Collaborative **H**ydraulics: **A**dvancing to the **N**ext **G**eneration of **E**ngineering
C.H.A.N.G.E.

U.S. Department of Transportation
Federal Highway Administration

On-Ramp to Innovation
every day counts

Advancements in Two-Dimensional Floodplain Modeling with SRH-2D / SMS

Image Sources (left to right): Washington DOT, FHWA Turner Fairbanks Hydraulic Resource Center, Banjo Hangout, Washington DOT Hydraulic Results / Digiglobe World Image and Washington DOT

WHAT is CHANGE?

Collaborative Hydraulics: Advancing to the Next Generation of Engineering

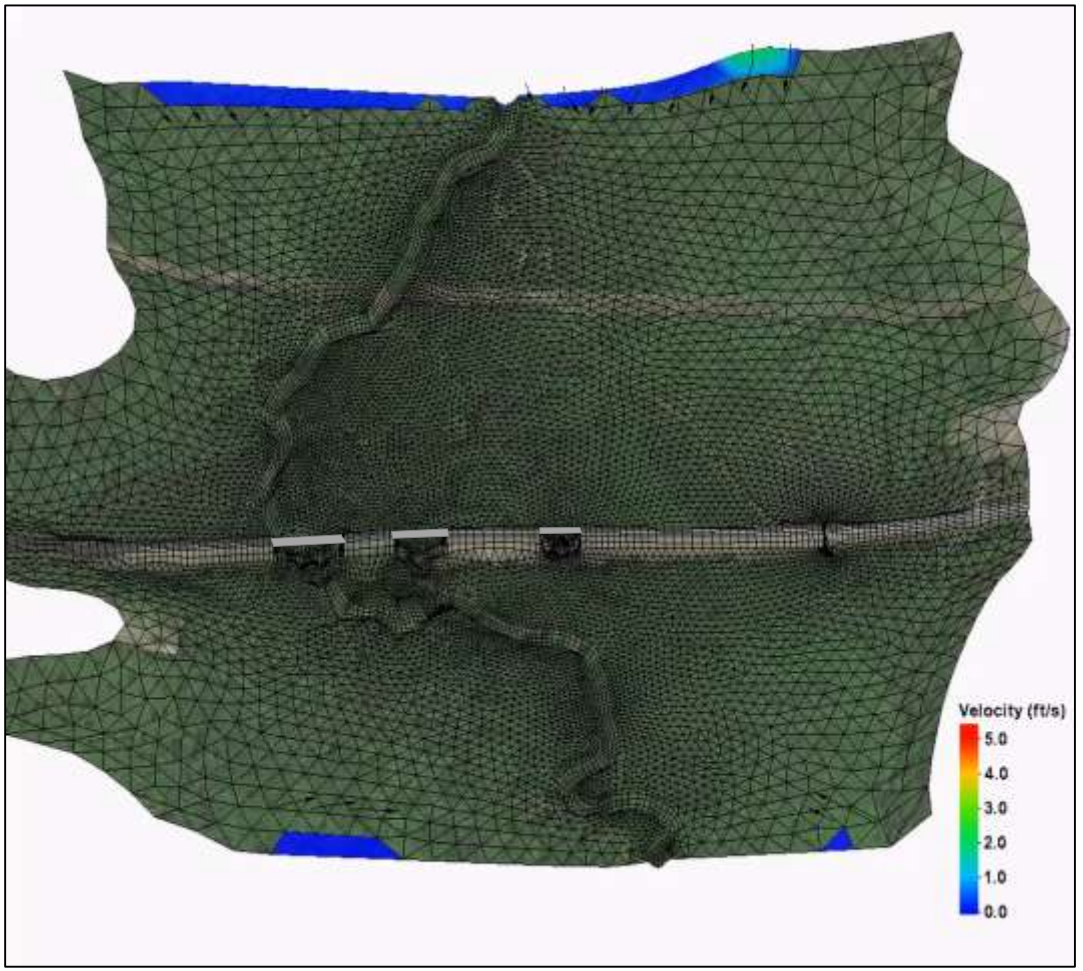


Image Source: FHWA

Why are we concerned about bridge hydraulics?

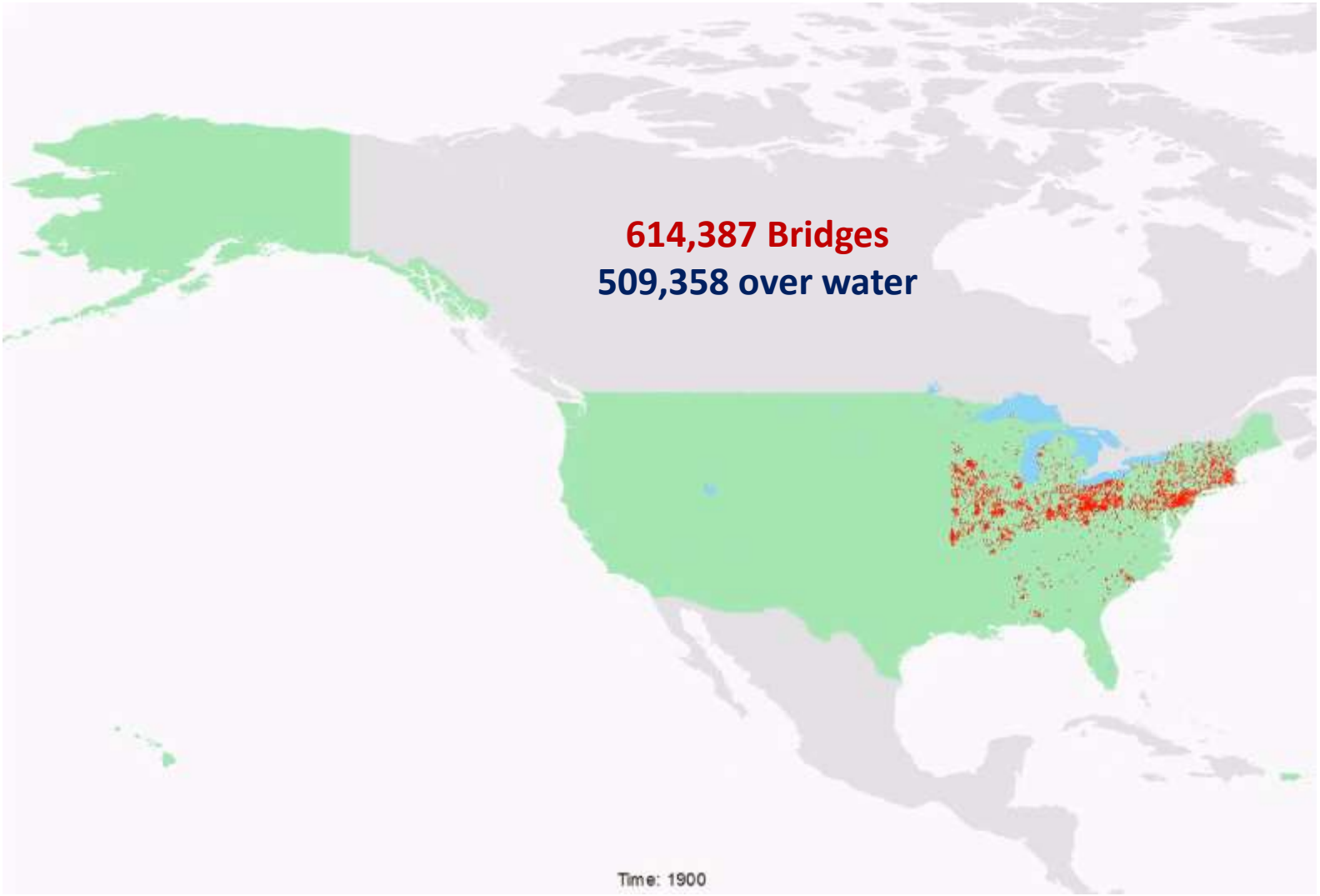


Image Source: FHWA

Hydraulic Modeling

Image Source: Creative Commons

The Past – Where did it all begin?

- Prior to 1957 Bridges were not hydraulically designed
- 1960 FHWA released HDS-1 – basic analysis approach
- 1966 US Army COE released HEC-2 – first water surface profile model (1D modeling)
- 1988 First use of 2D modeling by FHWA (FESWMS)
- 1996 US Army COE released HEC-RAS (1D)
- 2012 FHWA officially started recommending 2D modeling for **complex** bridge hydraulics

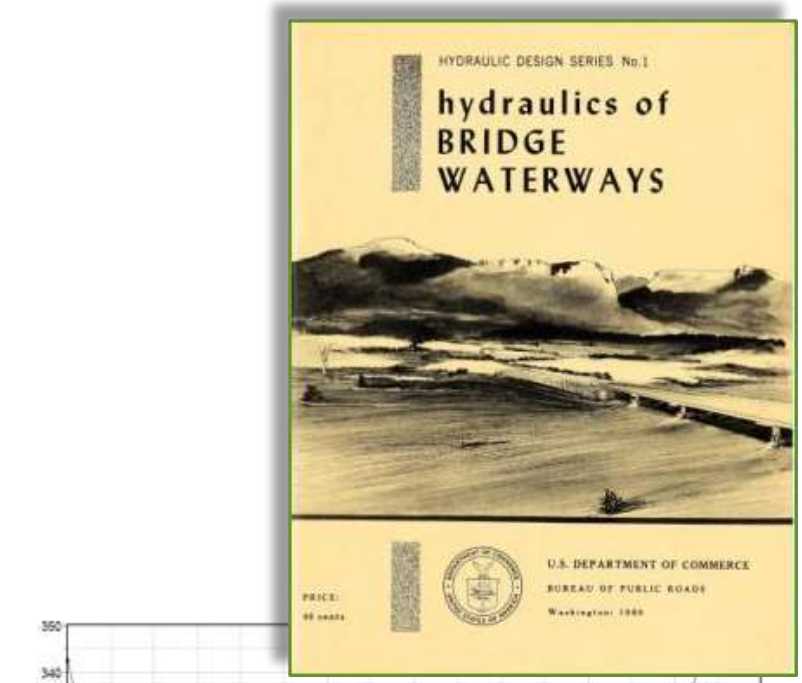
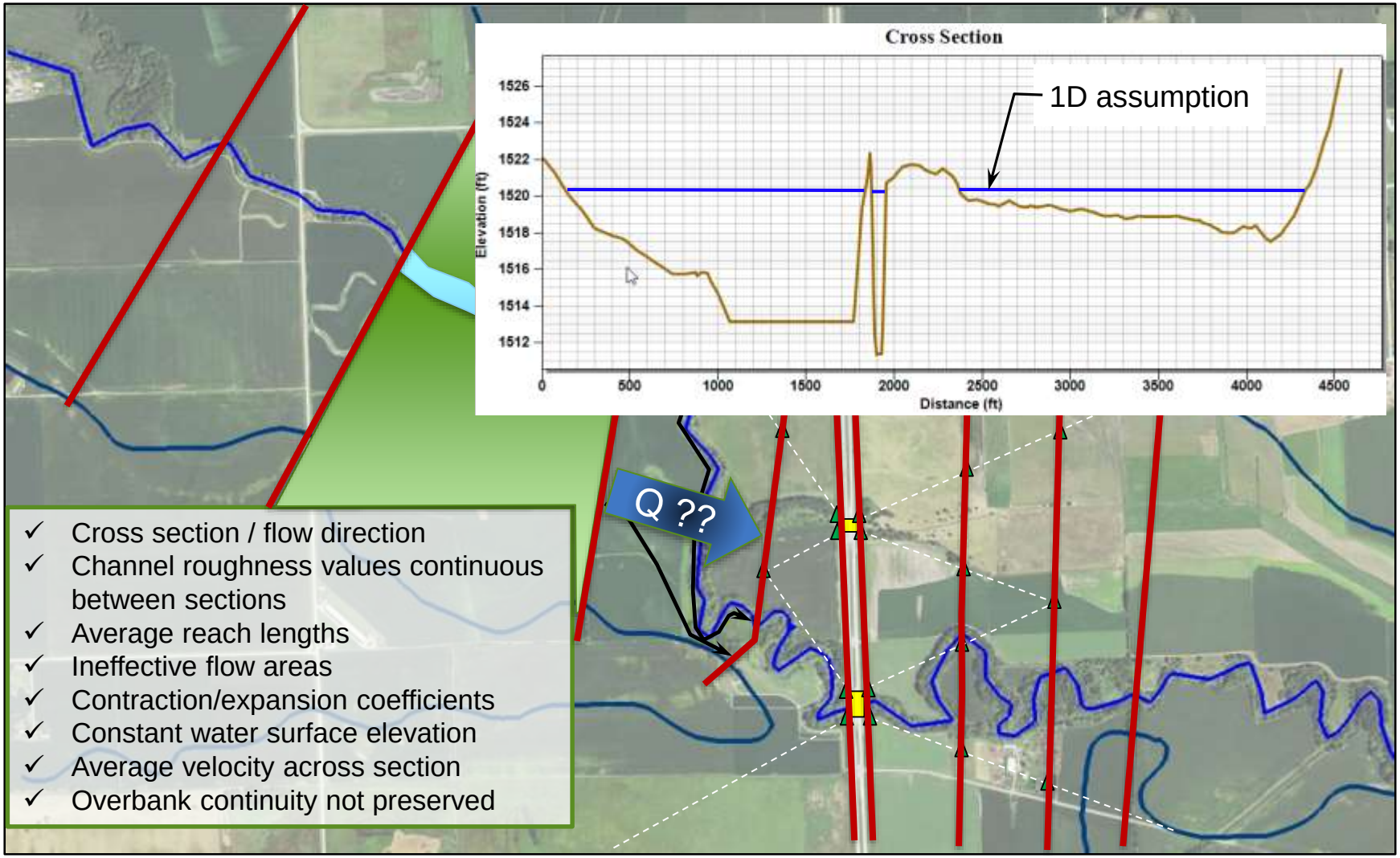


