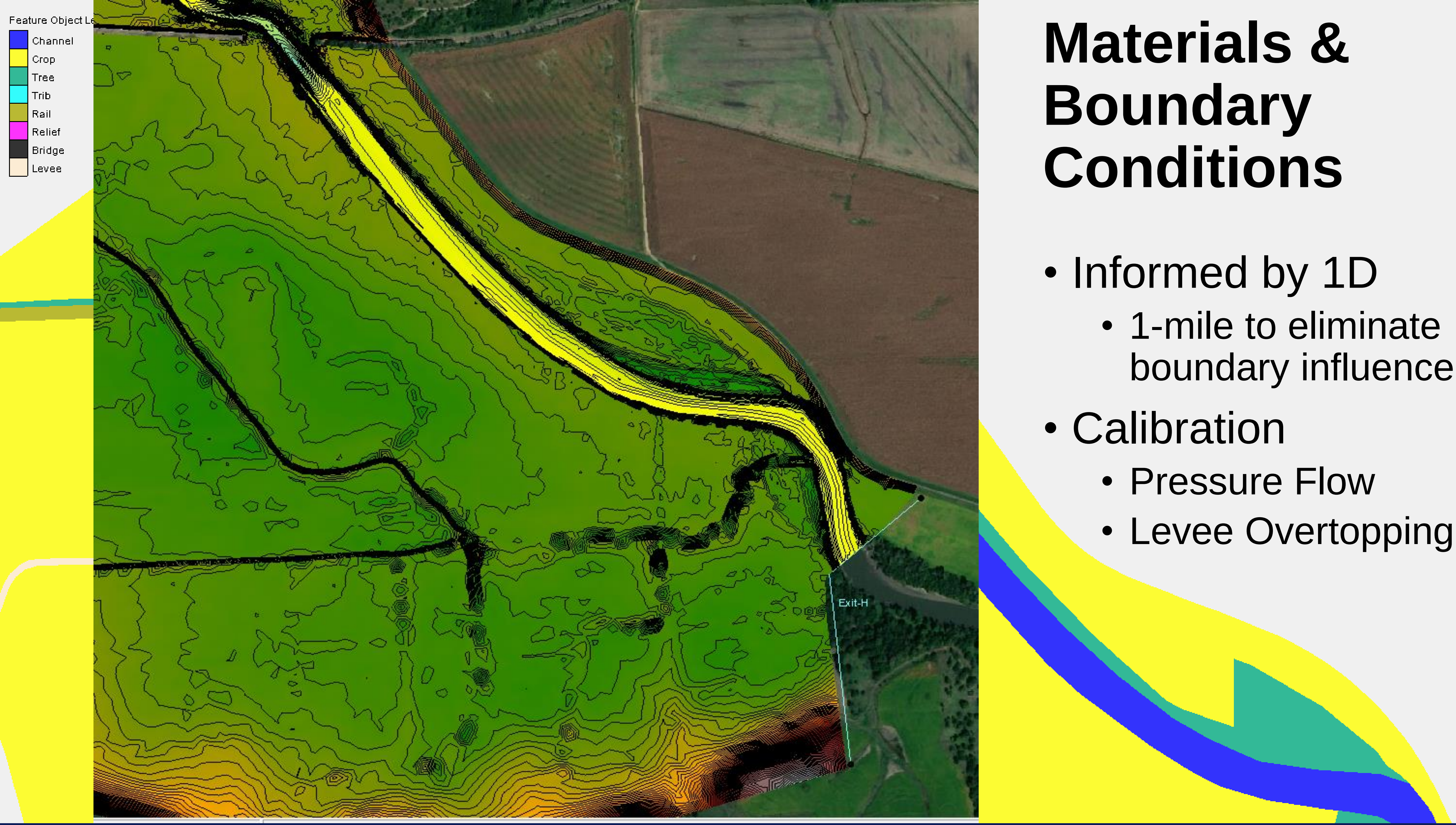
Quadrilateral Elements



Surface Terrain

- Stamped Channel
  - HEC-RAS
  - SMS
- Resolution vs Detail

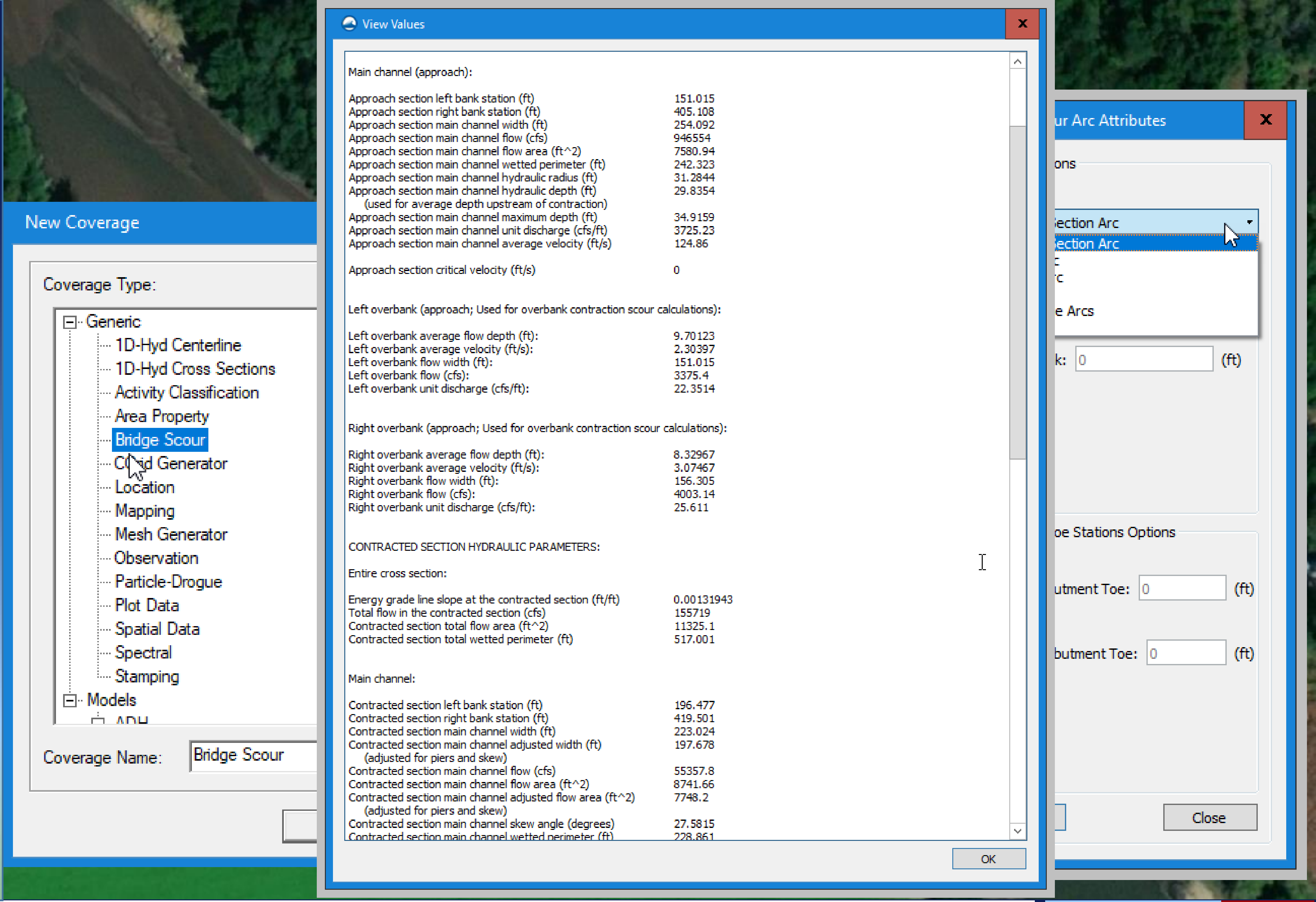




Materials & Boundary Conditions

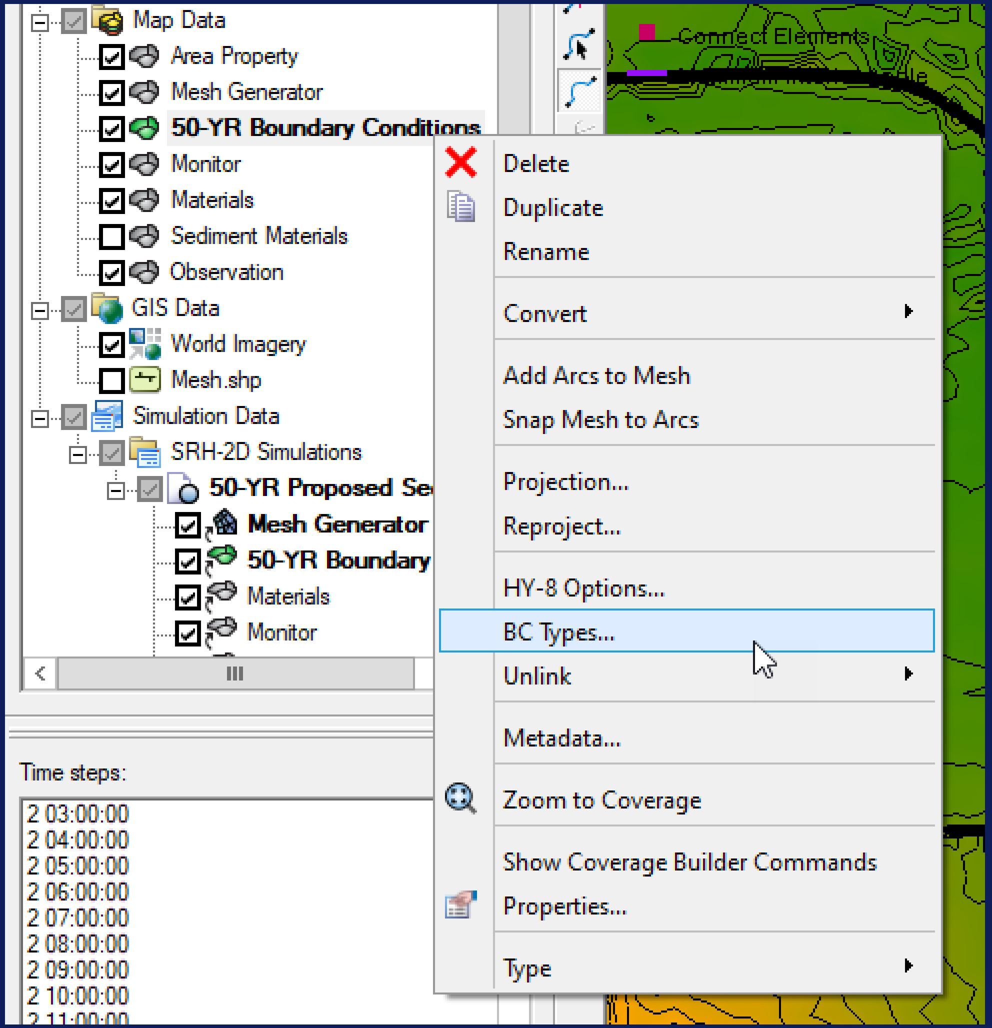
- Informed by 1D
  - 1-mile to eliminate boundary influence
- Calibration
  - Pressure Flow
  - Levee Overtopping