Image Sources: FHWA

The Past/Present – 1D Modeling Assumptions



- ✓ Cross section / flow direction
- ✓ Channel roughness values continuous between sections
- ✓ Average reach lengths
- ✓ Ineffective flow areas
- ✓ Contraction/expansion coefficients
- ✓ Constant water surface elevation
- ✓ Average velocity across section
- ✓ Overbank continuity not preserved

Image Source: Nebraska Department of Roads / Earthstar Graphics (Aerial Image)

The Past – 1D Modeling

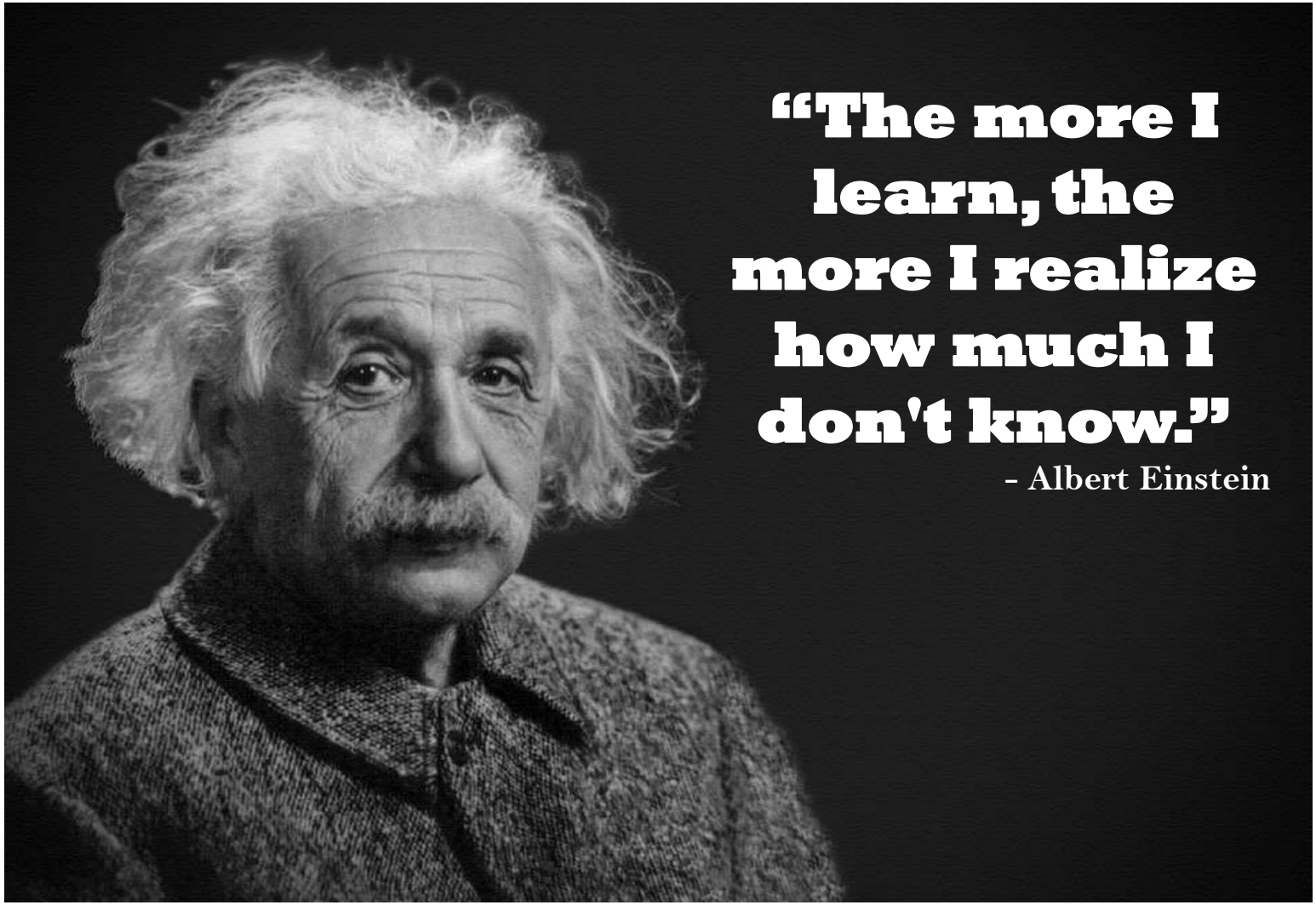


Image Source: Creative Commons Zero – CC0

The Past – Consequences of 1D Modeling Assumptions

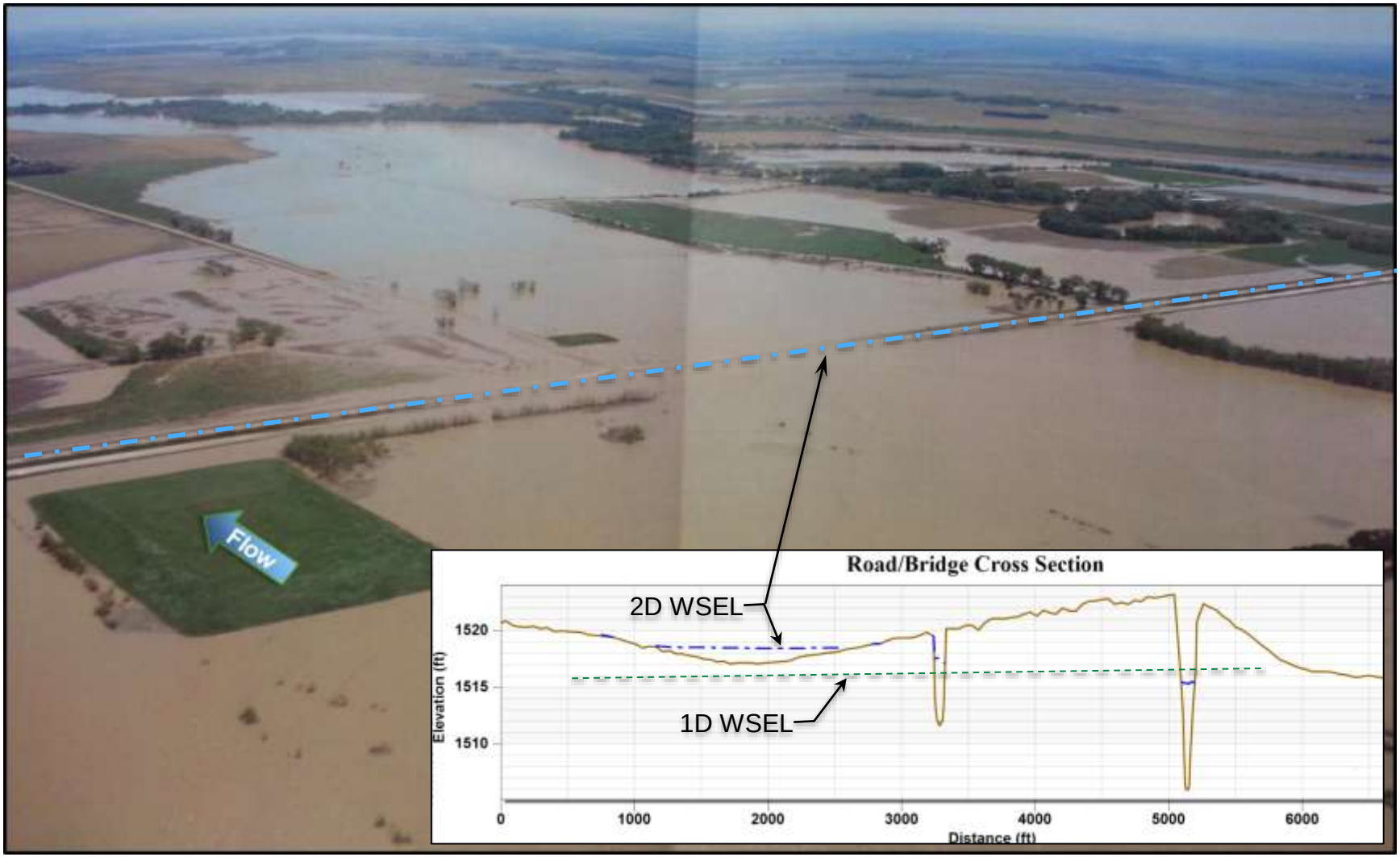


Image Source: Nebraska Department of Roads

What has changed?

- Greater availability of mapping data
- More computer power
- Improved 2D computer models
- Enhanced graphical interface
- More compatibility with CAD and GIS

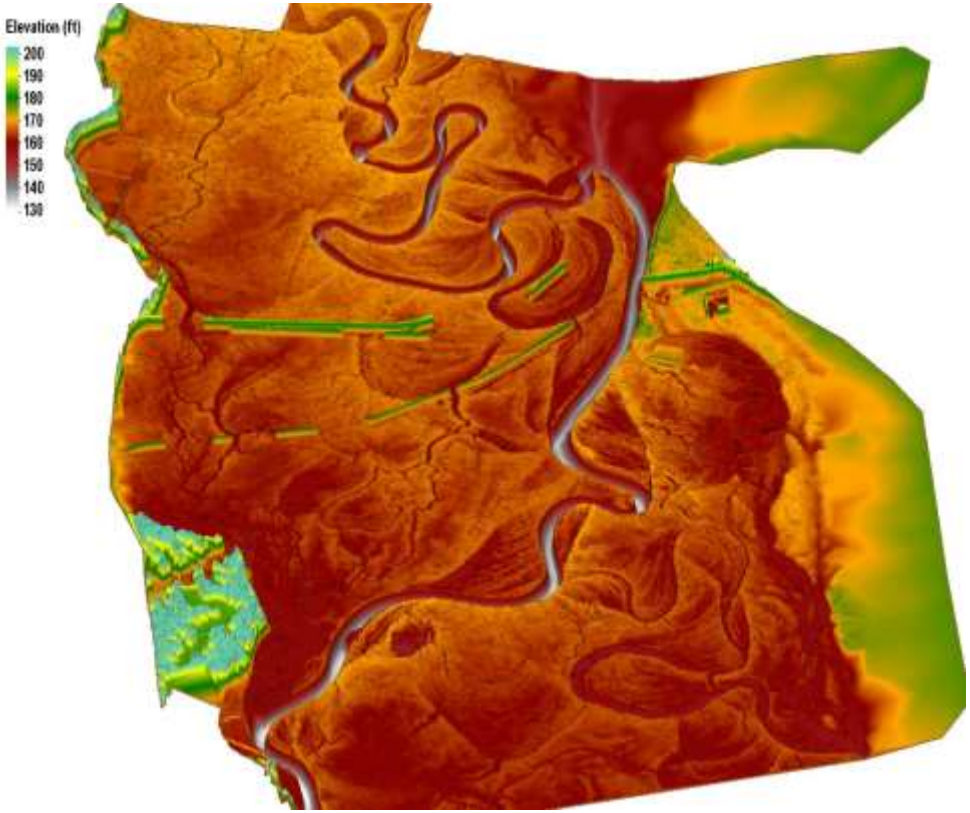
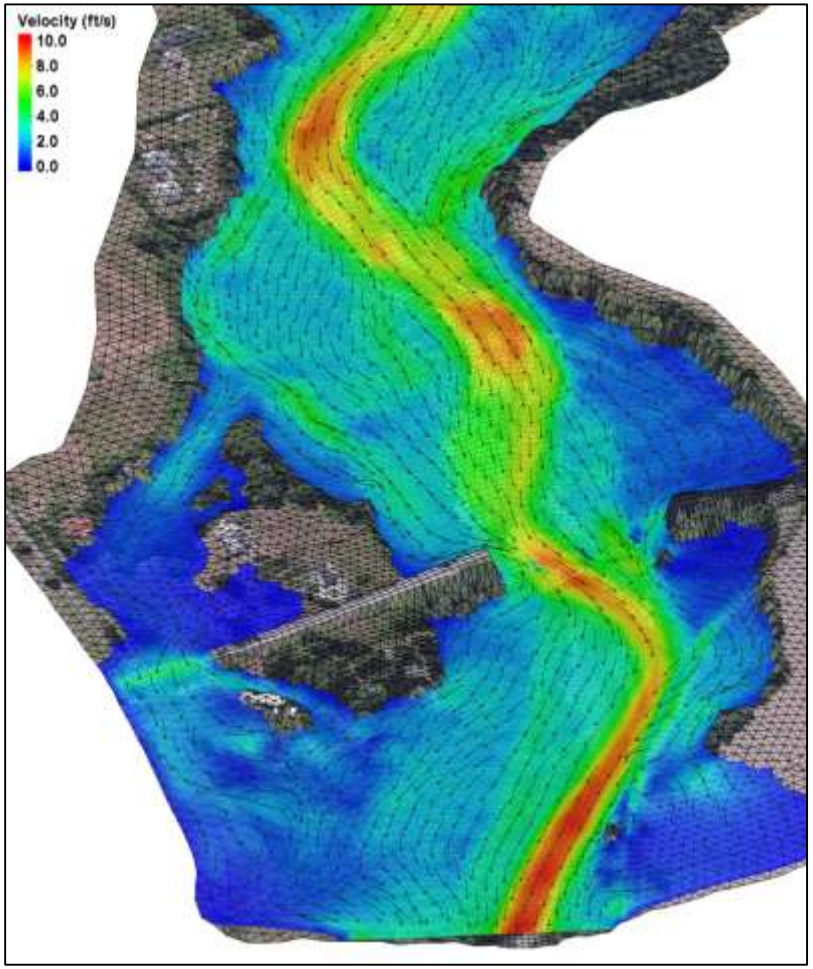


Image Source: FHWA

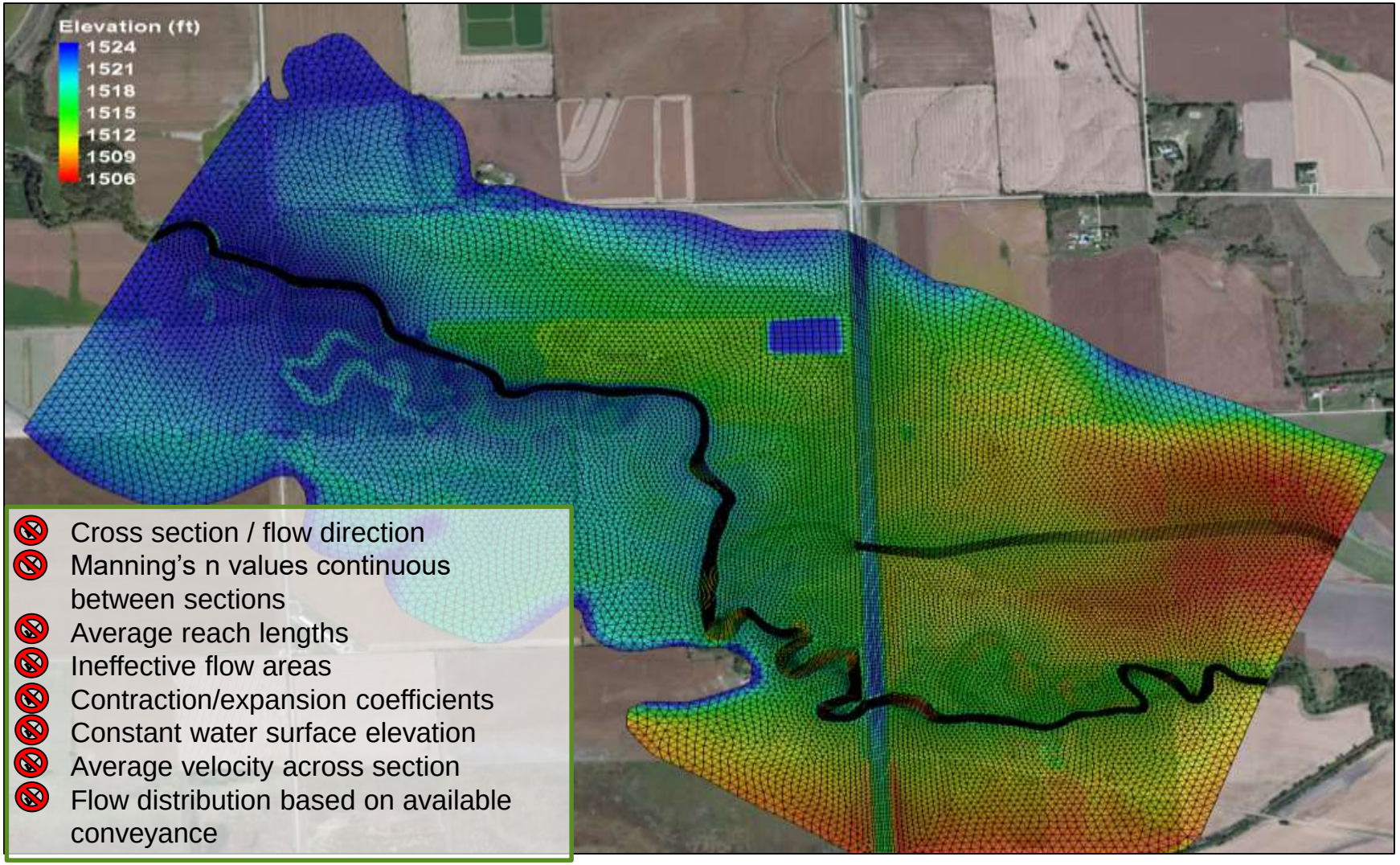
The Present – 2D Modeling Tools for Complex Hydraulics



- FHWA/USBR partnership (2013)
- SRH-2D two-dimensional hydraulic model
  - *Developed by Dr. Yong Lai (USBR)*
- Incorporated hydraulic structures
- Custom graphical user interface in SMS
  - *Developed by Aquaveo*
- Ongoing development for transportation hydraulics
- Free community version

Image Source: FHWA

The Present – 2D Modeling



- Cross section / flow direction
- Manning's n values continuous between sections
- Average reach lengths
- Ineffective flow areas
- Contraction/expansion coefficients
- Constant water surface elevation
- Average velocity across section
- Flow distribution based on available conveyance

Image Source: Nebraska Department of Roads / Earthstar Graphics (Aerial Image)

The Present – 2D Modeling Benefits

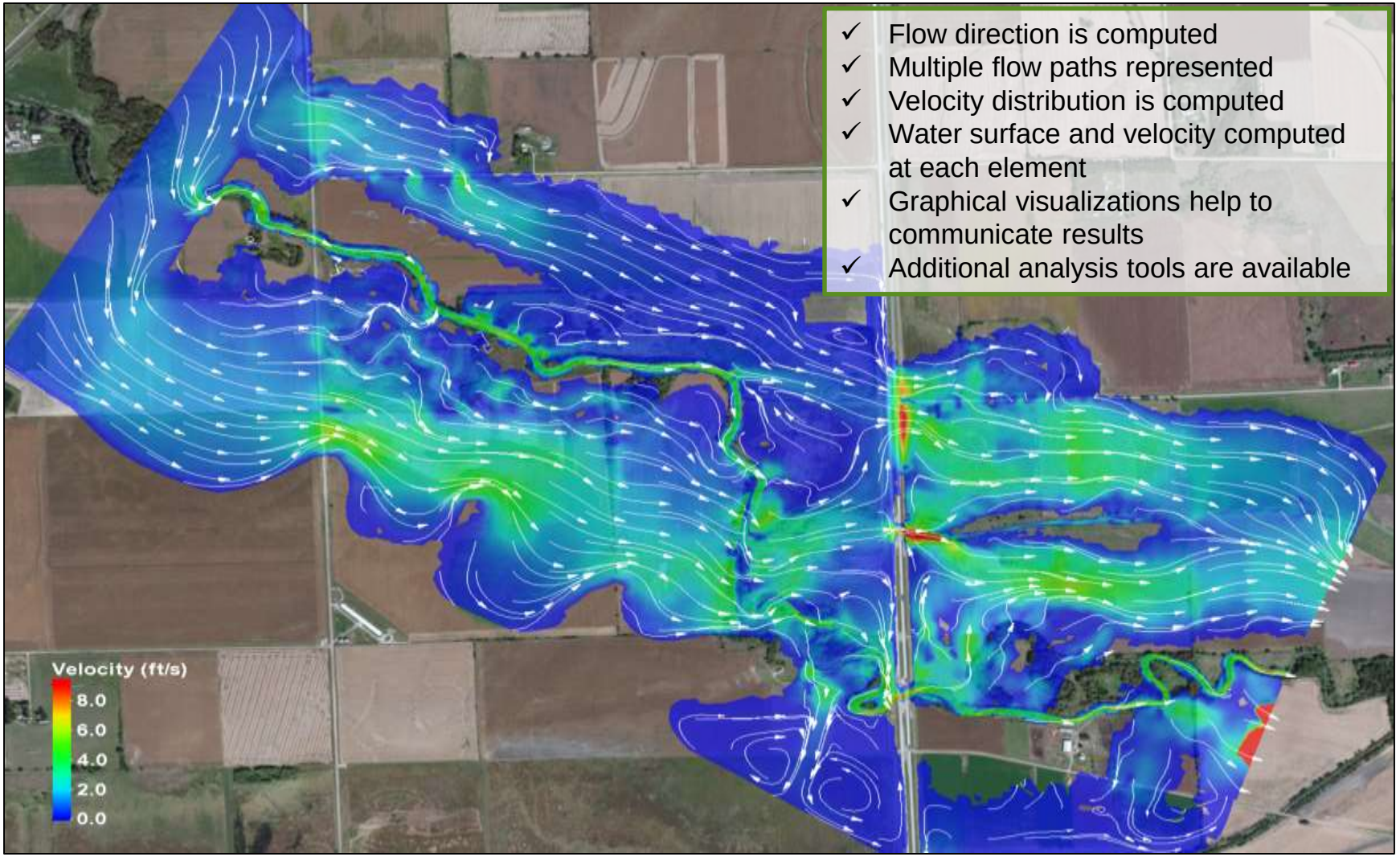


Image Source: Nebraska Department of Roads / Earthstar Graphics (Aerial Image)

The Present – 2D Modeling Graphical Visualizations

Image Source: Nebraska Department of Roads / Earthstar Graphics (Aerial Image)

The Present - Modeling Capabilities

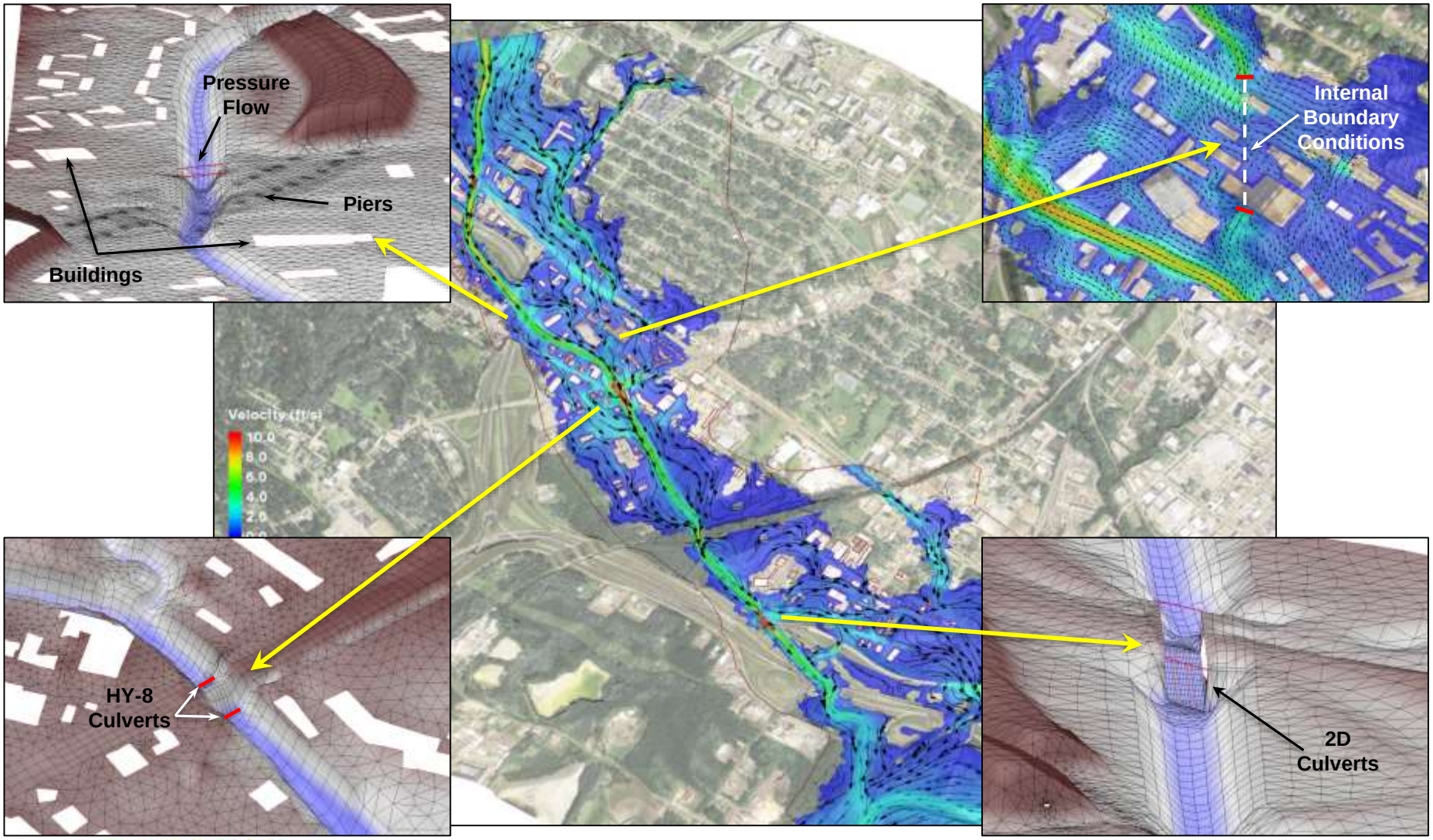
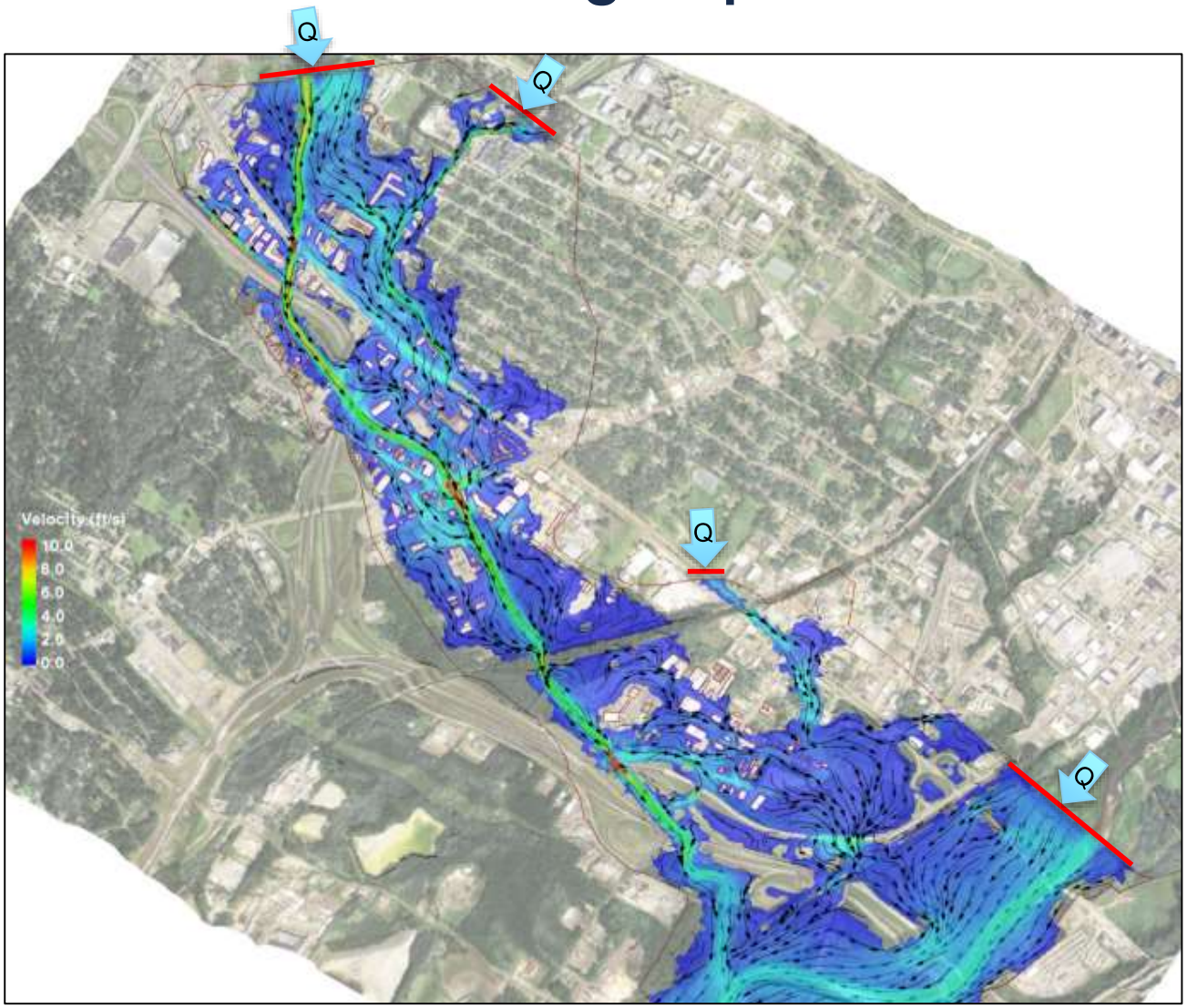