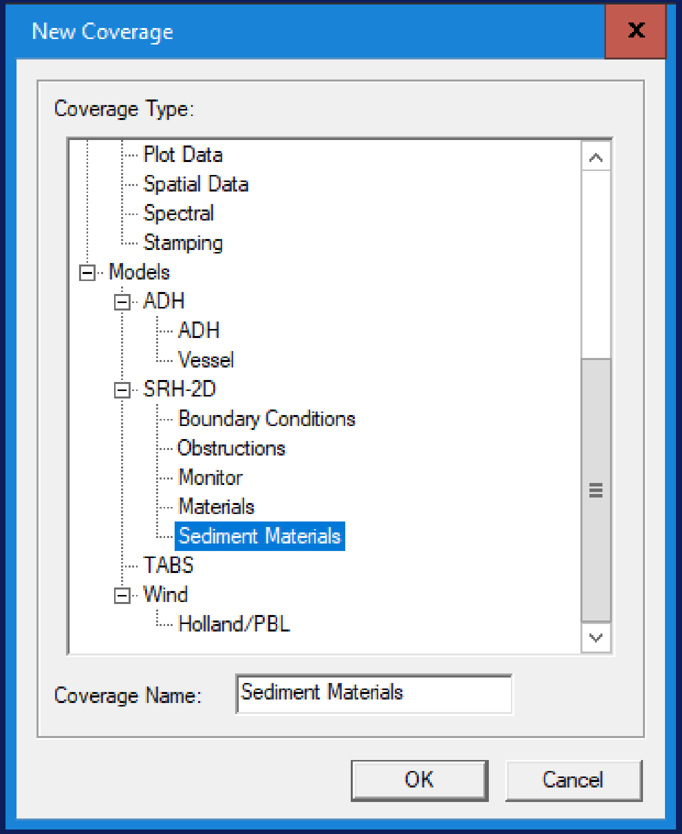
2D/1D Scour Tool



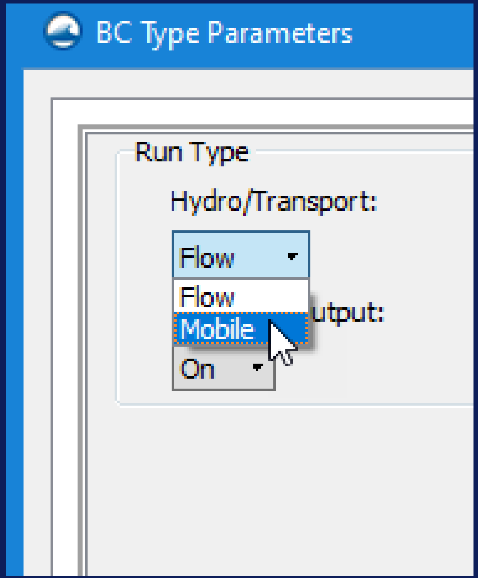
2D Sediment Workflow

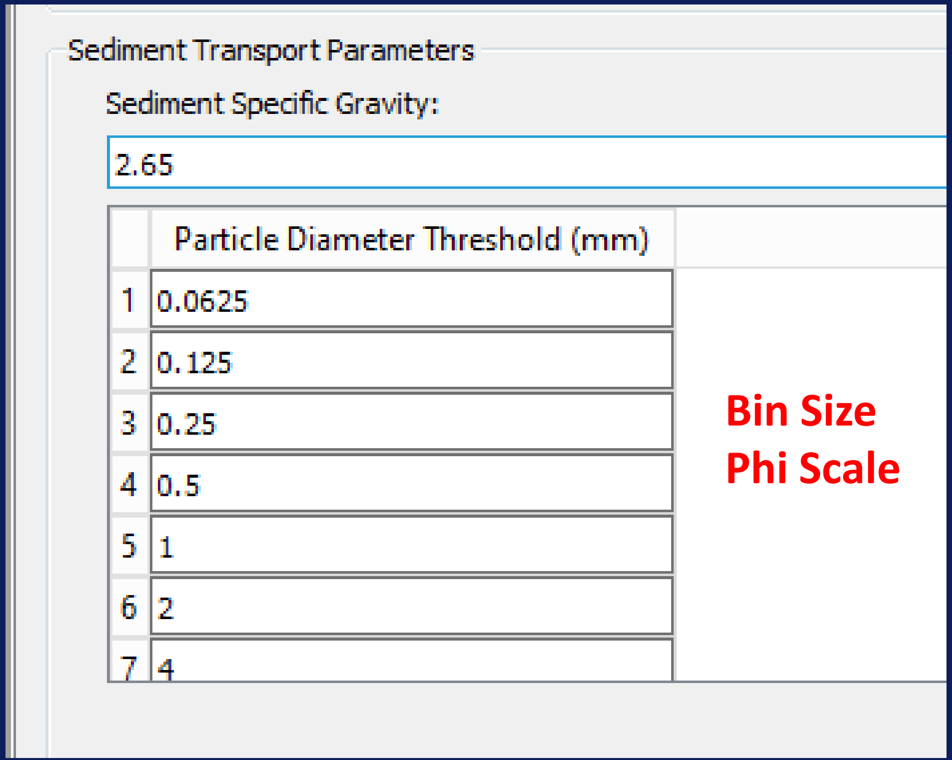
- 2 Changes
  - Boundary Condition
  - Materials