Image Sources: USGS / Earthstar Graphics (Aerial Image) – Mississippi DOT / FHWA

Present - Modeling Capabilities



Additional Features /Capabilities

- Multiple boundary conditions
- Internal source/sink
- Steady and unsteady flow
- Sub- and supercritical flow
- Normal/critical depth rating curves
- Bridge piers and blocked obstructions
- Gates
- Weirs
- Depth dependent roughness
- Sediment Transport

Image Sources: USGS / Earthstar Graphics (Aerial Image) – Mississippi DOT

Present – 2D Modeling Applications

Multiple Structures

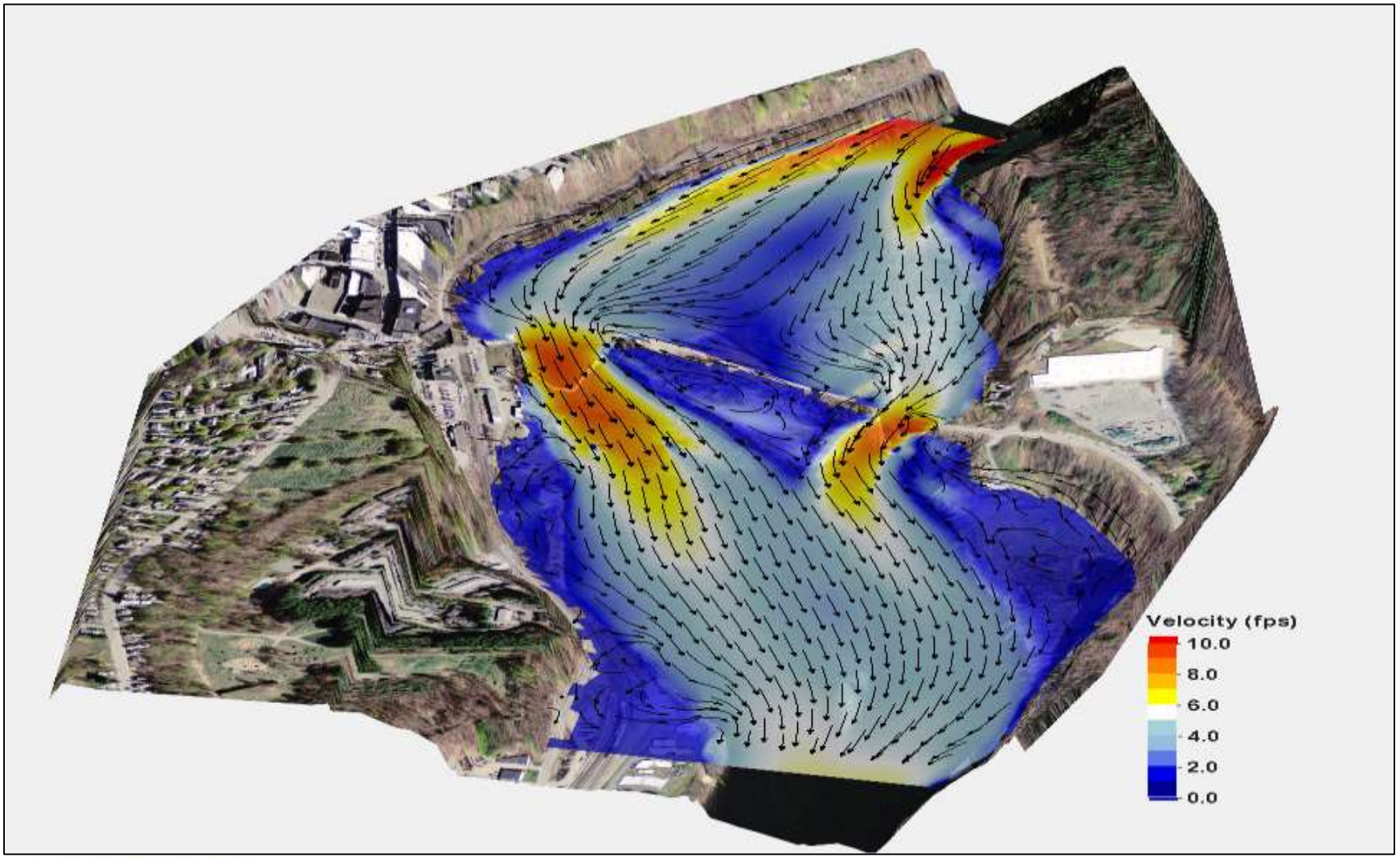


Image Sources: New Hampshire DOT / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Floodplain Mapping and Risk Assessment

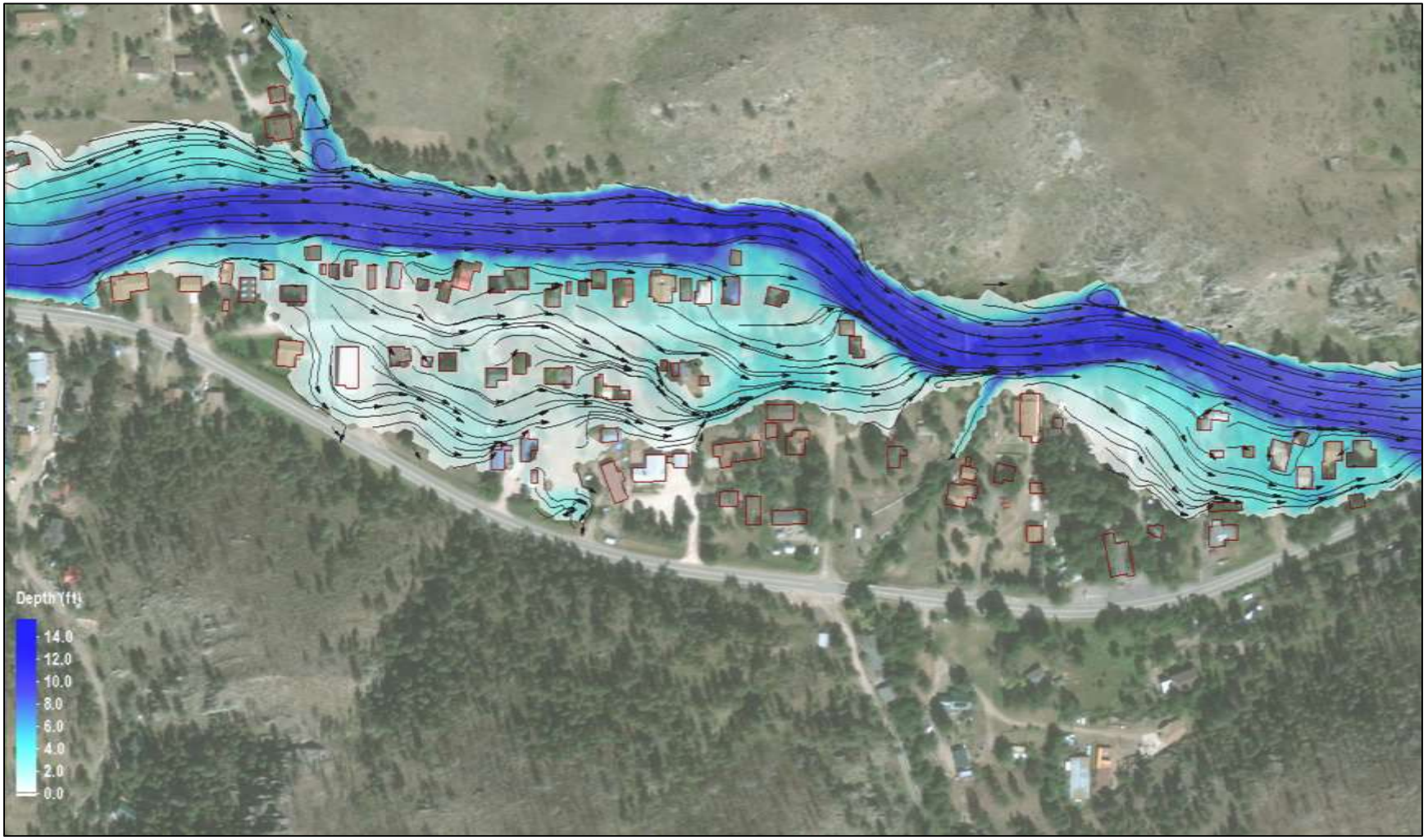


Image Sources: FHWA / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Flooding Impact Assessment

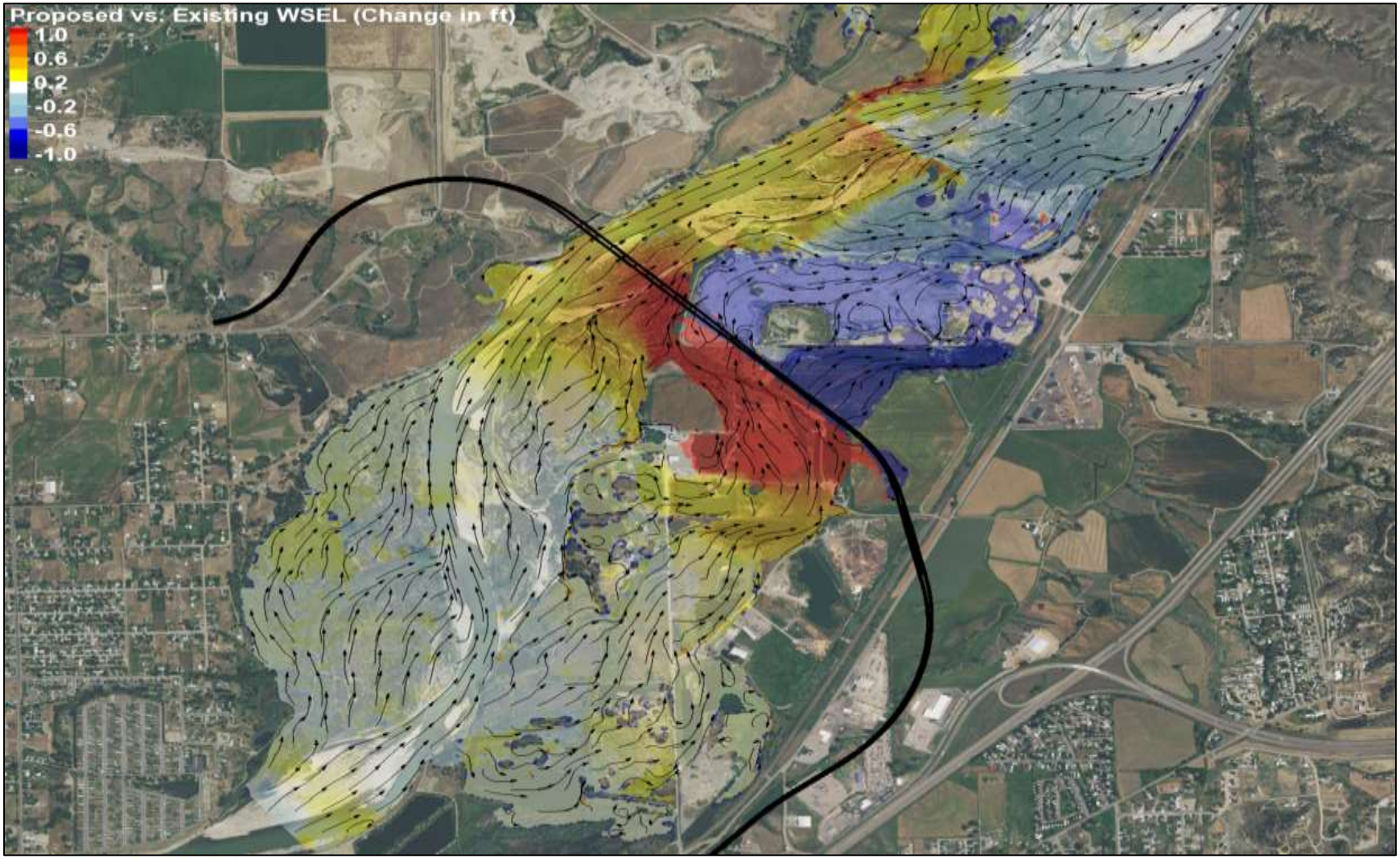


Image Sources: Montana DOT / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Undefined flow paths