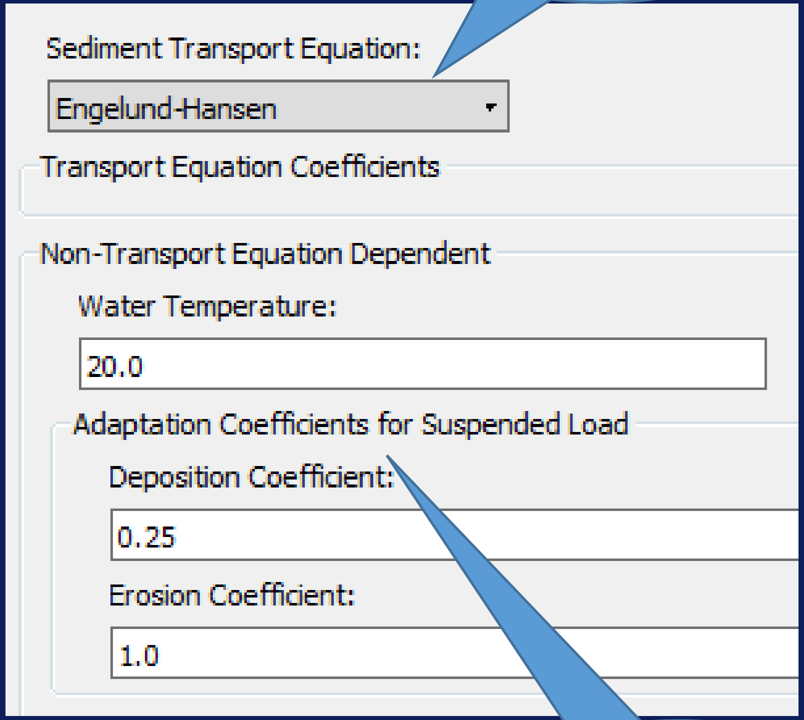
Boundary Condition – Sediment Transport





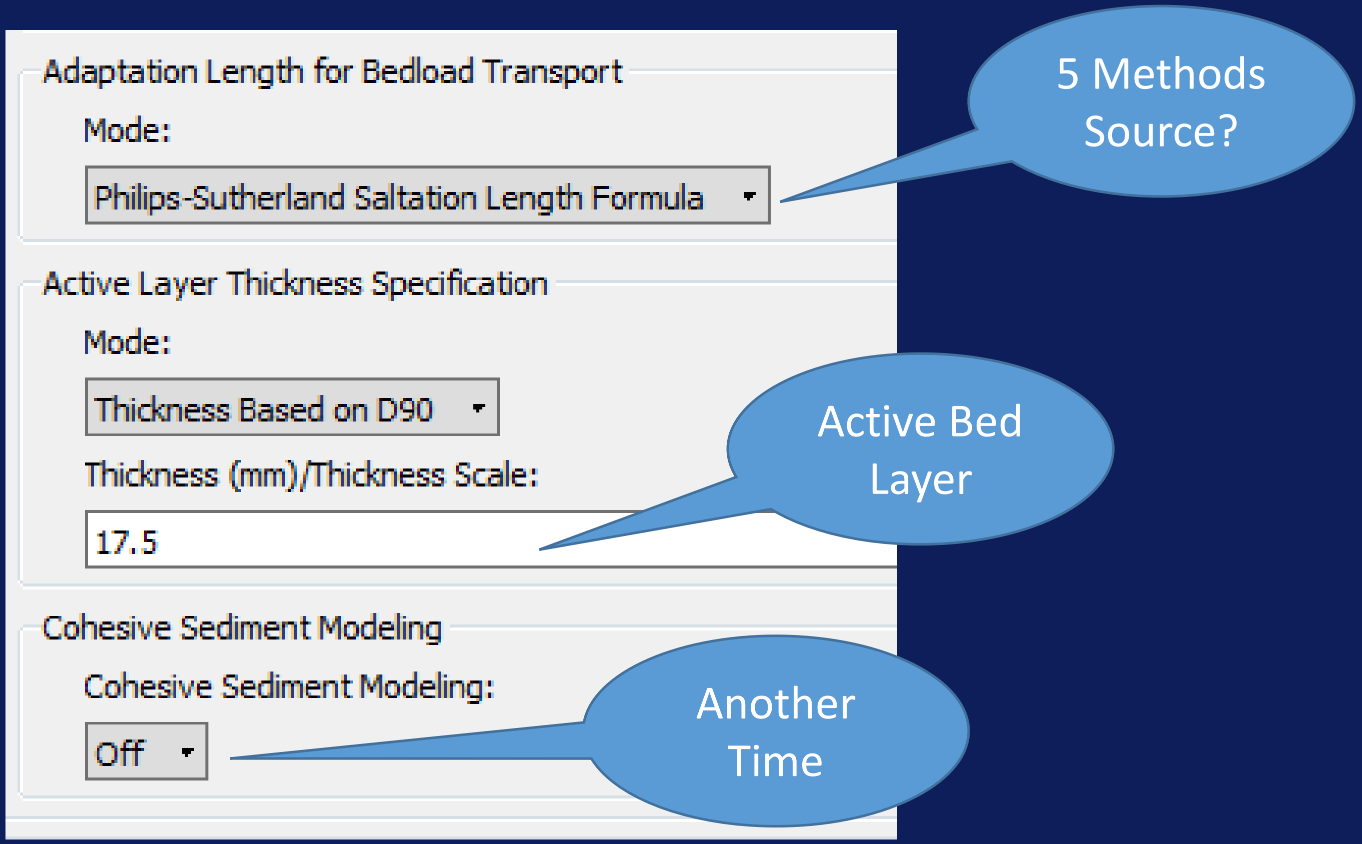
Bin Size
Phi Scale

8 Equations Source?



Defaults

Boundary Conditions - Part 2

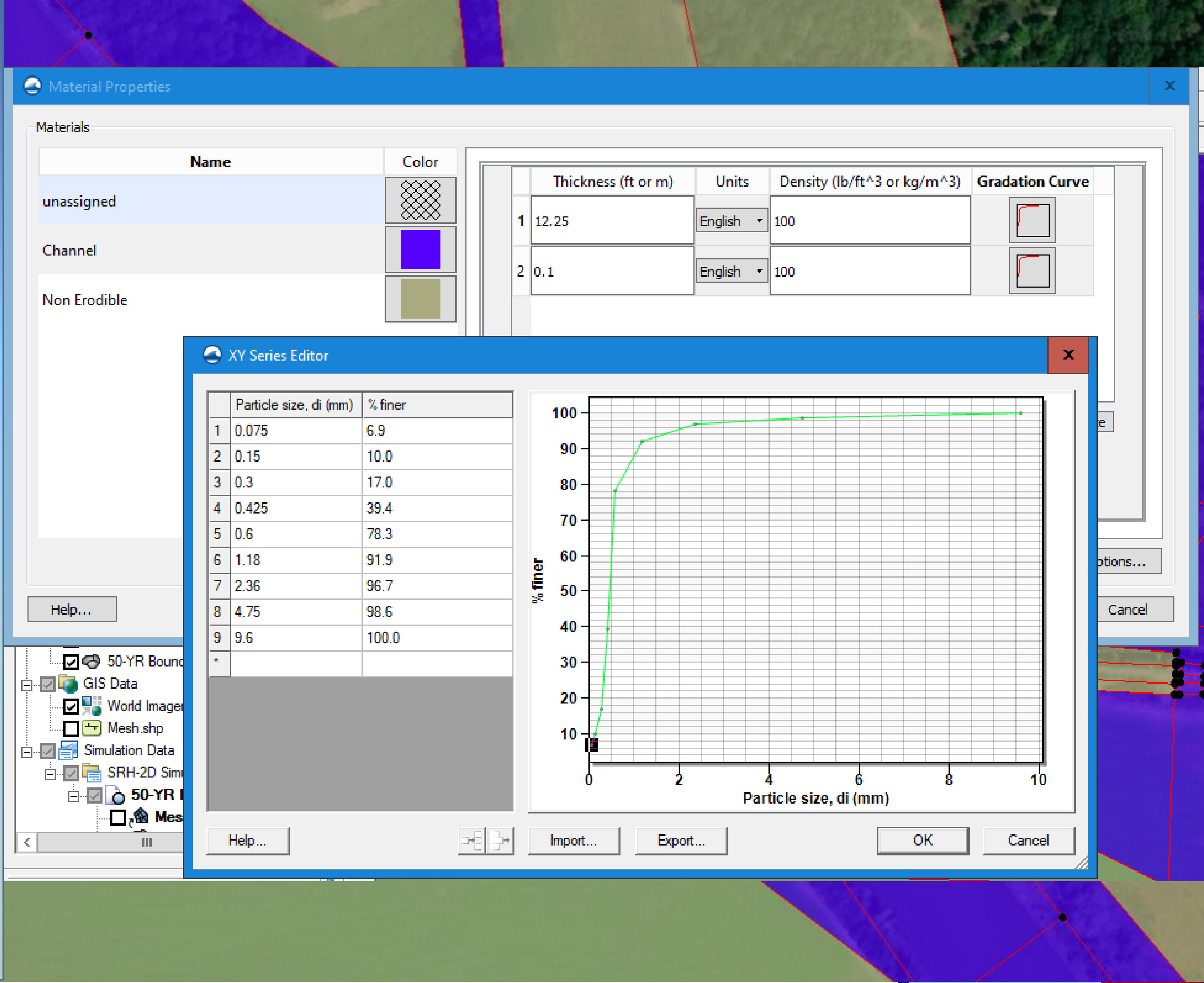


- Total Sediment Load
  - Bed Load
  - Suspended Load
  - Wash Load

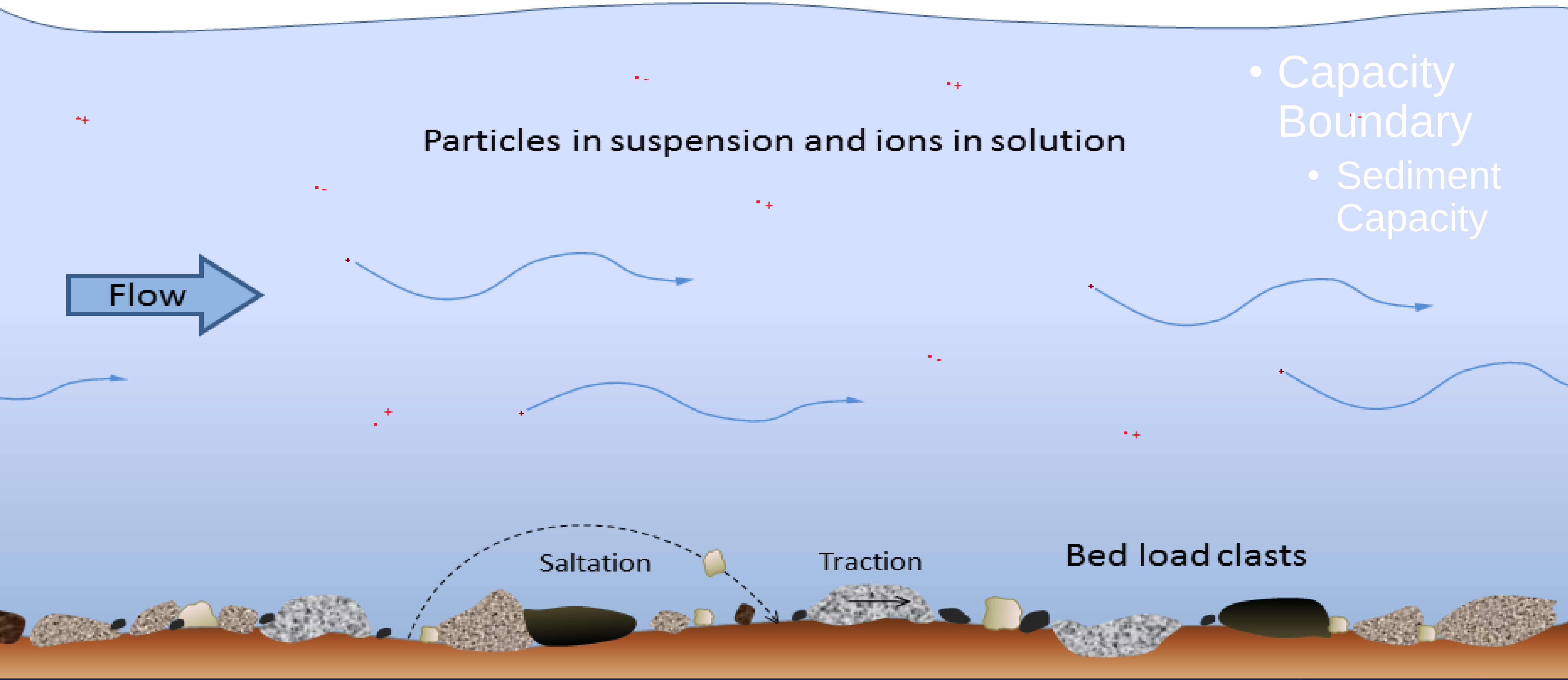
  - Sediment Type
    - FHWA!

Sediment Materials

- Soil Type
- Boring Investigation
  - Detail?
- Level of Influence



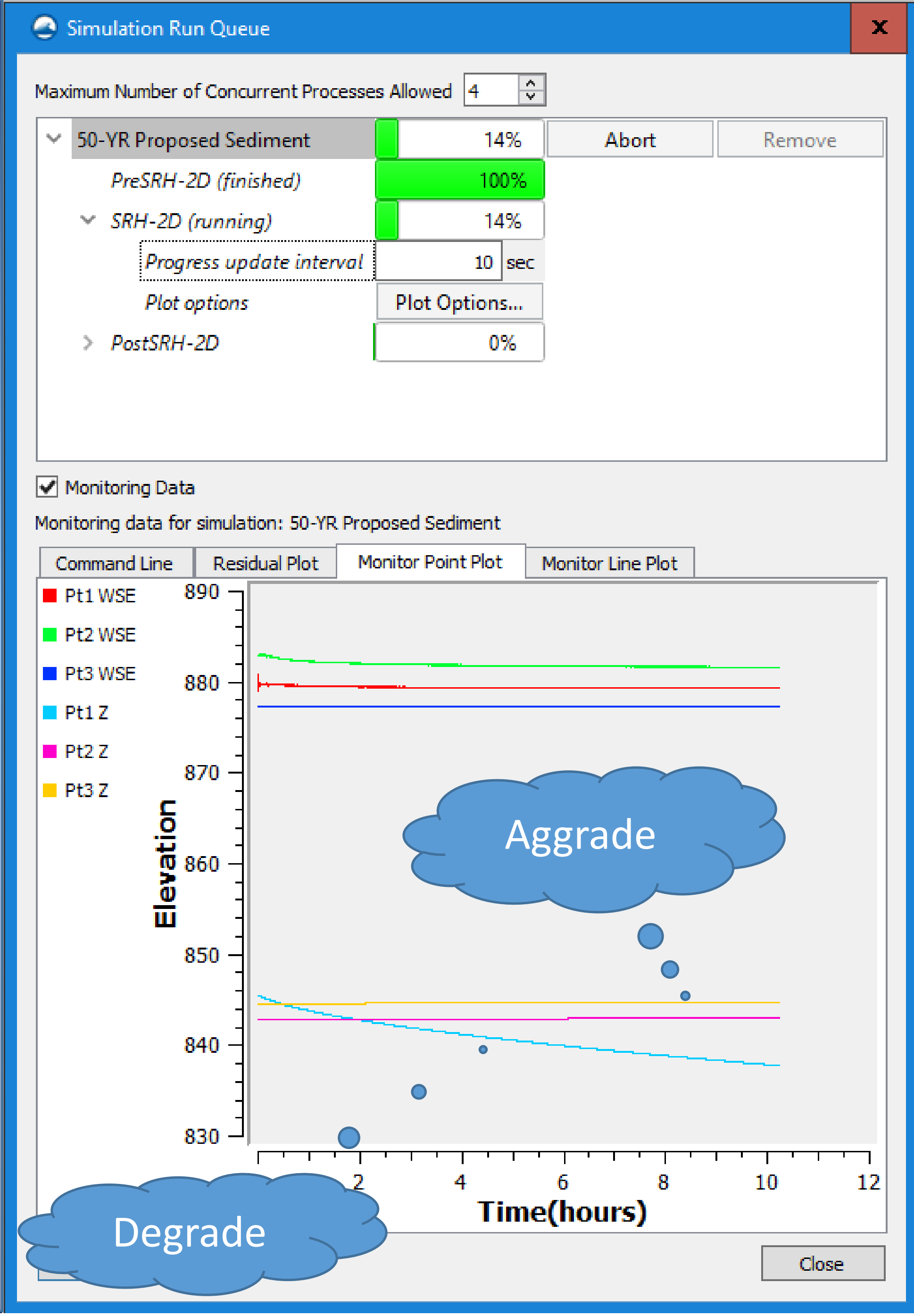
Upstream Sediment Inflow

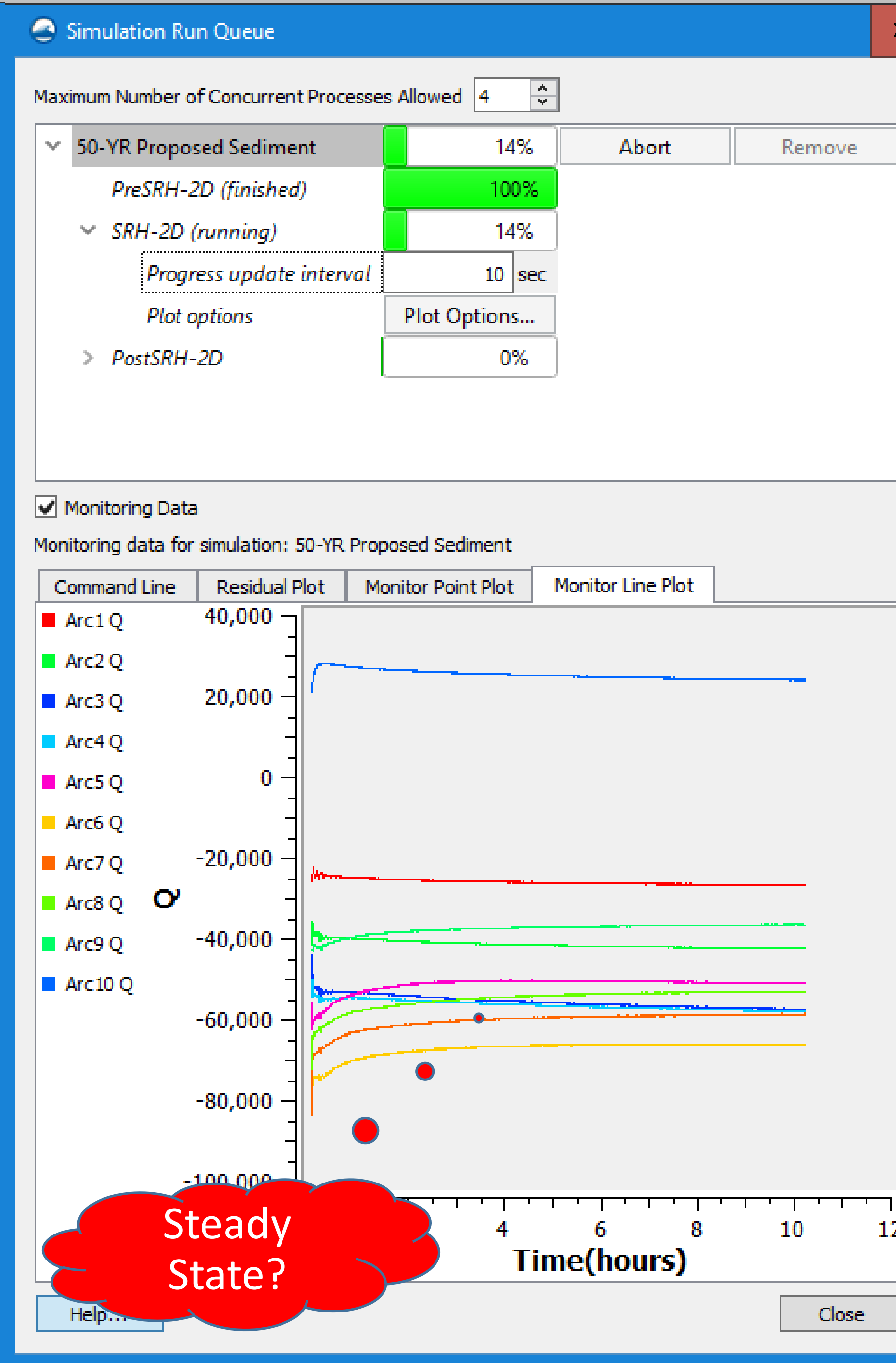