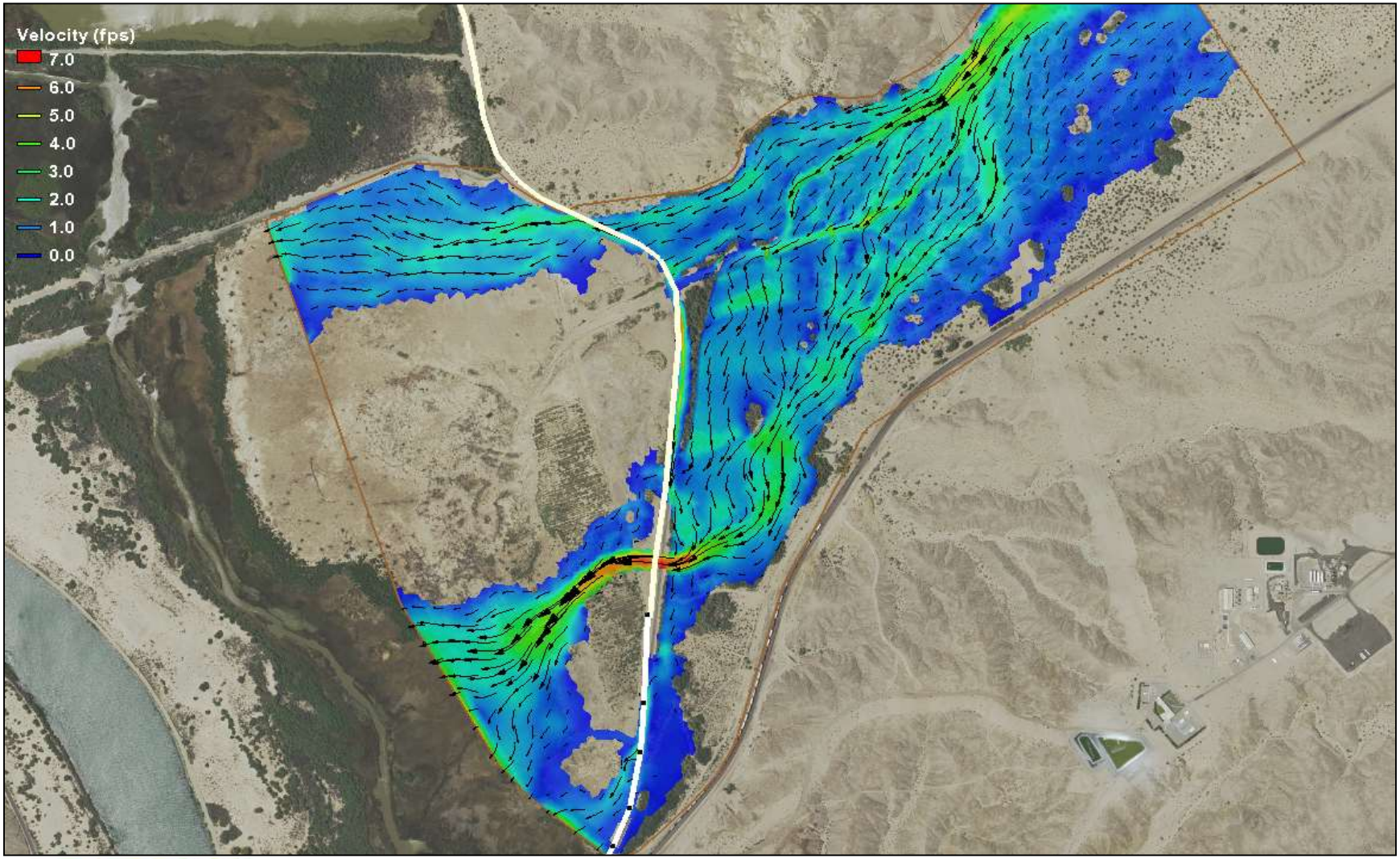


Image Sources: FHWA / Earthstar Graphics (Aerial Image)

Present - 2D Modeling Applications

Streamlined Bank Protection Design – Data Calculator

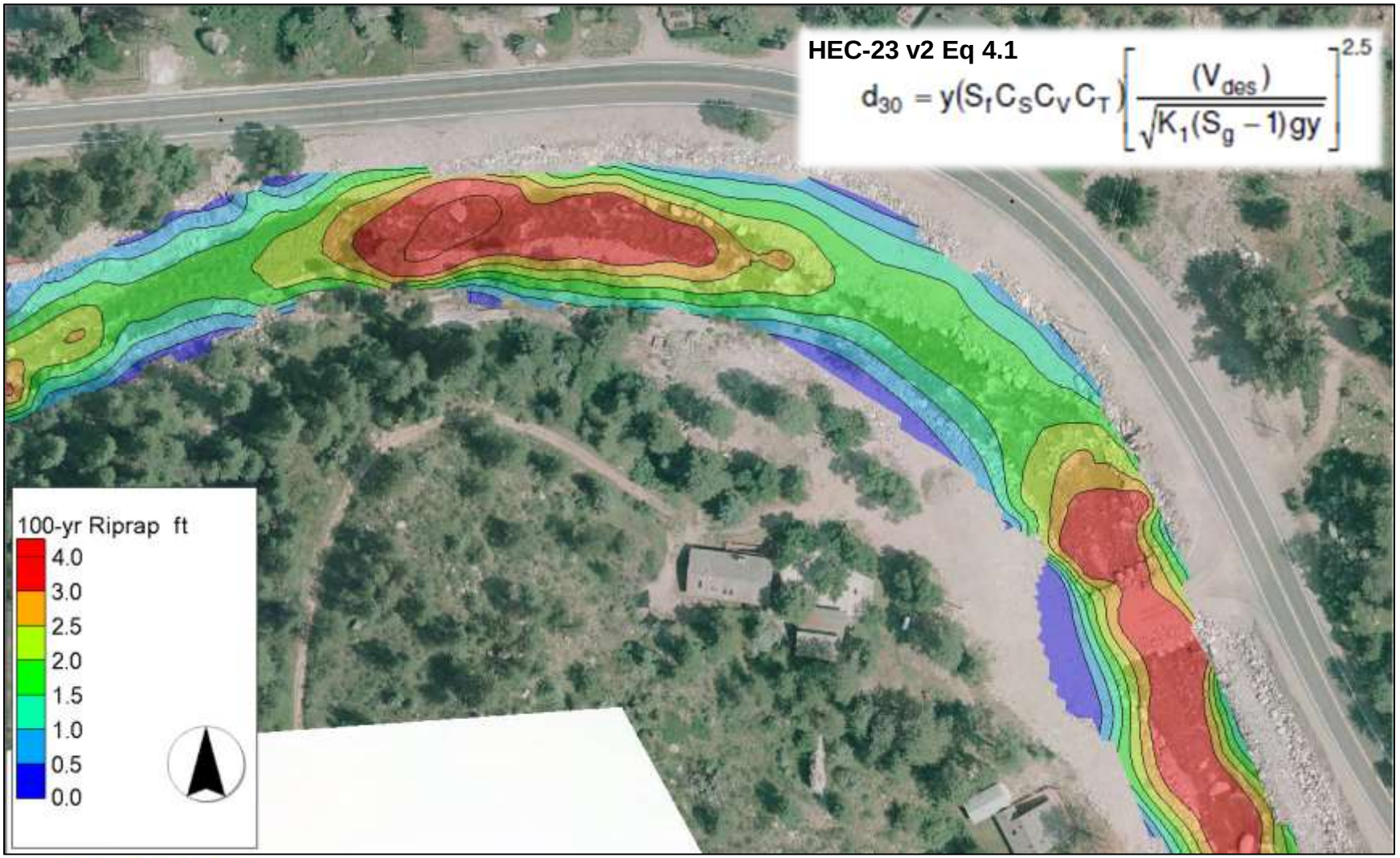


Image Sources: FHWA/ CDOT / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Flow around bends

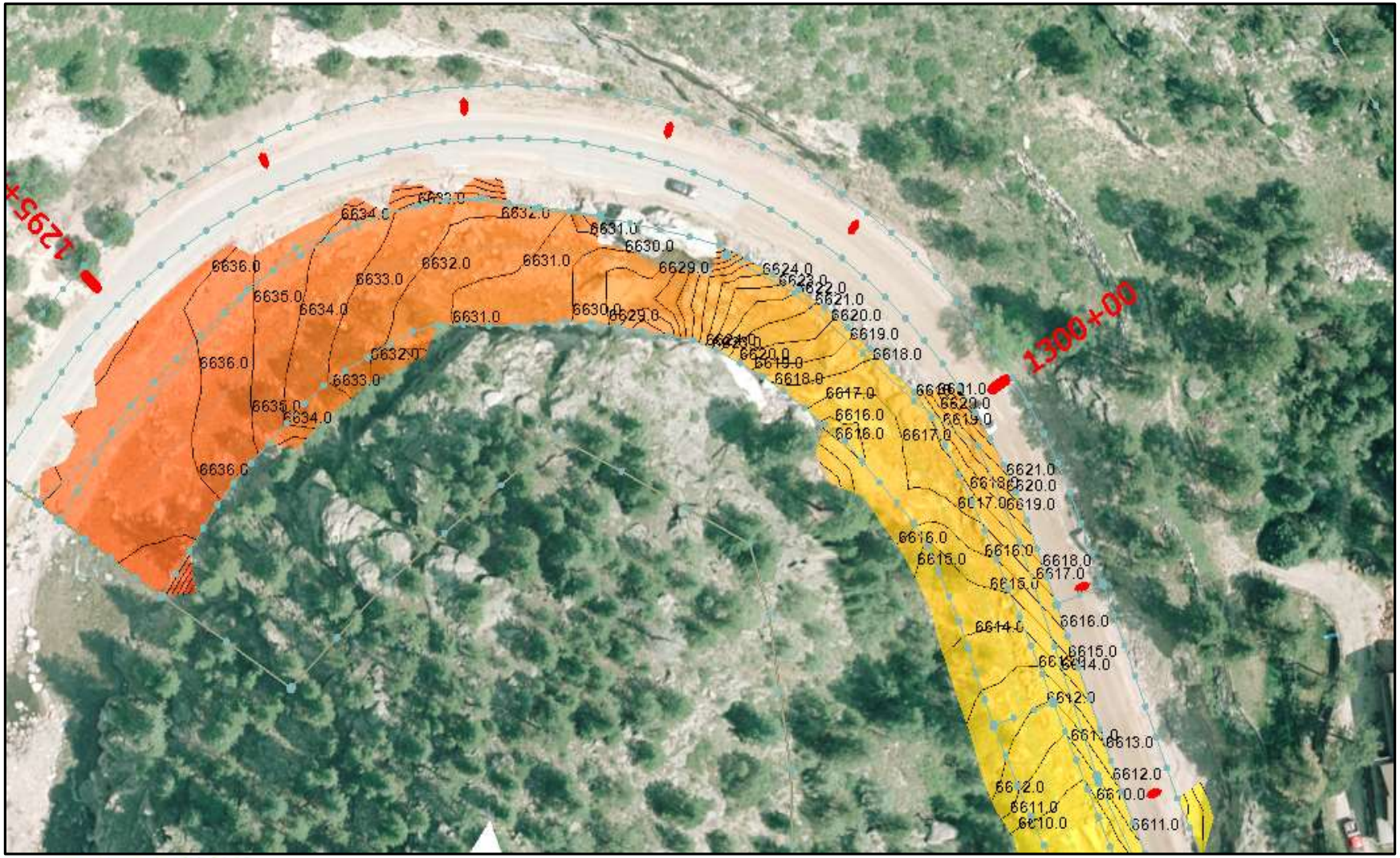


Image Sources: CDOT / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Instream Structures