- Capacity Boundary
  - Sediment Capacity

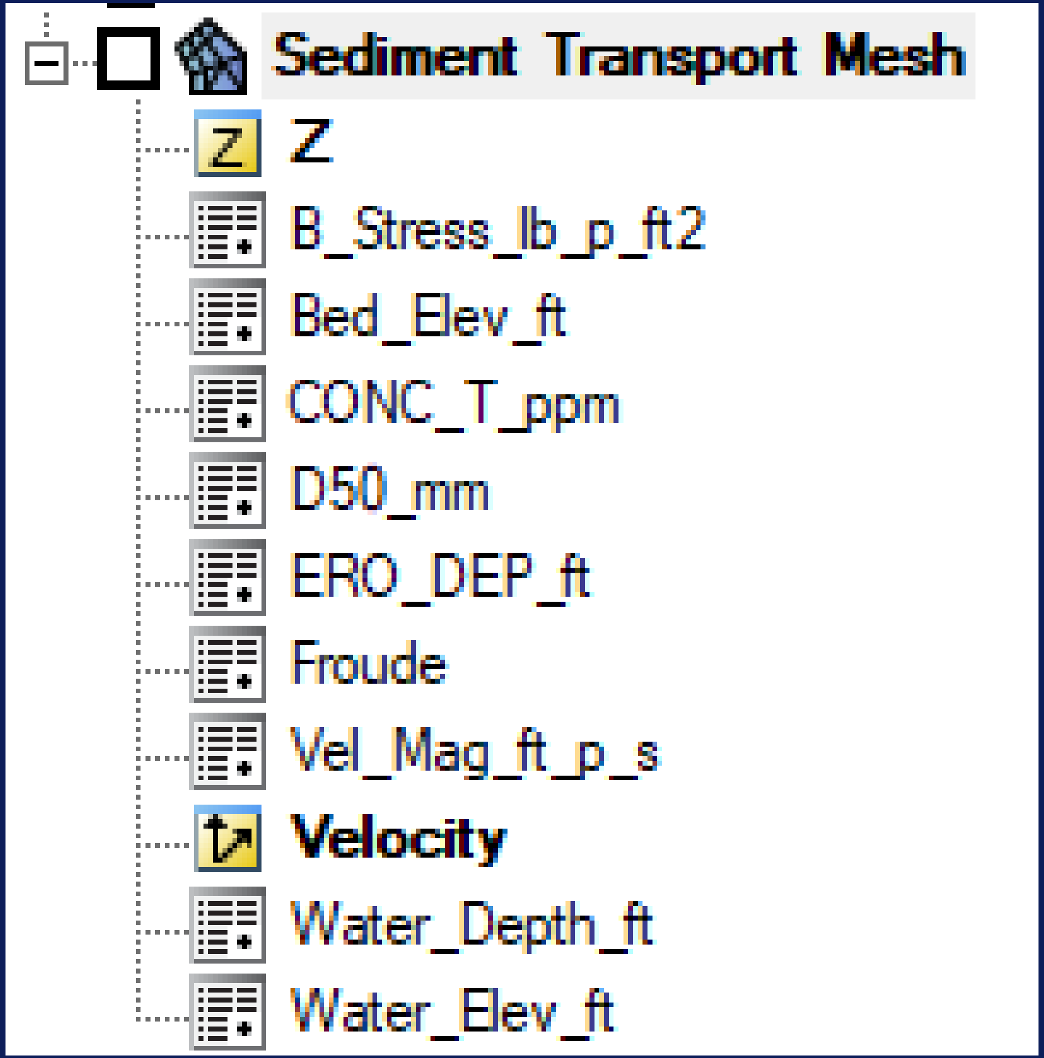
Model Results

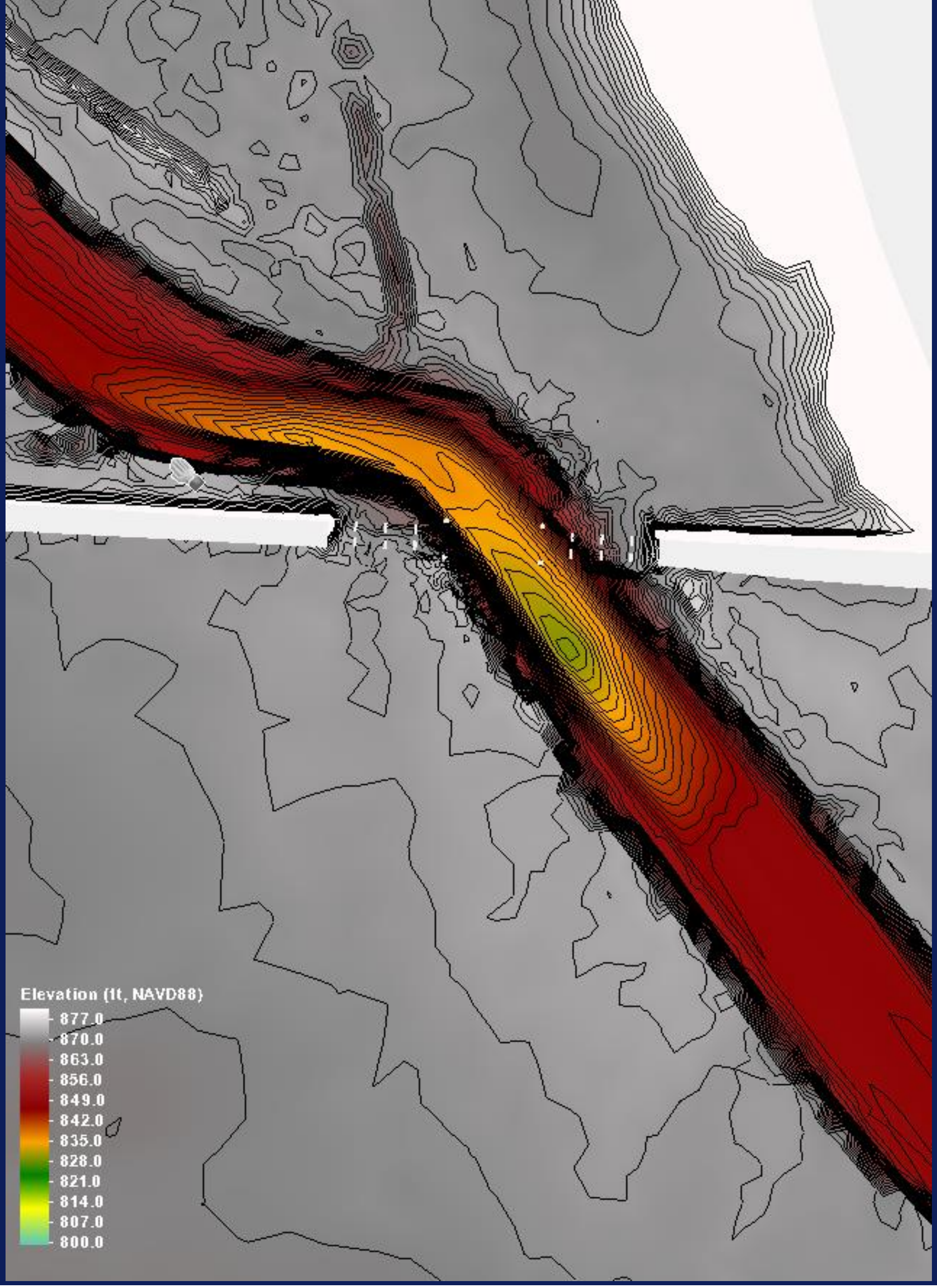
Simulation Queue

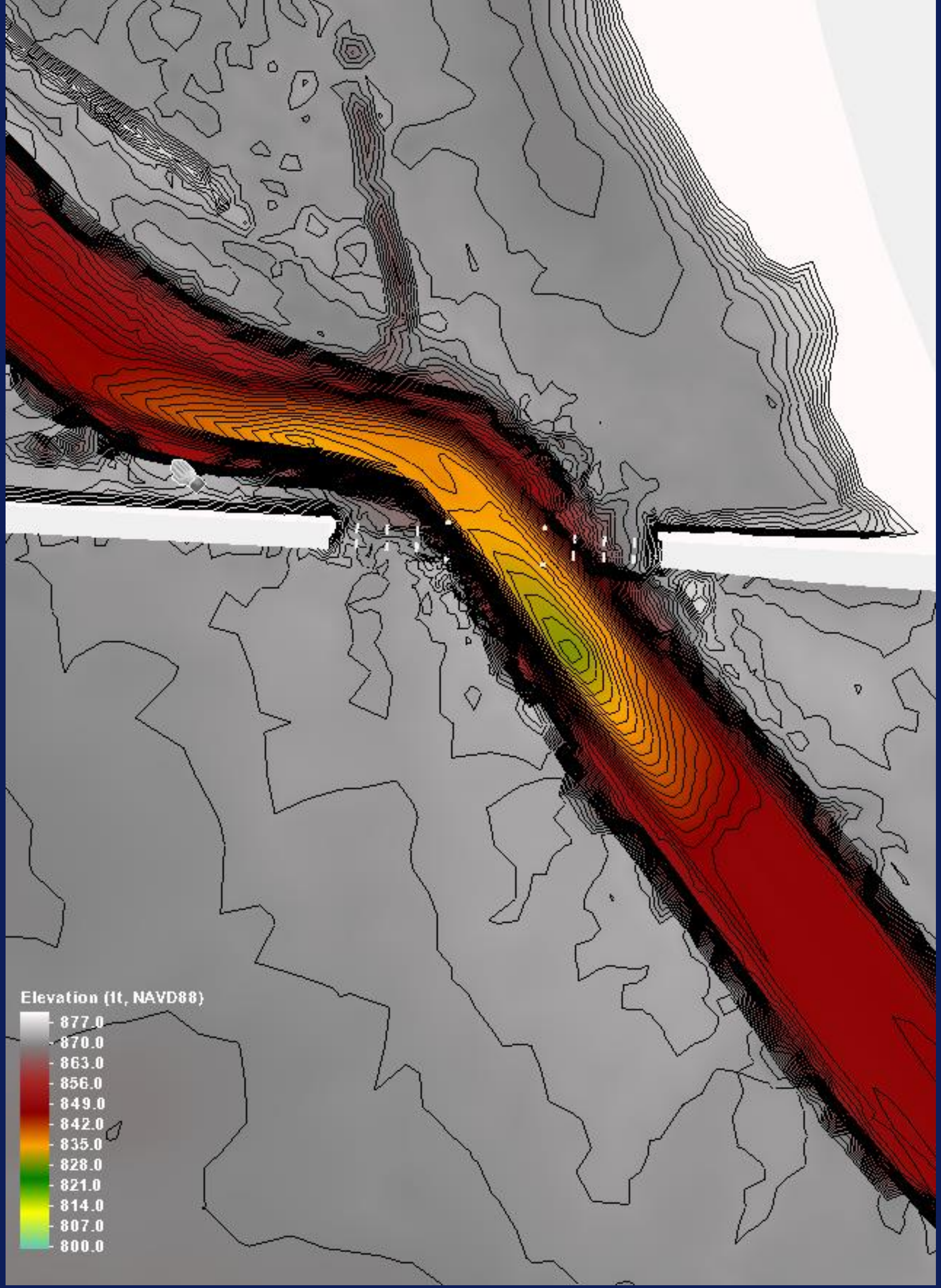


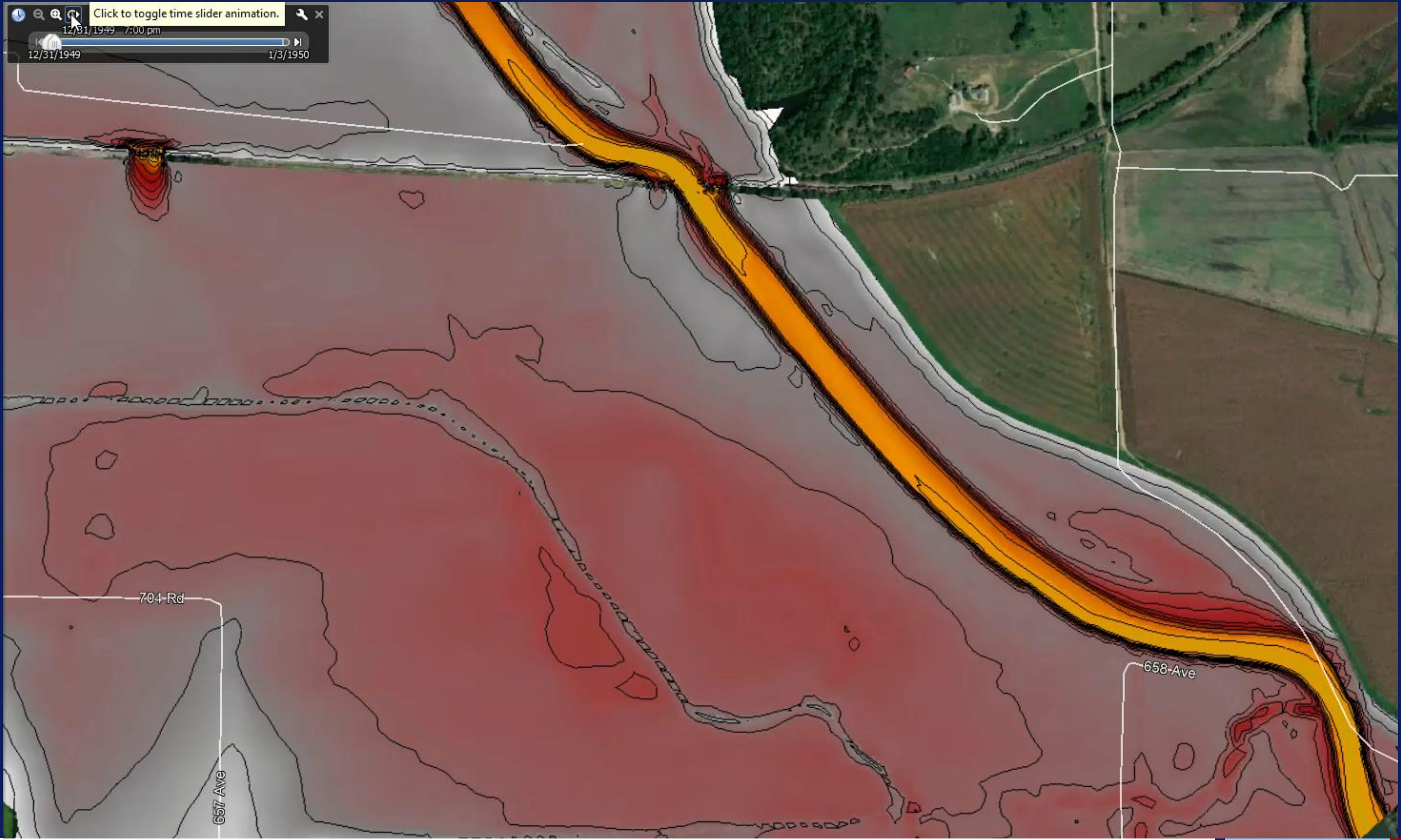


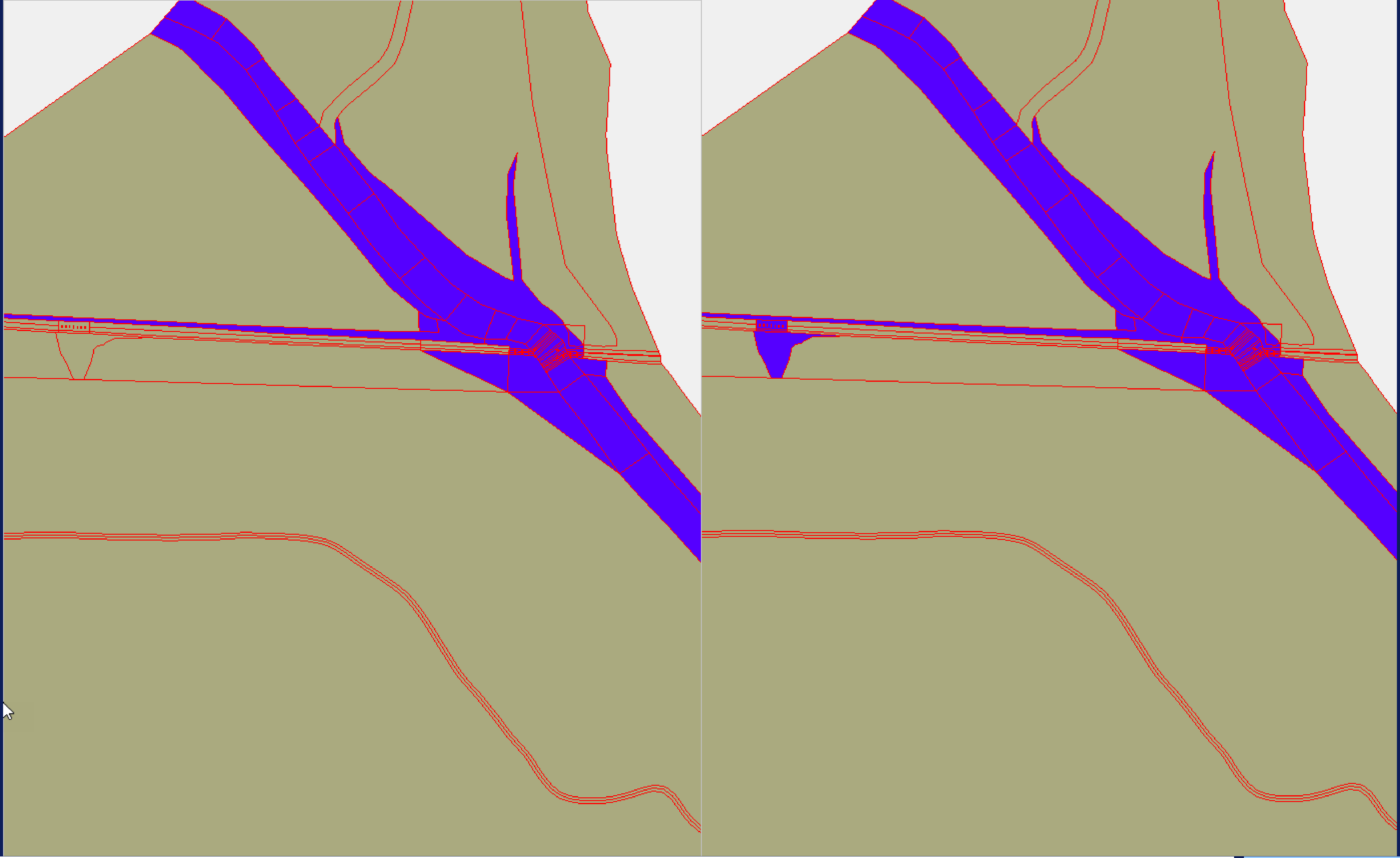
Available Results

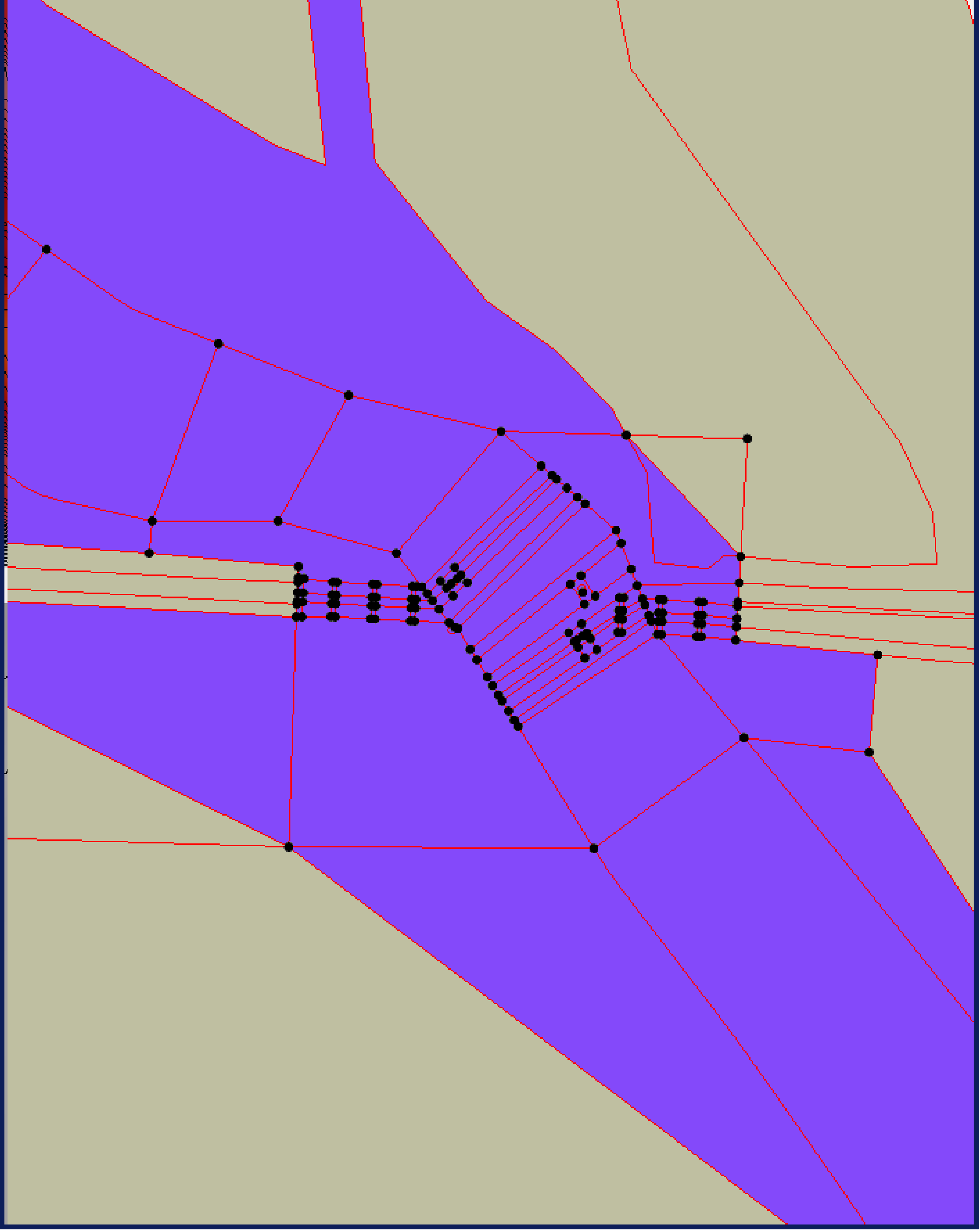
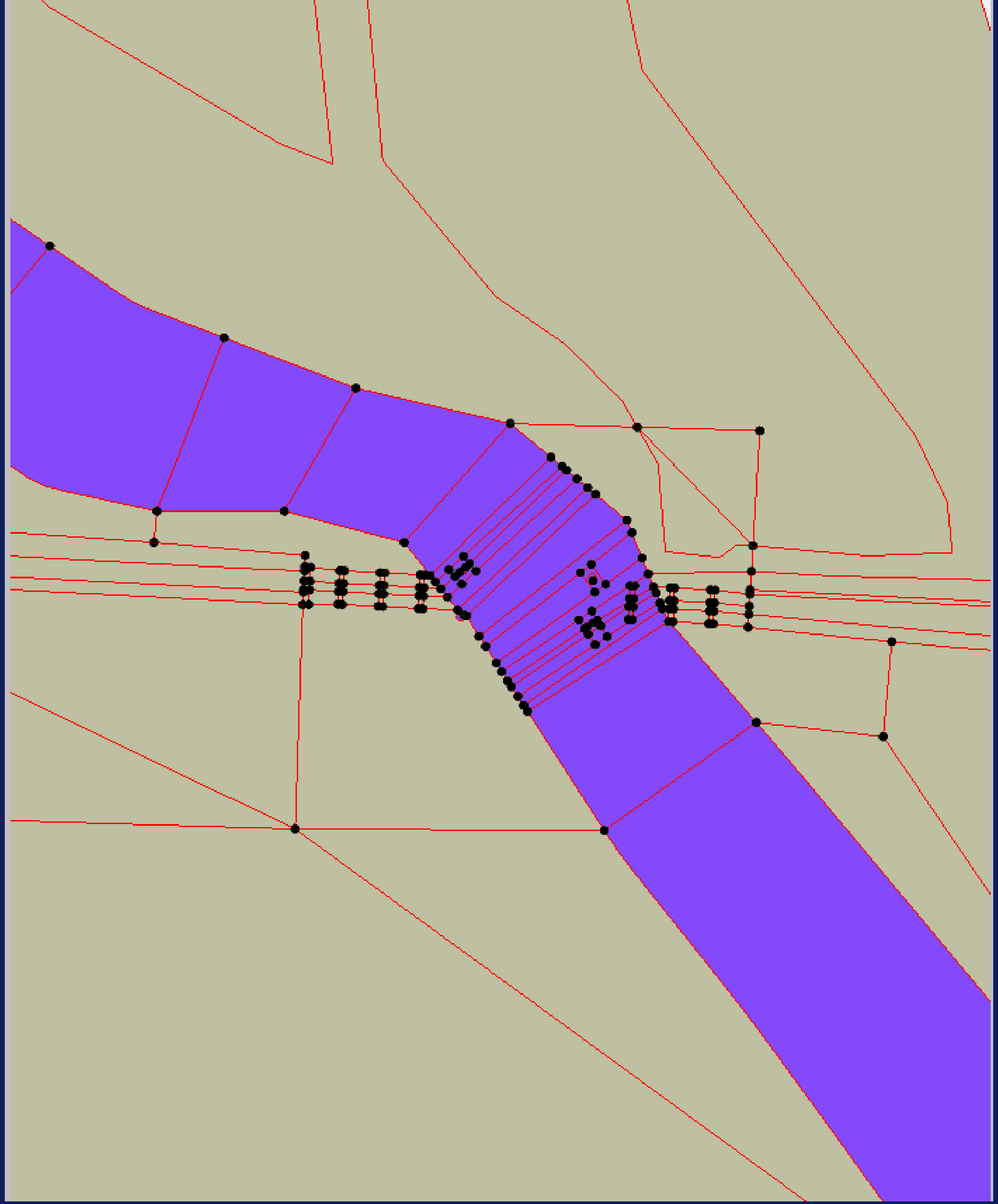