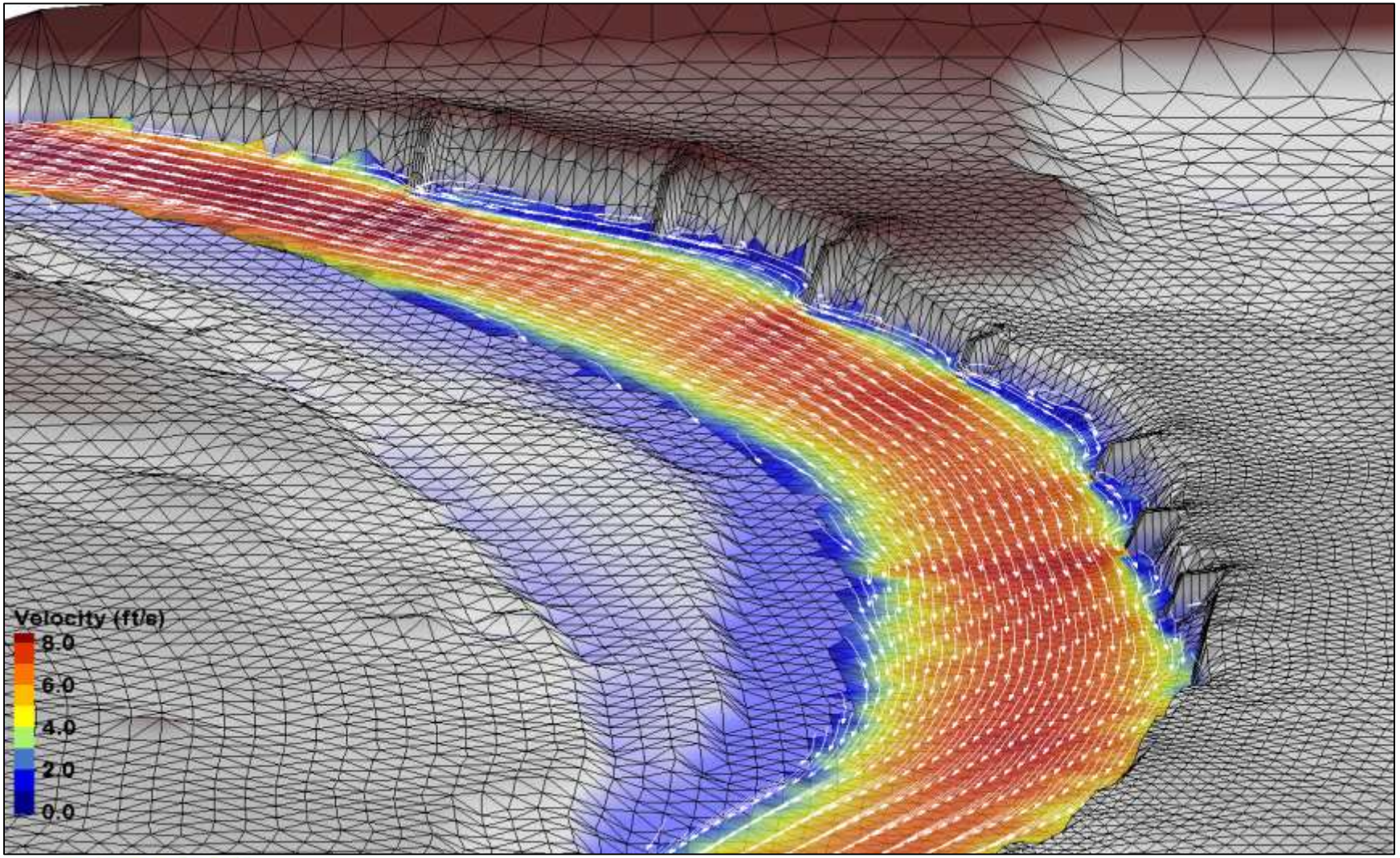


Image Sources: FHWA

Present – 2D Modeling Applications

Skewed Bridges

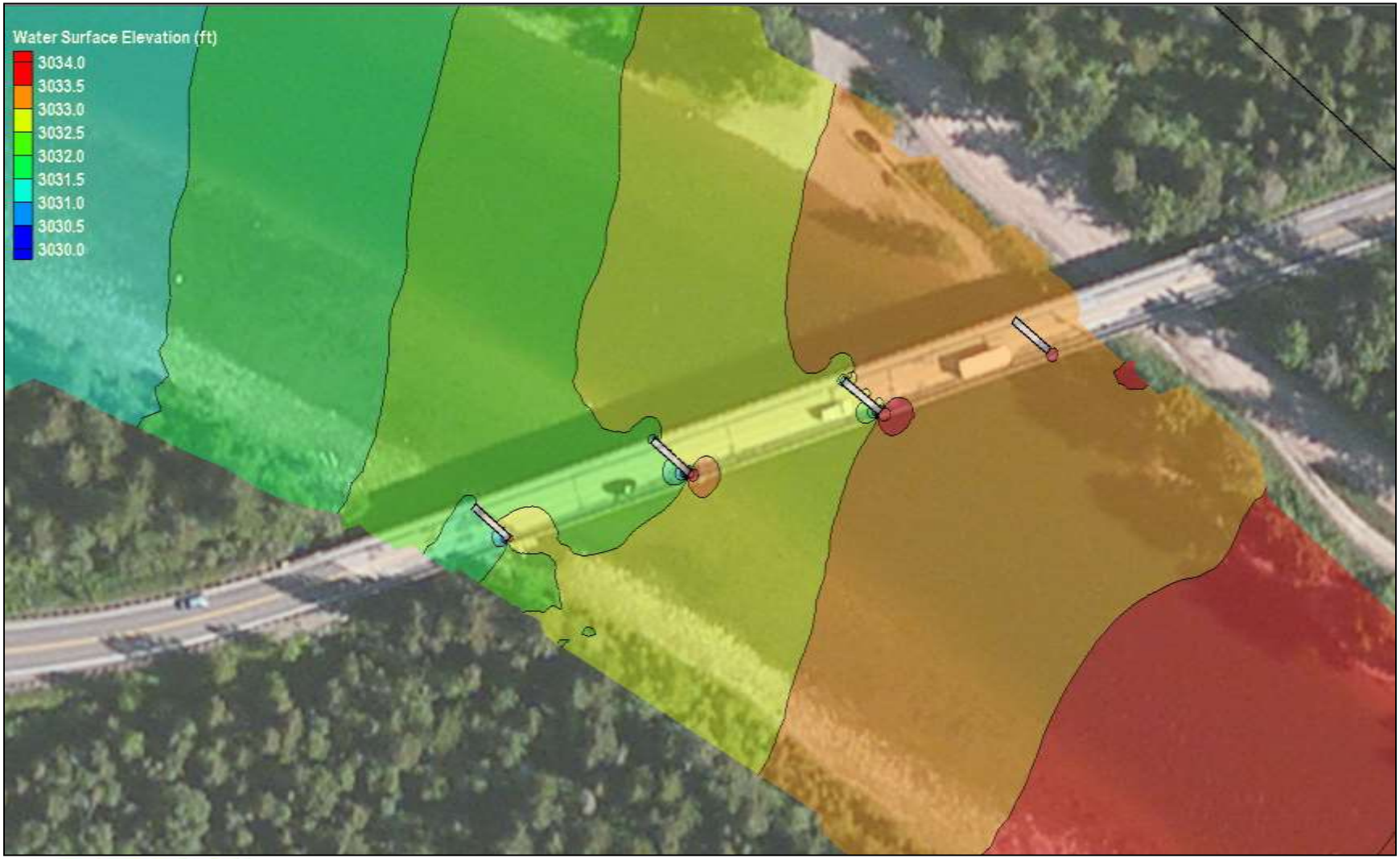
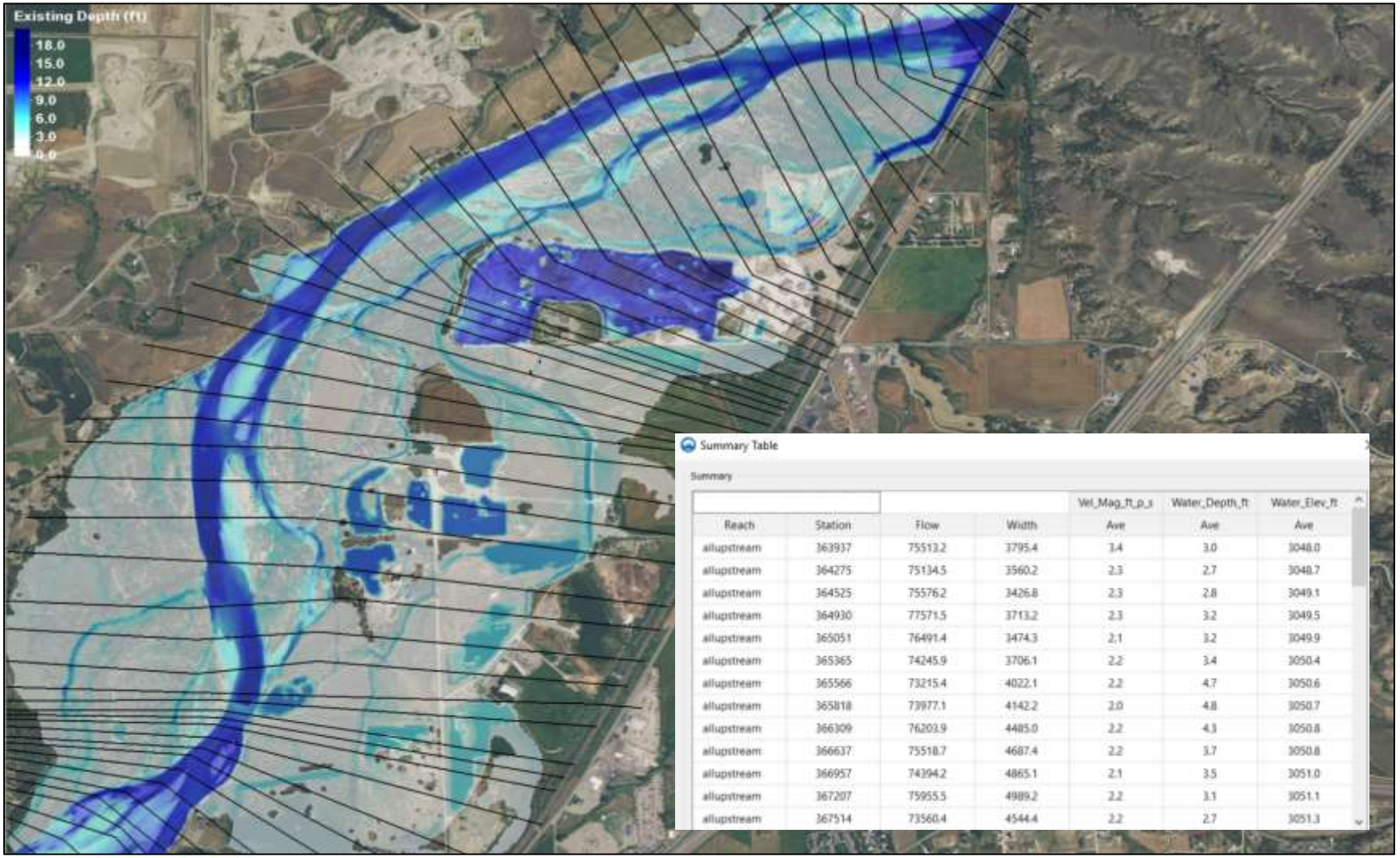


Image Sources: Montana DOT / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Comparison with 1D Model Results – Summary Tables



Summary Table

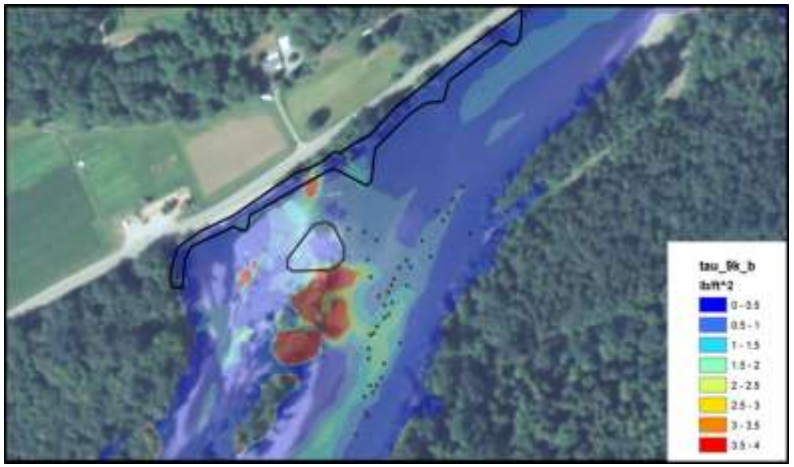
Summary

Reach	Station	Flow	Width	Vel_Mag_ft_p_s Ave	Water_Depth_ft Ave	Water_Elev_ft Ave
allupstream	363937	75513.2	3795.4	3.4	3.0	3048.0
allupstream	364275	75134.5	3560.2	2.3	2.7	3048.7
allupstream	364525	75576.2	3426.8	2.3	2.8	3049.1
allupstream	364930	77571.5	3713.2	2.3	3.2	3049.5
allupstream	365051	76491.4	3474.3	2.1	3.2	3049.9
allupstream	365365	74245.9	3706.1	2.2	3.4	3050.4
allupstream	365566	73215.4	4022.1	2.2	4.7	3050.6
allupstream	365818	73977.1	4142.2	2.0	4.8	3050.7
allupstream	366309	76203.9	4485.0	2.2	4.3	3050.8
allupstream	366637	75518.7	4687.4	2.2	3.7	3050.8
allupstream	366957	74394.2	4865.1	2.1	3.5	3051.0
allupstream	367207	75955.5	4989.2	2.2	3.1	3051.1
allupstream	367514	73560.4	4544.4	2.2	2.7	3051.3