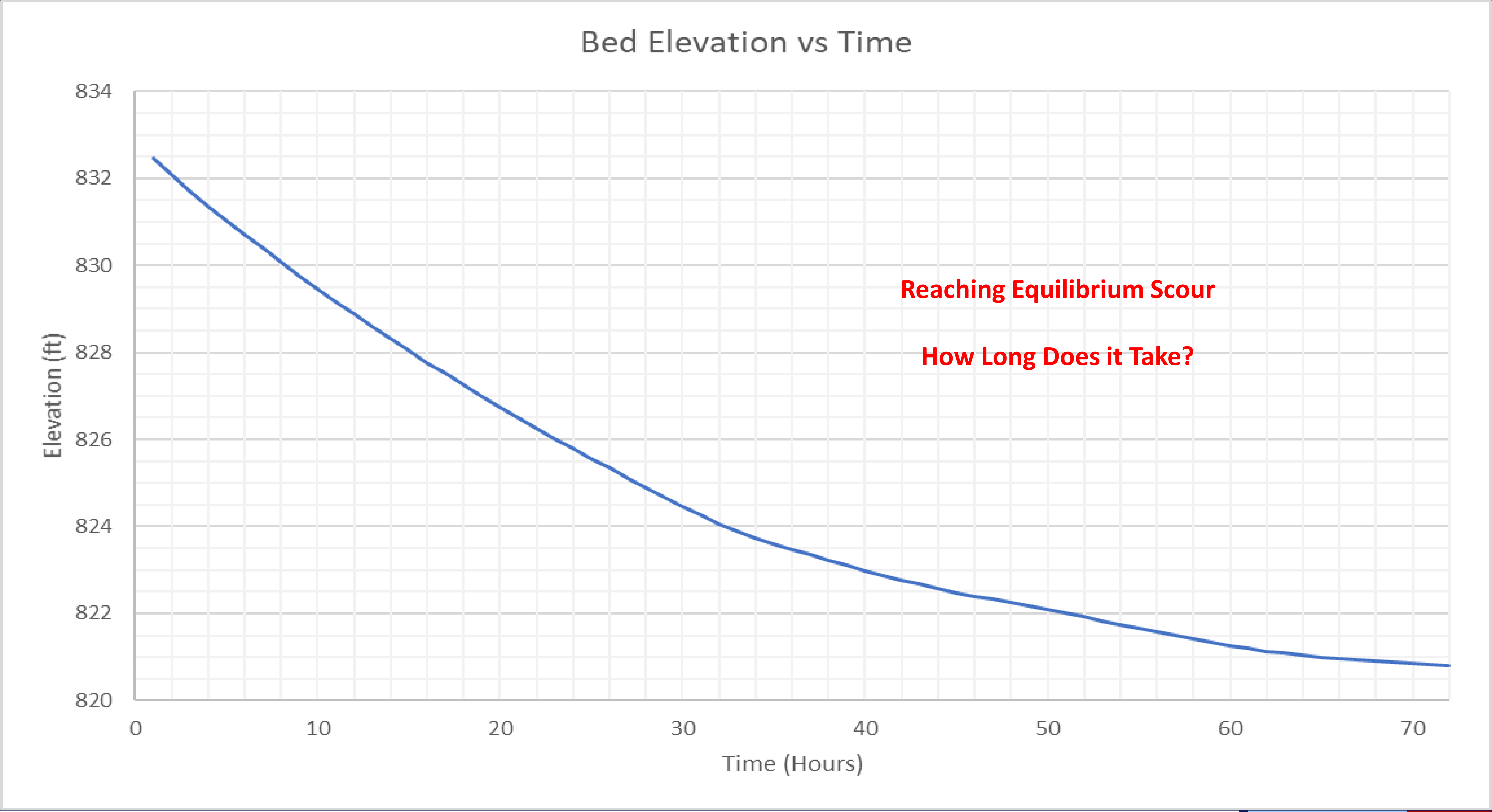

Elevation (ft, NAVD88)
877.0
870.0
863.0
856.0
849.0
842.0
835.0
828.0
821.0
814.0
807.0
800.0


Elevation (ft, NAVD88)
877.0
870.0
863.0
856.0
849.0
842.0
835.0
828.0
821.0
814.0
807.0
800.0


Click to toggle time slider animation.
12/31/1949 7:00 pm
12/31/1949
1/3/1950
704 Rd
657 Ave
658 Ave



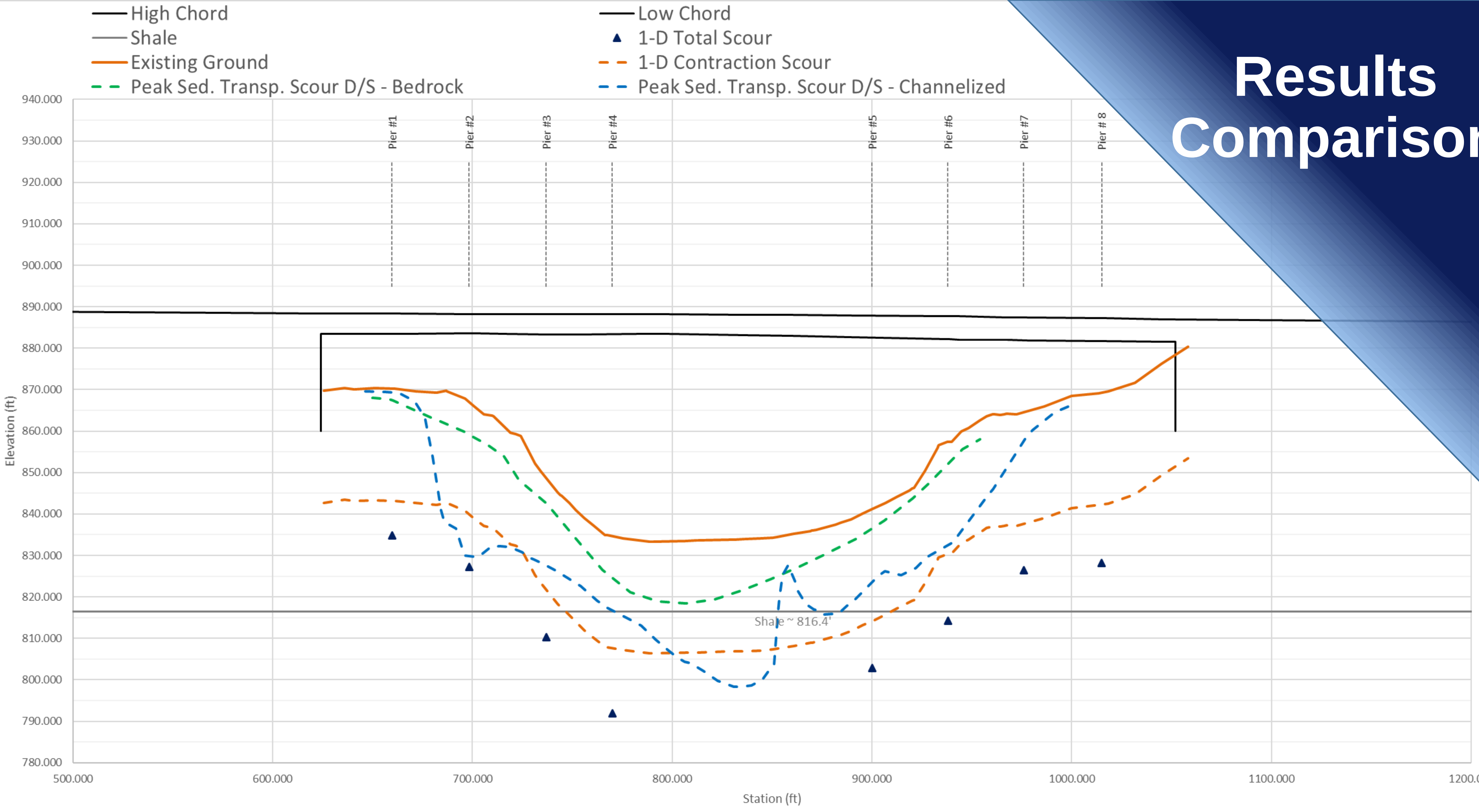

Bed Elevation vs Time
834
832
830
828
826
824
822
820
Elevation (ft)
0
10
20
30
40
50
60
70
Time (Hours)
Reaching Equilibrium Scour
How Long Does it Take?

How'd We Do

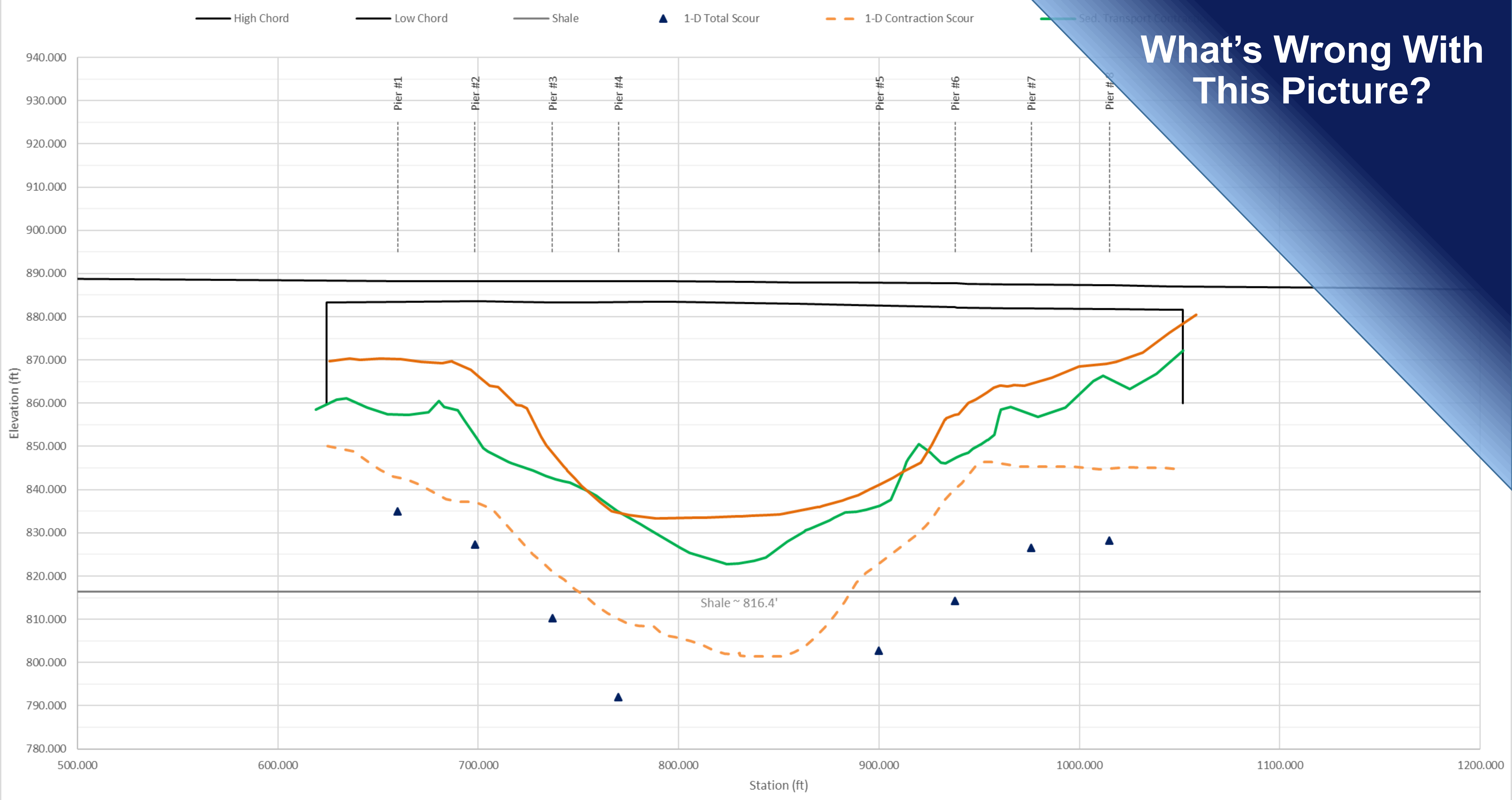
Comparison Table

Model	1-D HEC-18	2-D HEC-18	2-D Sediment Transport (Pre-Scour)	2-D Sediment Transport (Post-Scour to Bedrock)	2-D Sediment Transport (Post-Scour)
Flow Through Bridge (cfs)	95,317	92,339	92,339	84,700	101,000
Contraction Scour Depth (ft)	27.0	28.7	N/A	12.3	34.8
Contraction Scour Bed Elevation (ft)	806.3	804.6	833.0	820.7	798.22