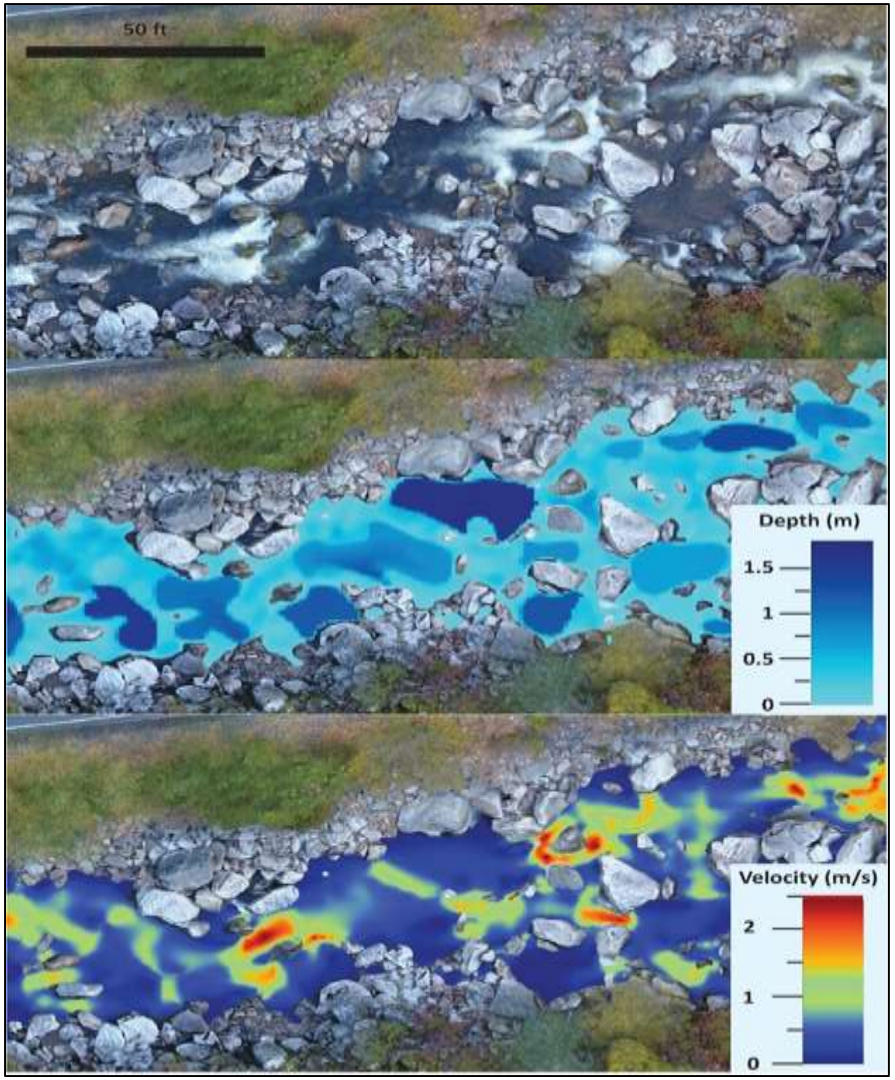
Image Sources: Montana DOT / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Habitat Analysis



Salmon spawning nest (redd) locations vs. channel shear stress



Fish passage analysis using flow depth and velocity distribution

Image Sources: Kramer / Timm (NHC)

Present – 2D Modeling Applications

Dam Break Analysis

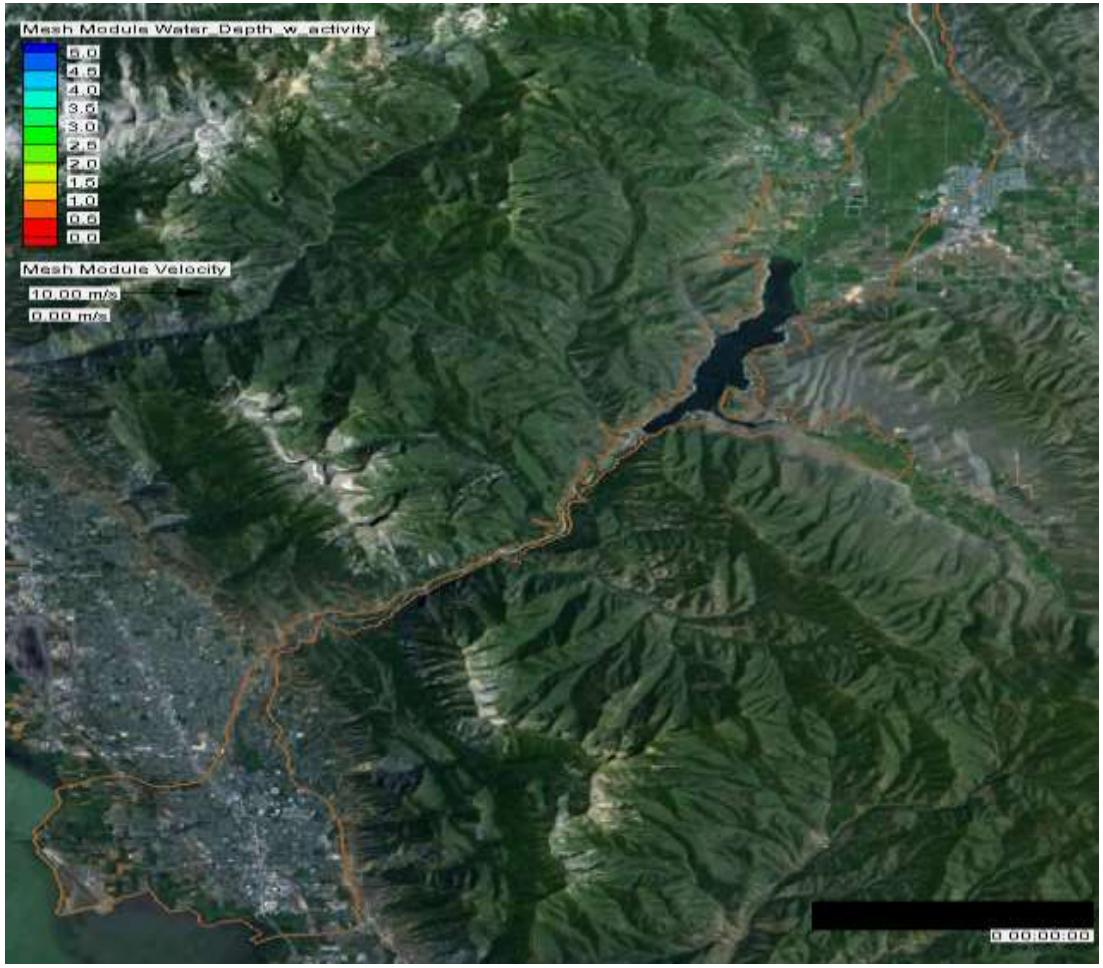


Image Sources: Aquaveo / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Tidal Boundary Conditions

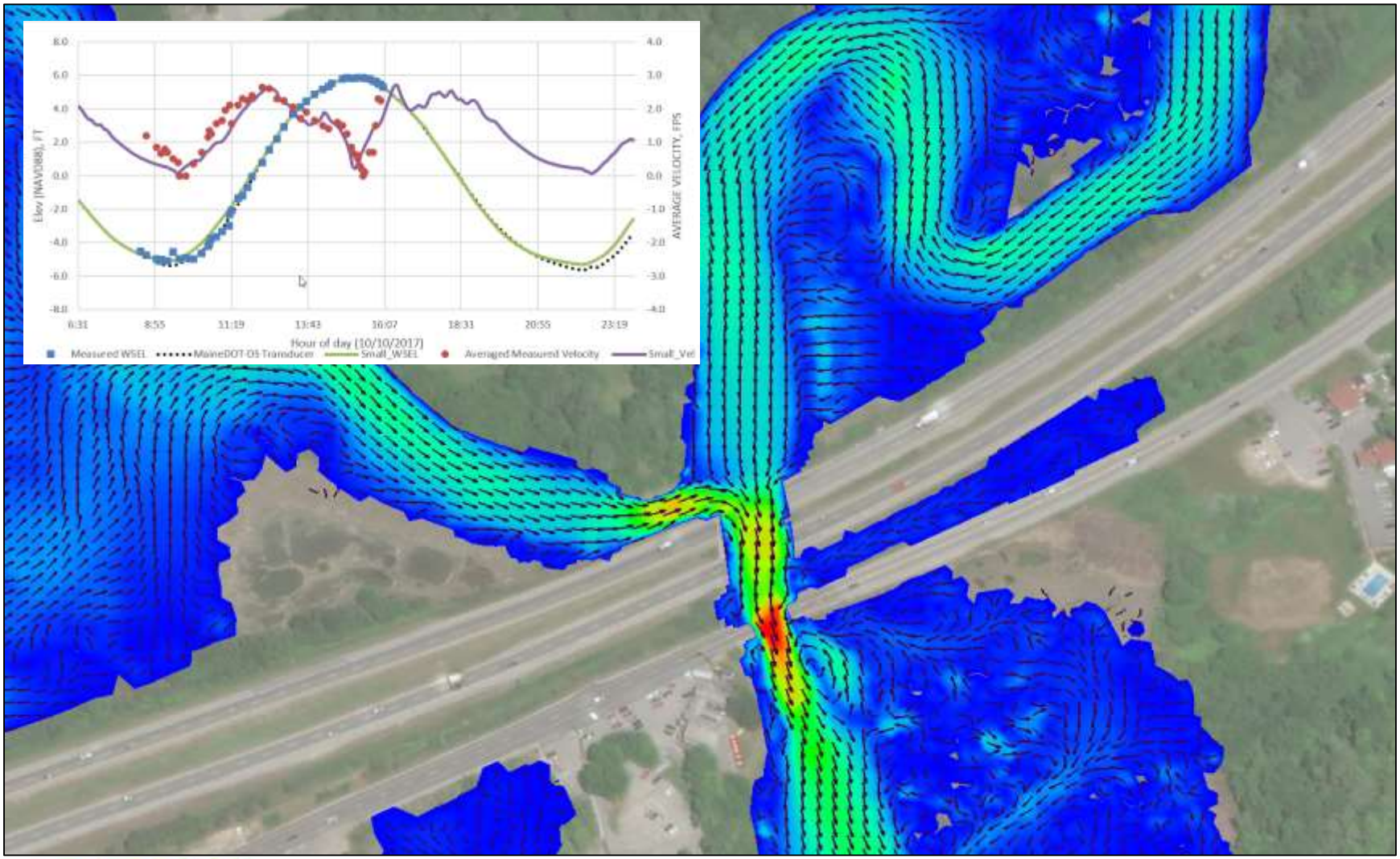
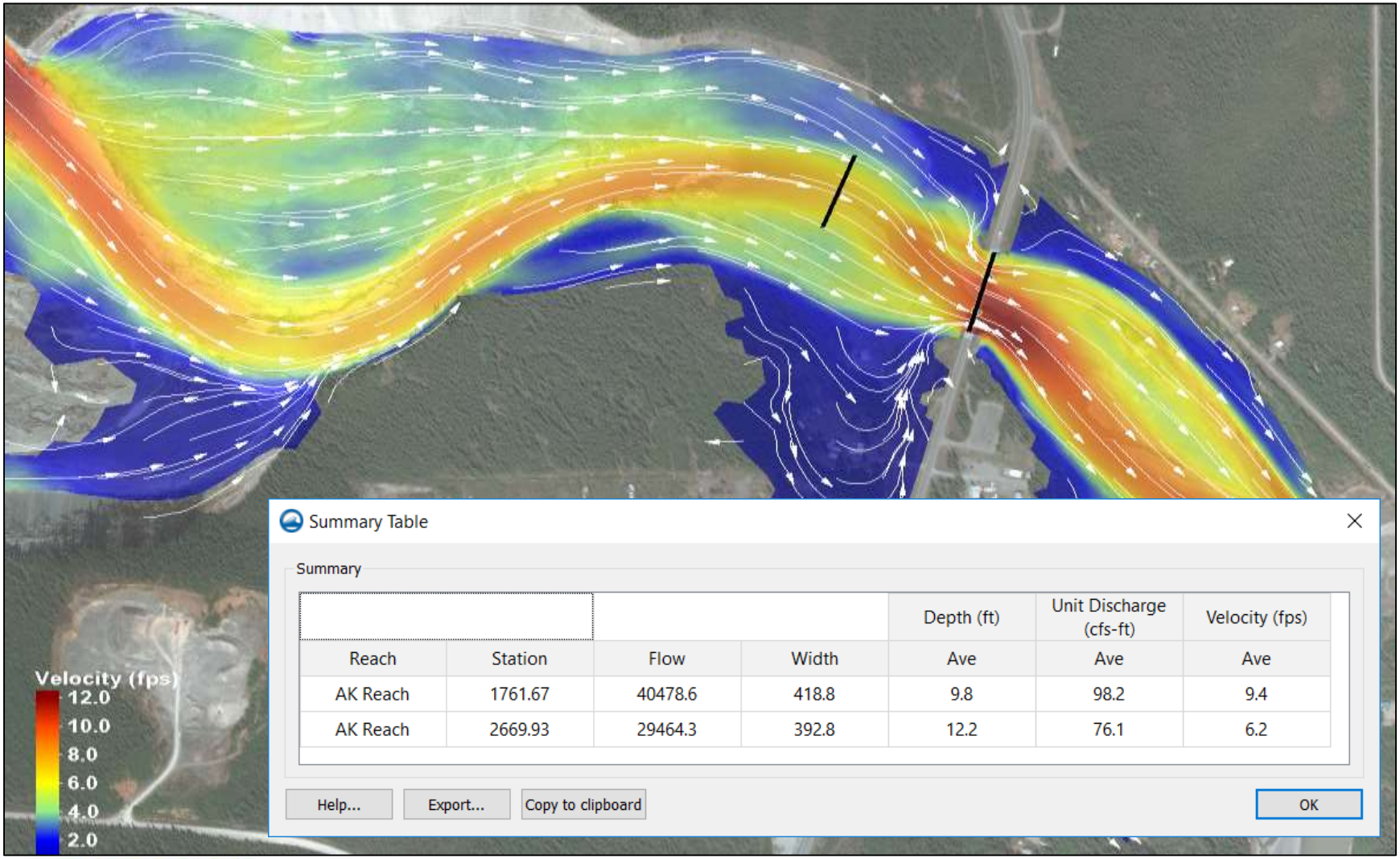


Image Sources: Aquaveo / Earthstar Graphics (Aerial Image)

Present – 2D Modeling Applications

Bridge Scour Assessment



Summary Table

Summary

				Depth (ft)	Unit Discharge (cfs-ft)	Velocity (fps)
Reach	Station	Flow	Width	Ave	Ave	Ave
AK Reach	1761.67	40478.6	418.8	9.8	98.2	9.4
AK Reach	2669.93	29464.3	392.8	12.2	76.1	6.2

Help... Export... Copy to clipboard OK

Image Sources: Alaska DOT/ WFL / Earthstar Graphics (Aerial Image)

The Future – Where are we going?

Image Sources: Creative Commons by 2.0 via Wikimedia Commons

The (near) Future – 2D Modeling Applications

Bridge Scour Assessment Tools

Parameter	Value	Units	Notes	Plot
Bridge Geometry				☑
Bridge Cross-Section				☑
Main Channel Contraction Scour				☑
Applied Contraction Scour Depth	1.49			
Clear Water Contraction Scour Depth	1.49			
Live Bed Contraction Scour Depth	5.51			
Applied Contraction Scour Elevation with LTD	1115.58			
Approach Cross-Section				
Local Scour at Piers				
Plot Pier Scour				
Piers				
Pier Name	Pier 1			
Pier Scour Depth	24.21			
Total Scour at Pier	25.70			
Total Scour Elevation at Pier	1091.37			
Piers				
Pier Name	Pier 2			
Pier Scour Depth	22.46			
Total Scour at Pier	23.95			
Total Scour Elevation at Pier	1093.12			
Local Scour at Abutments				
Left Abutment				
Plot Left Abutment Scour				
Abutment Scour Depth	14.38	ft	NCHRP Method	
Total Scour at Abutment	14.38	ft		
Total Scour Elevation at Abutment	1102.69	ft		
Right Abutment				☑
Plot Right Abutment Scour				☑
Abutment Scour Depth	14.38	ft	NCHRP Method	
Total Scour at Abutment	14.38	ft		
Total Scour Elevation at Abutment	1102.69	ft		

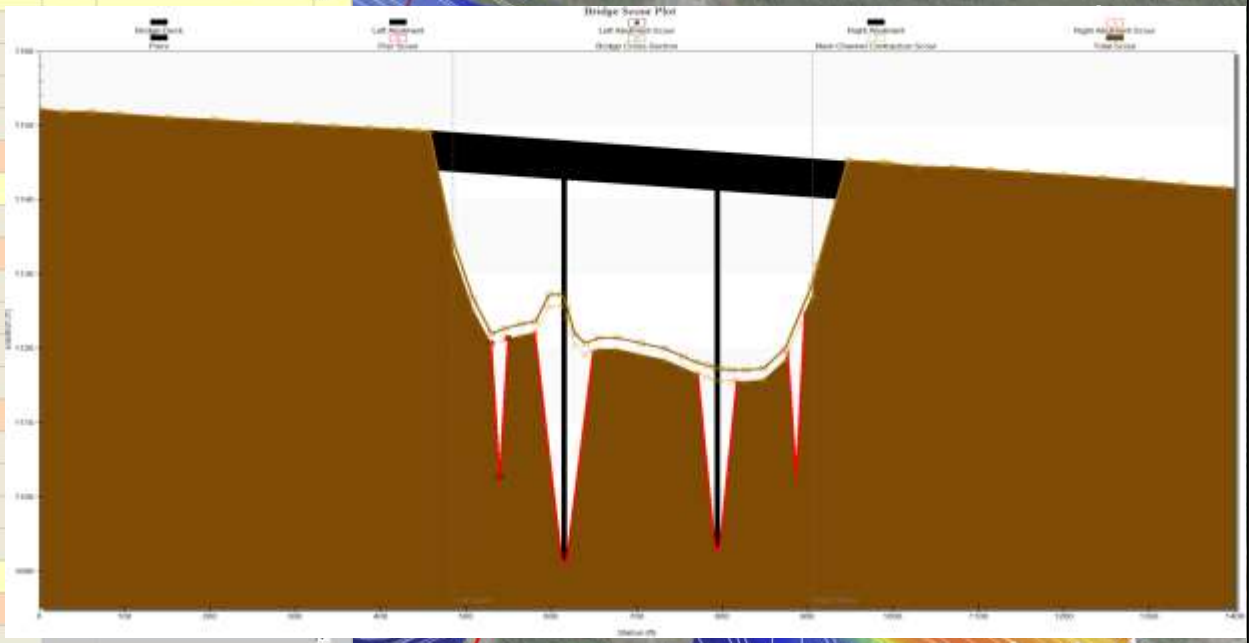


Image Sources: FHWA / Earthstar Graphics (Aerial Image)

The Future – 2D Modeling Applications

Bridge Scour Assessment Tools

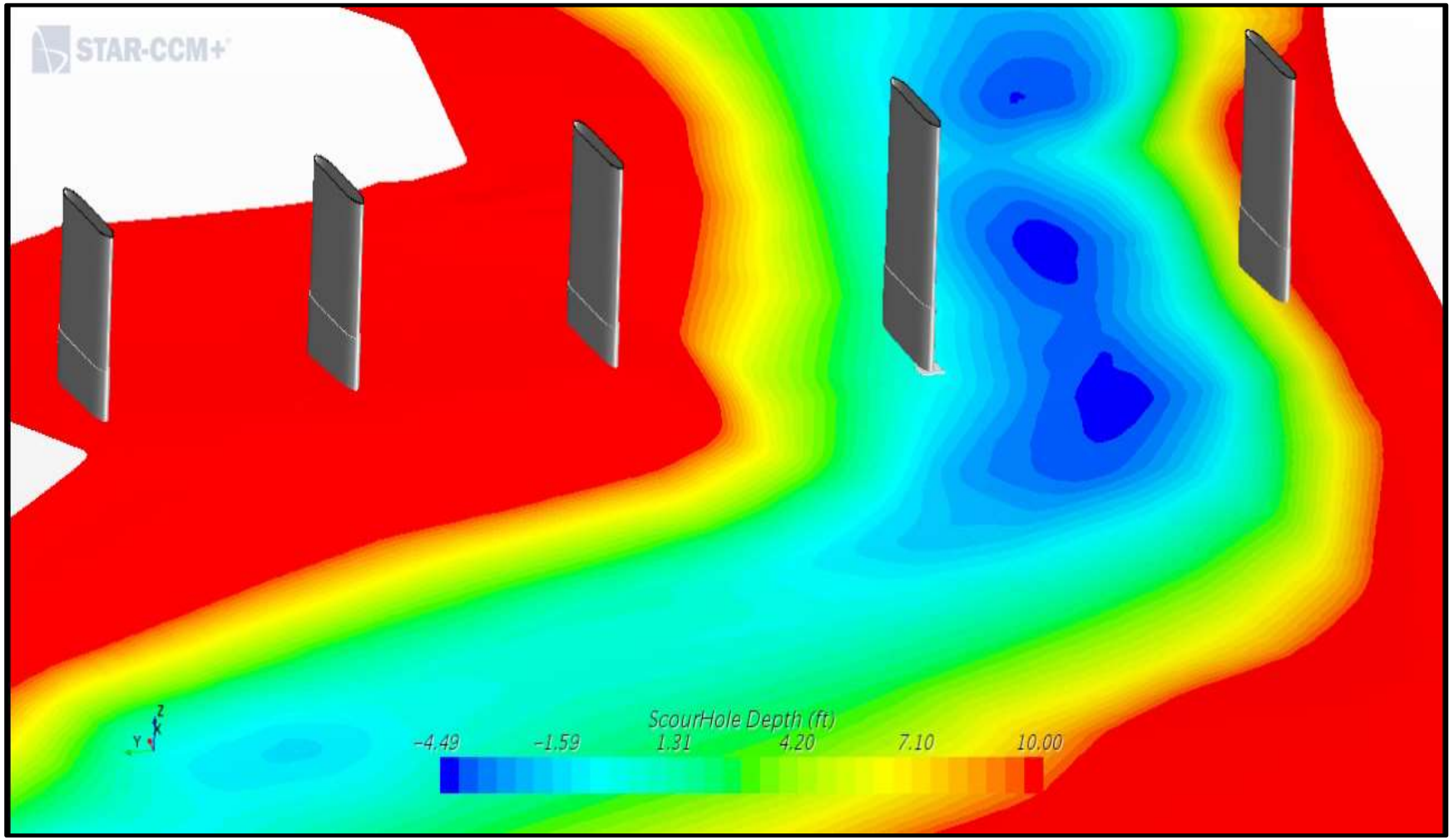


Image Sources: FHWA

The (near) Future

2D Floodway Delineation

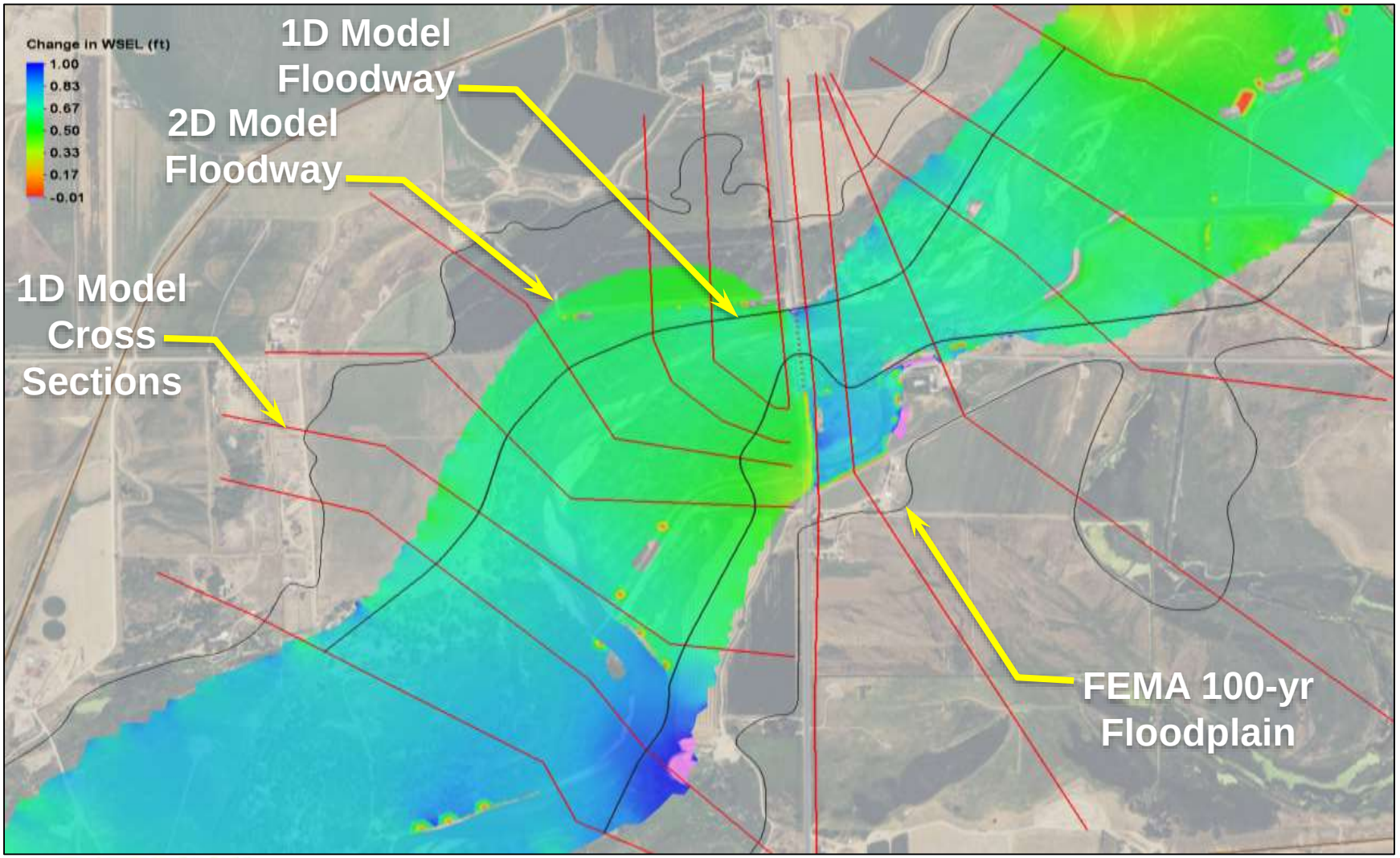


Image Sources: Colorado DOT / FHWA / Earthstar Graphics (Aerial Image)

Resources

START HERE

https://www.fhwa.dot.gov/engineering/hydraulics/ ***(Search FHWA Hydraulics)***

SOFTWARE

- Licensing (DOTs, Community License, Reviewer's license)
- Tutorials
- Online User's Guide

TRAINING

- NHI 2D hydraulic modeling course
- Advanced NHI 2D hydraulic modeling online training
- YouTube video tutorials ***(Search FHWA SRH-2D July 2017)***
- 2D Hydraulic Modeling User's Forum webinars ***(email Scott Hogan)***

TECHNICAL SUPPORT

- FHWA Resource Center (DOT/FHWA) and Aquaveo

Questions?

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