Results Comparison

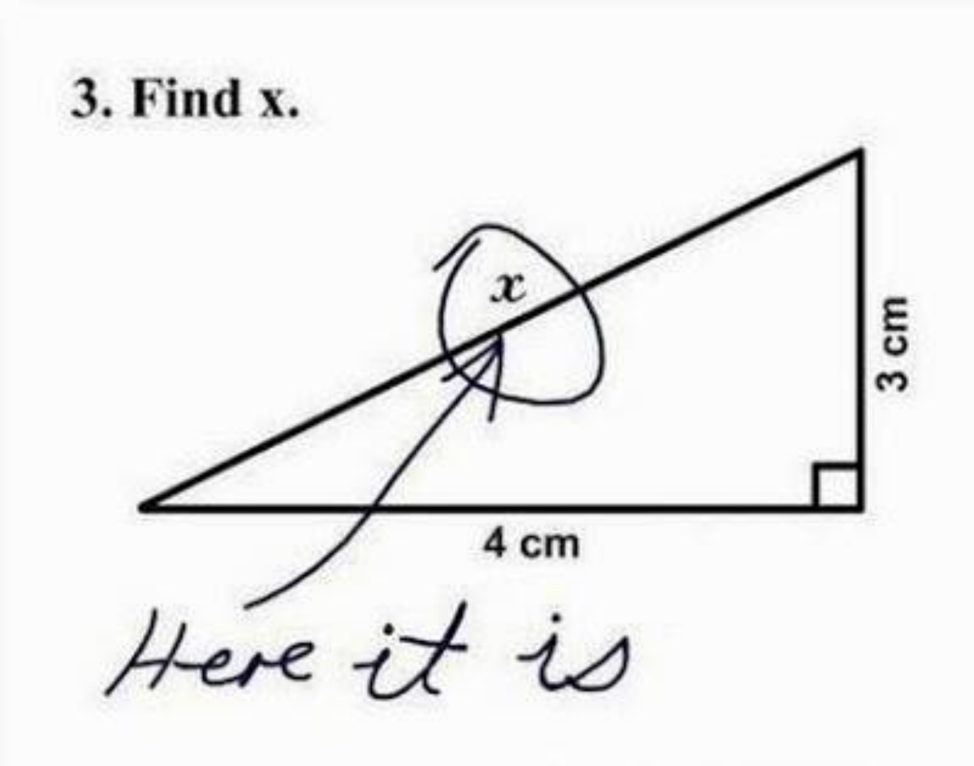


What’s Wrong With This Picture?



Questions to ask yourself

- What's the right level of complexity
  - 1D, 2D + 1D HEC18, 2D Sediment Transport
- How much historic data is available?
  - Calibration
- Where do I need borings?
  - How many
  - Is a surface investigation enough
    - Assumptions
    - Risk
- What about the channel
  - Equilibrium
  - Bed forms



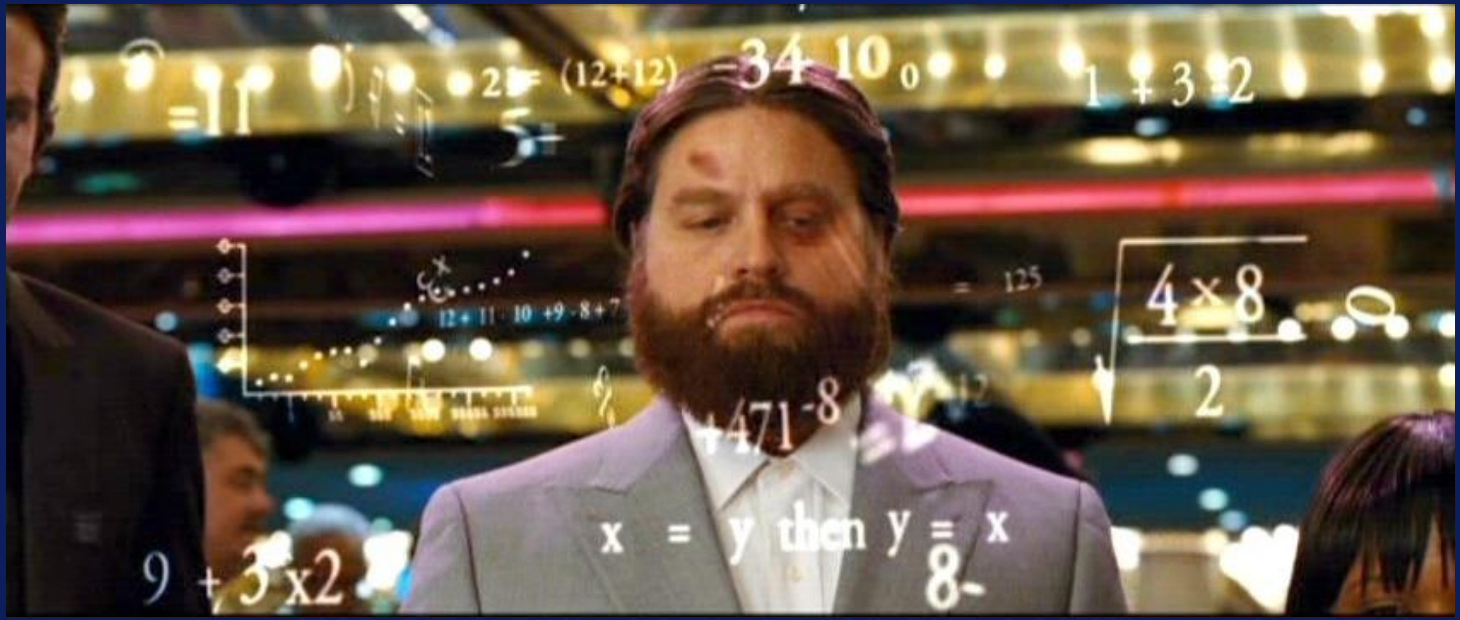
Simulation Time

- Steady vs Unsteady
  - ¼ Speed
  - 1 simulation hour = 1.5 real hours
  - Troubleshooting and Iterating

Key Variables

***Start With a Well Calibrated Hydraulic Model!!

- Upstream Boundary – Capacity
- Boring Locations
- Soil Distribution
- Equations
- Sediment Depth
- Concentration
- Flow Distribution
- Time



Moral of the Story

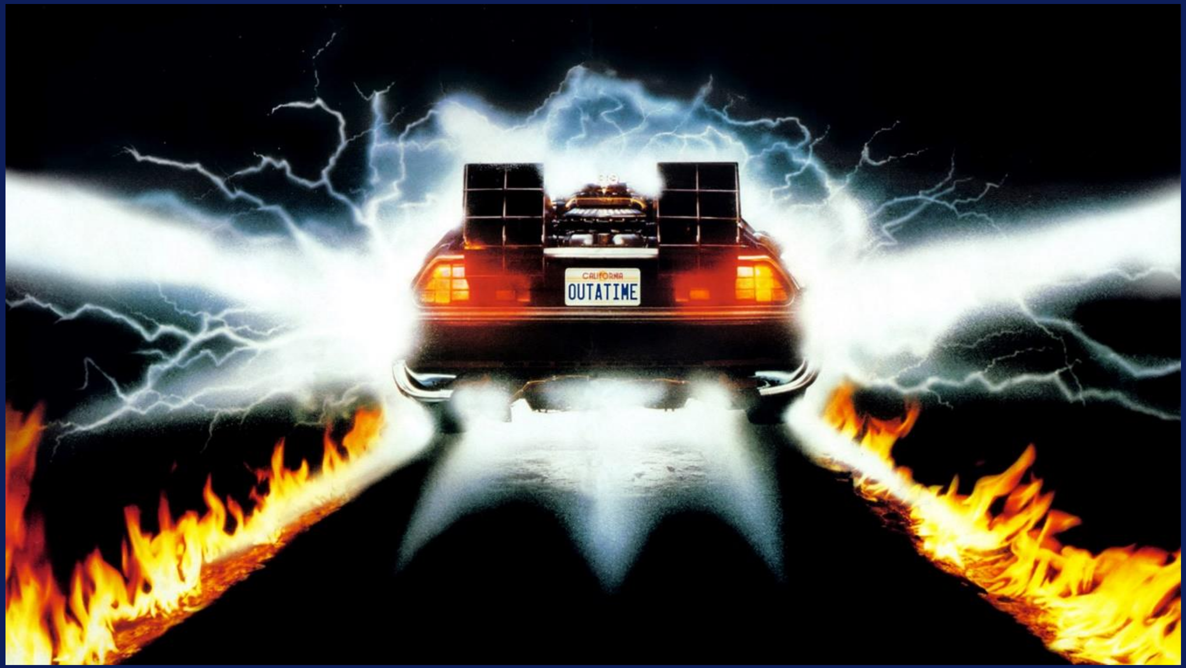
- HEC18 vs. Sediment Transport

- HEC-18
  - Continued refinement
  - 2D doesn’t fit every problem
  - HEC18 – 2D Informed

- Sediment Transport
  - Black Box
  - Viable Tool
  - Continued improvement and verification
  - Contraction Only

To Be Continued

- Continued Research
  - Unverified approach
  - Incorporating pier scour
  - Long term degradation
- Coming down the pipeline
  - Bank Migration
  - 3D modeling
    - Pier scour
    - Supercomputer?




I NEED A BUDGET ESTIMATE FOR MY PROJECT, BUT I DON'T HAVE A SCOPE OR A DESIGN FOR IT YET.
Dilbert.com
DilbertCartoonist@gmail.com
OKAY, MY ESTIMATE IS $3,583,729.
12-7-09 © 2009 Scott Adams, Inc./Dist. by UFS, Inc.
YOU DON'T KNOW ANYTHING ABOUT MY PROJECT.
THAT MAKES TWO OF US.